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ABSTRACT

THE EFFECT OF SOME MANAGEMENT FACTORS AND IMMUNOGLOBULIN LEVELS ON CALF MORTALITY IN MICHIGAN DAIRY HERDS

By

Theodore A. Ferris

Two trials in the M.S.U. herd plus studies involving 30 Michigan dairy herds were designed to determine if immunoglobulin levels as measured by the zincsulfate turbidity test (ZST) are influential upon neonatal calf mortality. Further to examine management practices and environmental situations that might influence immunoglobulin levels and the mortality rate.

Nine Holstein calves in the M.S.U. herd were allowed to remain with their dam for 36 hours postpartum, and another nine calves were separated one-half hour after birth and hand-fed 14 lb. of their dam's colostrum during 36 hours. Forty-eight hour serum samples for calves left with the dam were not significantly higher than calves hand-fed, 13.4±2.83 vs 8.73±1.62 ZST units. ZST levels at 24 hours significantly increased from 12 hours in hand-fed calves due to the second feeding of 4 lb. at 12 hours.

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Thirty-two Holstein calves were removed from their dam at one-half hour and fed 1 or 3 lb. of pooled colostrum initially at 1, 2, 6 or 12 hours. Thereafter 4 lb. of colostrum was fed every 12 hours within 38 hours postpartum. Calves were also blocked for two genetic groups within the M.S.U. herd and blocked for two calendar dates between January and May 1973.

Calves hand-fed 1 lb. of colostrum initially, increased only slightly in ZST units by 12 hours but had a six-fold increase between 12 and 24 hours due to the 4 lb. of colostrum fed 12 hours after the first feeding. Calves fed 3 lb. initially conversely increased significantly by 12 hours and had only a two-fold increase to 24 hours due to the second feeding of 4 lb. The 12 and 24 hour ZST values were affected by the initial feeding level, $P < .001$ and $P < .005$ respectively and the 24 hour ZST values were also negatively influenced by the interval to first colostrum (time), $P < .025$.

Neither 48 hour ZST values nor 48 hour serum gamma-globulin levels (g/100 ml) determined by electrophoresis and total protein analysis were significantly affected by the initial feeding level or the interval to the first feeding. An interaction for 48 hour ZST values between genetic groups and the interval to the first feeding occurred ($P < .025$). Covariate adjustment using grams of gamma-globulin fed within 38 hour/kg of birthweight did not significantly change the results. The covariate, however,

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approached significance P $<.1$. The fact that calves received three to four feedings within 38 hours varying from only 9 to 15 lb. could be responsible for non-significant differences in 48 hour serum values.

Thirty Michigan dairy herds were divided into a high (>15 per cent) or low (<10 per cent) mortality group based on the 1972 calendar year data. Mortality was calculated as the per cent of calves that were born alive which died within two months of age. The correlation coefficients between time to first colostrum and 48 hour ZST units for calves sampled were .01 in nine high herds and .07 in low herds recording this information. The coefficient between time to first colostrum and mortality was .35, ($P <.05$) in four high mortality herds. The correlations between hours the calf remained with the dam and ZST units were .13 (NS) for nine high herds and .30 ($P <.05$) for 11 low herds. The average ZST values were not significantly different between 13 low and 17 high herds but there was considerable herd variation within mortality groups. The average ZST values for surviving calves was significantly higher than for calves dying within two months postpartum (7.75±.53 vs 5.69±.53, $P <.05$) and more calves with low levels died in high mortality herds indicating that ZST levels were related to mortality in each group but interacted more with the "environment" in the high mortality herds.

Average ZST levels were highest in herds where calves ty

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typically remained with the cow for more than 24 hours. A group of herds with slightly lower ZST levels usually removed calves from the dam before 12 hours and assumed that most of them received colostrum for the first time when they were hand-fed. Finally herds with significantly lower average ZST levels were those where calves were generally left with the dam up to 12 hours and dairymen believed more than 50 per cent of the calves nursed the cow before they were hand-fed.

Meaningful and significant relationships between the previous years mortality rate and parameters measured in this study were 1) bedding dry matter per cent in the maternity areas $r = -.67$, $P < .001$; 2) number of cows in the maternity area $r = .49$, $P < .01$; and 3) square feet per animal in the calf barn $r = -.37$, $P < .05$. Herd size was not correlated to mortality, $r = .05$.

The number of cows in the maternity area and the maternity area dry matter per cent were also significantly related to the mortality rate of the calves sampled during the four months of this study. Herds using box stalls had lower mortality ($P < .001$) than herds calving cows in groups of three to 60 cows for both the previous year and during the study (9.6 vs 24.9 per cent and 5.5 vs 28.6 per cent). All low mortality herds were using box stalls and 13 of the high mortality herds were calving cows in groups.

Herds using specialized calf housing and herds using make-shift facilities in old barns had similar mortality rates in 1972.

THE EFFECT OF SOME MANAGEMENT FACTORS AND IMMUNOGLOBULIN LEVELS ON CALF MORTALITY IN MICHIGAN DAIRY HERDS

By

Theodore A. Ferris

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

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TABLE OF CONTENTS

Tabl

1

2

3

4

5

6

7

8

9

10

11

12

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

T
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CHAPTER I

INTRODUCTION

The effect of calfhood diseases on the profits of the beef and dairy industries is difficult to accurately determine. This is partly due to the unavailability of accurate estimates of death losses for a limited area and on a nation-wide basis. More difficult to determine is the monetary value of losses contributed by permanently stunted and unthrifty animals resulting from calfhood diseases.

Many diseases are responsible for the ever present sickness and death of young calves. Reisinger (1965), however, contributes 90 per cent to be due to a neonatal diarrhea complex. Escherichia coli is usually associated with the infectious diarrhea complex. Calves tend to become very weak and dehydrated after losses of water and electrolytes due to severe diarrhea. All too frequently the end result is death.

Calves do not receive any significant resistance to disease or immunity through placental transport in utero and they must therefore obtain immune proteins from colostrum or other sources. Hence, feeding, environment and management practices are important variables in providing protection to the newborn. Ehrlich in 1892, according to

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Smith (1948), first discovered that transfer of maternal antibodies through colostrum occurred when the newborn nursed. Subsequently, Famulener (1912) determined that colostrum had high concentrations of immune proteins. However, research indicates that by 24 to 48 hours postpartum calves lose their ability to absorb these immune proteins. Reasons for this cessation of absorptive ability have been the target of much research. These antibodies have the ability to prevent or alter the infectious diarrhea complex (Smith and Little 1922, Dam 1968, Penhale et al. 1970, Gay et al. 1965, McEwan et al. 1970b and Fey and Mangadent 1961).

Environment which the newborn calf is exposed is thought to contribute much to the occurrence of infection and the resistance of the newborn. Many factors such as air temperature, humidity, dampness of bedding and cool streams of air are believed to reduce the resistance of calves to disease because they place a stress on the calf.

This study was then undertaken to investigate immune levels in dairy calves in Michigan herds, their influence on mortality, and to investigate several variables that may influence gammaglobulin levels within these herds. Secondly, to compare high and low mortality herds in order to possibly assess differences in management, environment, and serum gammaglobulin levels that might relate to the differences in high and low mortality rates.

CHAPTER II

LITERATURE REVIEW

Calf Mortality Statistics

Many estimates of the extent of calf mortality during the last 36 years show that the annual loss was and still is 15 to 20 per cent of the calves born. Marsh (1968) compiled a table of calf losses in the U.S. experiment station operations and this is reproduced as Table 1.

Lassiter and Seath in 1955 (cited by Marsh 1968) estimated that of 300,000 calves born on Kentucky dairy farms each year, 20 per cent were either born dead or died within six months. Speicher and Hepp (1973) report the average mortality in 379 Michigan dairy herds surveyed was 13.4 per cent which includes 6.3 per cent dead at birth, 4.1 per cent dying in the first week, 1.5 per cent the second week and 1.6 per cent dying later. Ace (1973) summarized data taken from 545 questionnaires completed by Pennsylvania dairymen. Losses were 6.6 per cent at birth, 9.8 per cent in the first week and 5.7 per cent from one week to one month and a total by one year of 25.2 per cent. Oxender et al. (1973) found higher mortality from a questionnaire survey of 477 Michigan herds than did Speicher and Hepp. For 1971, the annual losses were 17.7 per cent with

TABLE 1. *Representative Dairy Calf Losses in the United States, for Experiment Station Operations, by State and Period.*[d]

TABLE 1. Representative Dairy Calf Losses in the United States, for Experiment Station Operations, by State and Period.[d]

			Losses[a]						
State	Period	Number of Pregnancies	Prior to Calving	To Post-Calving	To 1 mo	To 3 mo	To 6 mo	Total	Reference
Fla	1929-1949	408	--	5	--	--	13	18[b]	Arnold *et al*. 1953
Neb	1904-1948	2,428	7	4	--	12	--	23[c]	Davis 1952
Ky	1928-1952	1,067	3	6	3	--	2	14[c]	Lassiter and Seath 1955
Ia	-	600	--	8	6	--	5	19[b]	Ingels and Cannon 1936
Minn	1934-1945	592	--	8	16	--	6	30[b]	Miller and Gilmore 1949
Minn	1912-1947	1,007	--	6	6	--	5	17[b]	Miller and Gilmore 1949
Ill	1935-1947	809	--	6	--	16	--	22[b]	Ormiston 1949
Mo	-	943	10	8	--	--	6	24[c]	Ragsdale *et al*. 1926
NY	1932-1942	1,352	--	12	--	11	--	23[b]	Savage and McCay 1942
Mich	1932-1948	1,467	5	2	3	2	2	14[c]	Weaver *et al*. 1949
NY	1889-1928	644	11	8	--	9	--	28[c]	Wing 1933
Md (USDA)	1919-1960	1,235	--	7	--	8	--	15[b]	Plowman 1961

[a] Expressed as percentage of pregnancies.

[b] Prenatal losses not included.

[c] Prenatal losses are included.

[d] Reproduced from Marsh, H., 1968.

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6.4 per cent born dead, 8.5 per cent died 0-14 days and 2.8 per cent died from 15-60 days. Mortality was somewhat higher in Jersey (20.9 per cent) and Guernsey (19.4 per cent) herds than Holstein herds (17.7 per cent) but the differences were not significant (Oxender <u>et al</u>. 1973). Johnson and Harpestad (1970) reported breed differences in first year mortality rates of females in Illinois DHI herds. Ayrshire (18) herds had 4.2 per cent losses, Brown Swiss (64) herds 10.5 per cent, mixed (54) herds 12.7 per cent, Holstein (949) herds 13.1 per cent, Jersey (45) herds 16.9 per cent and Guernsey (76) herds 18.2 per cent.

Speicher and Hepp (1973), Johnson and Harpestad (1970), Oxender <u>et al</u>. (1973) and 1972 Michigan Telfarm data (Brown <u>et al</u>. 1973 and Nott and Speicher 1973) all indicate higher mortality in larger herds. Data in Table 2 from Speicher and Hepp (1973) shows herd size and seasonal variation while Table 3 from Oxender <u>et al</u>. (1973) shows that calves born dead are relatively constant regardless of herd size except for the five herds over 200 cows. In 36 herds, with more than 500 cows, surveyed by Speicher <u>et al</u>. (1972) indicated their death rate after birth was between six and ten per cent. Labor which specialized in caring for calves in these herds may be the key to lower deaths. Data of Speicher and Hepp (1973) also indicate no relationship between herd size and calves born dead. Oxender <u>et al</u>. (1973) suggest that in herd expansion programs, the number of cows and milking facilities might be enlarged without

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TABLE 2. Relationship between herd size and calf mortality prior to weaning in 379 Michigan dairy farms.[a]

		Calf Mortality		
	No. of	Seasonal		
Herd Size	farms	Winter[b]	Summer	Annual[b]
No. Cows		%	%	%
25	37	11.1	8.4	9.7
25-39.9	156	13.7	10.0	11.8
40-54.9	90	17.2	10.1	13.5
55-69.9	55	20.6	9.5	14.8
70-84.9	20	19.9	9.5	14.1
85	21	20.1	13.7	16.6
All Herds	379	17.1	10.3	13.5

[a] Speicher and Hepp 1973.

[b] Significant trend for increasing calf mortality with increasing herd size ($P < 0.01$).

TABLE 3. Effect of herd size on calf mortality.[c]

				Died		
	No. of	Birth		0-14	15-60	Total
Herd Size	Farms	Live	Dead	Days	Days	Mortality*
No. Cows		%	%	%	%	%
50	217	93.9	6.1	7.5**	2.5	16.1[a]
50-100	199	93.6	6.4	8.8	2.9	18.1[ab]
100-200	56	92.5	7.5	10.6	2.8	21.1[ab]
200	5	89.6	10.5	18.1	6.8	34.9[b]

*Different letters in that column indicate significant differences ($P < 0.05$).

**Difference in column significant ($P < 0.05$) ANOV. Author's terminology.

[c] Oxender *et al.* 1973.

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changes in calf-raising facilities or in labor for rearing calves.

Michigan Telfarm data for 1972 (Brown et al. 1973 and Nott and Speicher 1973) indicate losses to weaning at 14.9 per cent in southern Michigan dairy herds and 12.8 per cent in northern Michigan dairy herds. However, the average herd size was 71 cows and 54 cows for southern and northern herds respectively. Speicher and Hepp (1973) also report 18.2 per cent losses in October through March in southern Michigan counties and 11.5 per cent in northern counties with annual losses of 14.4 and 8.6 per cent respectively.

Type of housing was also associated with rate of mortality in the two Michigan surveys (Speicher and Hepp 1973, and Oxender et al. 1973), Tables 4 and 5. The data indicate that herds housed in stanchions have less mortality than those in free stalls but that type of housing and herd size are confounded. Speicher and Hepp (1973) also found a relationship to the type of calf housing, and this is in Table 6.

Again, type of calf housing and herd size are confounded, with greater calf losses in the larger herds whose calves were housed as part of the loose housing barn. Oxender et al. (1973) remarked that increases in population density of animals in larger herds might also contribute to spread of bacterical and viral infections.

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TABLE 4. Relation of dairy herd housing to extent of calf mortality.[a]

Type of Housing	No. of farms	Mean Herd Size	Mortality		
			Seasonal		
			Winter[b]	Summer	Annual[b]
Stanchion	153	36.4	14.7	9.4	12.0
Switch	24	43.8	14.0	8.9	11.3
Loose Housing	97	49.0	18.6	12.1	15.1
Free Stall	105	56.0	19.0	10.0	14.2

[a] Speicher and Hepp 1973.

[b] Significant trend in calf mortality with type of housing, for both annual and winter data ($P < 0.01$).

TABLE 5. Relation of dairy herd housing to extent of calf mortality.[a]

Type of Housing	No. of farms	Births		Died		Total Mortality*
		Live	Dead	0-14 Days*	15-60 Days	
		%	%	%	%	%
Stanchion	125	94.1	5.9	6.7^{a}	2.1	14.7^{a}
Free Stall	259	93.5	6.5	9.6^{b}	3.2	19.3^{b}
Loose Housing	31	93.0	7.0	10.3^{ab}	3.5	20.9^{ab}

*Numbers bearing different superscript letters are significantly different ($P < 0.05$).

[a] Oxender *et al.* 1973.

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TABLE 6. Relationship between type of calf housing and calf mortality prior to weaning on 367 Michigan dairy farms.[a]

Calf Housing	No. of Farms	Mean Herd Size	Calf Mortality		
			Seasonal[b]		
			Winter	Summer	Annual[b]
Within Stanchion Barn	128	35.2	13.0	7.9	10.4
Separate Calf Barn	185	52.6	18.9	10.3	14.3
Part of Loose Housing	54	46.6	18.9	13.3	15.9

[a] Speicher and Hepp 1973.

[b] A significant trend in calf mortality with type of calf housing, for both annual and seasonal data ($P < 0.01$).

Johnson and Harpestad (1970) also found a negative relationship between level of fat produced and rate of mortality. Michigan Telfarm data for 1969 agree with this idea.

In summary, the data reviewed indicated larger herds have higher mortality and that type of herd housing, calf housing and whether the herds are in southern or northern Michigan counties all interrelate when evaluating calf mortality. The unanswered question in these surveys is what is different or being done differently with calves in larger herds, or in high mortality herds regardless of herd size.

Influences of Calf Mortality on Replacing Cows in Dairy Herds

The annual rate of cow removal as reviewed by Dayton (1966) Table 7, varied from 8.8 per cent to 30.9 per cent with a mean of 23.8 per cent. The Annual Summary of Michigan Dairy Herd Improvement Records from 1959 through 1968 shows an average cow removal rate of 27.0 per cent sold plus 1.6 per cent that died (Table 8). There are 2.65 per cent of the herd leaving for dairy purposes, 13.68 per cent for low production and 10.6 per cent from involuntary causes. In this section I will try to evaluate the effect of various mortality rates on the number of available herd replacements.

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TABLE 7. Annual rates of removal reported in the literature.

Report	Country	Annual Removal Rate
Baltzer (1940)	United States (Michigan)	24.1%
Seath (1940)	United States (Kansas)	30.9%
Asdell (1951)	United States	16.8%
Johnson (1958, 1959, 1960, 1961, 1962, 1963)	United States (Michigan)	25.4% 1958 29.0% 1959 27.6% 1960 26.6% 1961 27.9% 1962 29.9% 1963
Specht and McGilliard (1960)	United States (Michigan)	26.3%
Rabold (1958)	Germany	15.0%
Leali (1956)	Italy	8.8%
Clark (1958)	Australia	16.8%
Withers (1955, 1957, 1959)	Great Britain	22-24%
O'Connor and Hodges (1963)	Great Britain	29.3% 1957-58 23.4% 1959-60

Data from M.S. Thesis of A. D. Dayton, 1966, Michigan State University, Differential Removal of Daughters Among A. I. Sires.

TABLE 8. Data from annual summary of Michigan Dairy Herd Improvement Records, showing distribution of animals leaving the dairy herd.

				Reason for Sale	
Year	Died	Sold	Dairy Purposes	Low Production	Involuntary
	% of Total Herd		% of Those Sold		
59	1.8	27.2	12.4	43.5	44.1
60	1.7	25.9	11.3	42.8	45.9
61	1.5	25.1	11.6	43.9	44.5
62	1.5	26.4	9.5	47.0	43.5
63	1.6	28.3	8.9	48.8	41.8
64	1.3	23.4	9.7	50.2	39.5
65	1.4	30.5	9.6	54.6	35.8
66	1.8	30.4	7.8	58.9	33.3
67	1.8	30.8	9.2	58.3	32.4
68	1.4	22.5	8.5	59.5	31.9
Ave.	1.6	27.0	9.8	50.7	39.3
			-- % of Total Herd --		
			2.6	13.7	10.6

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Metzler (1972) used the following equation to calculate the number of available herd replacements.

Equation 1

$$\frac{\frac{NC_1L}{2} \times C_2}{I} \quad \text{or} \quad \frac{\frac{(130 \times .85 \times .85)}{2} \times .90}{1.08} = 39$$

Where:

N = Cows bred per 100 cows in milking herd (100 cows + 30 heifers)

C_1 = Per cent bred which calve

L = Per cent of calves which live to breeding age

2 = To account for normal sex ratio

C_2 = Per cent of heifers reaching breeding age which also reach milking herd

I = Calving interval

This equation includes several variables affecting the number of herd replacements. In the present discussion the primary interest is in (L).

The Telfarm data (Brown _et al_. 1973, Nott and Speicher 1973), indicate that 98 calves were born per 100 cows in a herd. This figure (98) can then replace the term NC_1 in the previous equation and since the new term calving percentage is expressed on an annual basis, the calving interval (I) can also be omitted from the previous equation. Therefore:

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Equation 2

$$\frac{B \times L}{2} \times C_2 \quad \text{or} \quad \frac{98 \times .85}{2} \times .90 = 37.5$$

Where:

B = Calves born per 100 cows

L = Per cent of heifers reaching breeding age

2 = To account for normal sex ratio

C_2 = Per cent of heifers reaching breeding age which also reach the milking herd

These expressions give similar values. However, the accuracy of the estimates for the variables may be questioned. Metzler (1972) did not remark on the derivation of his variables. The value of (L) in any situation will depend on the mortality per cent of bulls and heifers being equal up to breeding age. This may be unlikely on many farms where bull calves are sold during the first or second week of life. Applying the above equations to large populations may be in error due to over or under estimation of actual female losses. Even so, generating the replacement numbers based on hypothetical mortality rates will be of value if all other variables are held constant. The following are estimates of available replacement heifers based on use of different mortality levels in the equations.

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	Equation 1	Equation 2
(L)	Replacements (N)	
.90	41.4	39.7
.85	39.0	37.5
.80	36.8	35.3
.70	32.2	30.9
.60	27.6	26.5

From the generated replacement numbers above, a mortality rate of 40 per cent (this will include heifers sold for various reasons) or 60 per cent survival to breeding age leaves only 26-27 heifers to replace the 28.6 cows removed from a hundred cow herd in Michigan. Logically, the number of cows culled annually would be equal to the number of heifers available to replace culled cows. There would be the exception where replacements are used to increase herd size and animals are bought to increase herd size or replace culls. Therefore, one might assume that 29±2 or 3 heifers are entering the milking string annually. Then indirectly one would estimate the survival rate of 60 per cent to be close to the average in Michigan. This then leads to the conclusion that 40 per cent of heifer calves either are born dead, die or are disposed by breeding age.

Moore *et al.* (1974) reported 31 per cent of the potential replacement heifers were lost prior to calving during 14 years (1958-1971) at the Lewisburg Experiment Station in Tennessee. They remarked that above average feeding and management conditions existed. Death losses of over 19 per cent were contributed to by scours and/or pneumonia 9.5, stillbirth 4.1, accident 1.9, abnormal 1.4, abortion .7, and miscellaneous 1.9. Sales of females accounted for 11.7 per cent, which were for breeding problems 6.4, dairy 2.4, twin with bulls .9, unthrifty .8, grade .6, and other .5.

Two points can now be made from these calculations. First, the data from Speicher and Hepp (1973), 1972 Michigan Telfarm Records (Brown et al. 1973, and Nott and Speicher 1973) and Oxender et al. (1973) gives estimates on mortality to weaning (13.4, 14.9, 12.8 and 17.7 per cent respectively) that are too low to account for a 40 per cent loss up to breeding age and therefore are too low to account for only about 29 heifers entering the milking herd per 100 cows. This discrepancy here may be due to methods of recording mortality in dairy herds. Second, herds with high mortality in heifers will be able to replace very few low producing cows because the dairymen will first have to replace those lost for involuntary reasons.

In summary, then, the average Michigan dairyman is replacing only 14 per cent of his cows for low production from the "bottom" of his herd. This leaves little or no increasing effect on the herd production average which is directly related to income.

Discussion of Diarrhea in Young Calves

Oxender et al. (1973) report from their questionnaire survey that 70 per cent of the Michigan dairy herds considered diarrhea as a disease problem in young calves and 40 per cent

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considered pneumonia as a disease problem. Numerous workers have associated diarrhea in young calves with *E. coli* infection (Wood 1955, Radostits 1965, Smith and Little 1922).

Colibacillosis is a term that has been applied to a group of diseases caused by infection with bacteria classified as *E. coli*. *E. coli* are gram-negative, rod-shaped bacteria that conform to the definition of the family Enterobacteriaeae. All gram-negative bacteria contain endotoxins which are confined within the bacterial cell and are present in *non-pathogenic gram-negative* bacteria as well as those that cause disease (Barnum *et al*. 1967). *E. coli* are usually found in fecal contents of normal animals and are acquired in the G.I. tract by ingestion (Gay 1965, Barnum *et al*. 1967, and Wood 1955). Wood (1955) found fecal swabs taken within a few hours of birth were invariably sterile although those taken on the 7th, 14th and 21st day of life revealed large numbers of coliform bacteria. He also noticed a constant change in rectal flora of each calf from week to week, and in some instances more than one strain were present at one time. From 1950 to 1953 there was a shift in predominant bacteria strains observed by Wood in the calf house and several times during the three-year period the house was left idle. In many calves and pigs with diarrhea, *E. coli* can be cultured from the spleen, liver, kidneys, blood, the mesentric lymph nodes and intestinal contents (Smith and Little 1922, Radostits 1965, Leece and Reep 1961, and Wood 1955). In the absence of a colisepticemia, _E. coli_ are usually cultured only from the intestinal contents and congested mesentric lymph nodes (Wood 1955).

Barnum _et al_. (1967) write that calves which died of acute septicemia colibacillosis are usually well hydrated and in good flesh. The intestinal tract in most cases appears normal. Fey (1962) was unable to reproduce the disease with strain 078:K80 in calves which already received colostrum except for a temporary dysentery. However, this serotype would easily kill colostrum-deprived calves but the point here is that greater success in producing septicemia occurred in colostrum fed calves when the _E. coli_ strain was artificially fed first and colostrum was withheld for several hours.

Barnum _et al_. (1967) writes that the enteric syndromes of colibacillosis (local gut infections) are associated with and are assumed to be the result of large numbers of enteropathogenic _E. coli_ in the small intestine. They remark that calves necropsied with the enteric or enteric-toxemic colibacillosis usually have extreme dehydration, varying degrees of distention of the intestinal tract with fluids, and pasting of the rear quarters and tail with fluid or semi-solid feces. Intestinal walls are thin, atonic and translucent while the ingesta remains essentially unchanged from abomasum to rectum.

There are several problems associated with the positive determination of pathogenic strains responsible for death in calves. Potential pathogenes were often found in feces of calves not becoming ill as well as calves that died presumably from these pathogenic strains that were cultured (Wood 1955 and Glantz *et al*. 1968). Amstutz (1965) remarked when cultures are derived from necropsy non-pathogenic bacteria may migrate into the tissue when the taking of necropsy samples are delayed. Gay (1965) remarks that routine culture methods tend to select for *E. coli* and because of this it is extremely difficult to assess the significance of an infection of *E. coli* from a specimen.

Development of disease, according to Dam's (1968) review of literature, depends on the interaction between the more or less pathogenic types of *E. coli* involved and a number of resistance-reducing factors. These may be insufficient birth hygiene, malnutrition including wrong or no application of colostrum and bad housing with crowding of animals. Dam (1968) suggests the pathogenicity of the strains of *E. coli* and environmental conditions are more important than a gammaglobulinemia or hypogammaglobulinemia (lack of or low serum gammaglobulin) in calves, based upon his observations of 34 calves in five herds. There was a lower average gammaglobulin level for calves that died of colisepticemia but levels in calves from a control herd with no septicemia and in several other surviving calves were lower than the average of those dying from septicemia. Dam apparently assumes then that the reason these calves

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with lower levels survived may be due to differences in pathogenicity of the E. coli involved and in environmental conditions rather than specific antibody action of the gamma globulins.

Reisinger (1965) suggests when colostrum is not consumed that E. coli populate the upper portion of the small intestine under stress conditions. From this he postulates that allowable time to first colostrum feeding for protection against E. coli is inversely proportional to the total adverse contributing factors.

Amstutz (1970, 1965) theorizes several possibilities why E. coli causes diarrhea and may be more virulent in one herd than another.

1) Many different strains or serotypes of E. coli which are ingested by the calf during or shortly after birth comprise the intestinal flora. Potential pathogens may be present, but in such a low proportion of the total that they are incapable of producing disease. A change in intestinal environment results in marked increases in non-pathogens. This relative shift in bacterial population may result in a flora that is able to invade the intestinal wall and interfere with normal functions.

2) E. coli are not capable of producing disease when confined to the lower portion of the digestive tract but when specific antibody containing colostrum is not in the gut within a short time after birth then under certain feeding and management conditions and unsatisfactory environment the organisms multiply rapidly, release potent

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endotoxins, and produce generalized toxin reactions damaging the intestinal epithelium. These bacteria then enter the general circulation and invade other tissues causing widely divergent signs of neonatal diarrhea.

3) A virus invades the animal and in some manner, possibly a synergistic action with resident _E. coli_ produces a modification of the intestinal wall which makes it pervious to _E. coli_.

4) Numerous _E. coli_ serotypes occur in nature and most are non-pathogenetic but some are capable of producing disease. When a pathogenetic serotype becomes established in a herd, infectious diarrhea results. A highly virulent pathogen may be introduced by a purchased animal or show animal.

Anderson (1973) and Appleman and Owen (1971) suggest that an organism increases in ability to produce disease as it passes from animal to animal and with each sequential passage, the virulence increases to the point where, after several passages severe disease results in every animal inoculated. Reisinger (1965) and Ingram _et al_. (1956) suggest certain pathogenic strains become dominant by selection or survival and this is reason for "infection" build-up in calf houses after a period of time. This phenomena may be likened to the transfer of resistance factor in human pathogens. This idea has not been explored in bacteria infecting calves.

The possibility of immunization of calves against

E. coli is being probed. Conner et al. (1973) have indications that intra-uterine immunization of calves to a specific E. coli strain can provide the neonate protection against a challenge dose of the strain. Calves were immunized orally via amniotic fluid while in utero. Three of five calves immunized where born healthy and survived the challenge dose of E. coli type 026. Four control calves given 1.5 x 10^{10} organisms died in two to ten days.

Recent work by Mebus et al. (1969, 1972) indicates that certain viruses may be responsible for initiating the diarrhea complex in some cases. Electron microscopic examination of material from the feces of a diarrhetic calf revealed many viral particles about 65 mu in diameter. Reproduction of diarrhea with bacteria-free filtrates derived from feces from infected calves and containing viral particles indicated that a virus was the probable cause of diarrhea, but due to finding E. coli in the feces of experimental calves it became necessary to produce diarrhea in calves not contaminated with E. coli, i.e., calves in which E. coli is not found in the feces. This was done in three calves kept free of E. coli and given bacteria-free filtrate. When non-invasive E. coli strains were present, the calf recovered in one or two days; however, when an invasive strain of E. coli was present there was an intestinal overgrowth of E. coli followed by a septicemia, a temperature of 104° to 105° F and death in three to five days. On the basis of their research, Mebus and co-workers

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believe that the neonatal diarrhea produced in these experimental calves, which lasted six to eight hours, was caused by a virus. Mebus et al. (1972) then developed a vaccine for this reo-like virus which significantly reduced ($P < 0.01$) calf mortality in 15 of 18 herds having the reo-like virus isolated from calf feces during the previous year and in 15 of 17 herds that were presently having diarrhea problems. The virus vaccine significantly reduced diarrhea in 14 of the 17 herds. Mebus et al. (1972) also found a corona-like virus in seven herds.

Several workers have reported the water and electrolytic changes in calves which have diarrhea (Lewis and Phillips 1972, and Blaxter and Wood 1953). Radostits (1965) writes that most workers have reported a reduction in bodyweight, loss of body fluid, decrease in serum level of sodium, increase in blood urea nitrogen, and a variable reduction or increase in serum potassium. Blaxter and Wood (1953) and Lewis and Phillips (1972) reported normal daily fecal losses of 50 to 60g, and 5.9g per Kg of calf, but with diarrhea fecal losses increased up to 40 and 22 times respectively.

Clinical signs observed with calves during severe scouring are dullness, ataxia, loss of appetite and dehydration. Body gains declined and often became negative (Blaxter and Wood 1953, and Lewis and Phillips 1972). Table 9 shows a comparison of fecal and urinary losses for normal and diarrheic calves from data of Lewis and Phillips (1972).

TABLE 9. **Fecal and urinary water[*] and electrolyte[+] losses.[a]**

TABLE 9. Fecal and urinary water* and electrolyte+ losses.[a]

	No. of calves normal-diarrheic	Fecal loss			Urinary loss		
		Normal	Diarrheic	Increase	Normal	Diarrheic	Decrease
Total*	7-5	5.9±1.0	129.8±33.3	22.0X	61.4±8.6	24.3±4.1	0.40X
% Water	7-8	72.8±2.8	94.1±0.5	21.3%	97.6±0.5	94.2±1.2	3.4%
Water	7-5	4.3±1.0	122.1±33.3	28.4X	59.9±8.6	22.9±4.1	0.38X
Sodium	7-5	9.5±2.5	258.5±68.6	27.2X	40.0±7.3	25.1±13.0	0.63X
Potassium	7-5	5.6±1.4	97.8±45.7	17.5X	156.3±33.5	94.5±18.6	0.60X
Chloride	7-5	7.6±2.7	282.9±109.8	37.2X	87.9±20.3	48.7±16.8	0.55X
Calcium	2-2	5.4±3.5	130.8±14.3	24.2X	0.95±0.73	0.34±0.15	0.36X
Magnesium	2-2	0.41±0.35	16.4±0.74	40.0X	6.85±0.63	3.69±0.87	0.54X

*In g per kg bodyweight per day (mean±S.E.).

+In mg per kg bodyweight per day (mean±S.E.).

[a] Lewis and Phillips 1972.

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Three of these calves had spontaneous diarrhea, two were induced by feeding 2g of sucrose per Kg of bodyweight two times daily, and three were induced by feeding intestinal contents and mucosal scraping from field case calves that died of diarrhea. Renal compensation to the ensuing dehydration is evident as the urinary water loss is decreased to 0.38 of normal volume. With the exception of Ca^{++} which is decreased to 0.36 of normal, all other urinary electrolytes were decreased to only 0.54 to 0.63 of normal (Lewis and Phillips 1972).

Tables 10 and 11 compare fecal losses of calves when in a normal, loose and diarrheic condition (Blaxter and Wood 1953). A marked increase of water and dry material occur in diarrheic calves and here the percentage of water being the greatest can then be used to indicate intensity of diarrhea.

The usual amount of hydrochloric acid destroys many of the bacteria which enter the abomasum and partially inhibit the growth of E. coli in this area. However, during the first one to two days of life, gastric acidity is relatively low and Barnum (1967) and co-workers believe this partially explains the high susceptibility of newborn animals. Barnum et al. (1967), however, did not cite specific evidence for these statements. They reiterate Reisinger's statement that any interference with the motility and secretions of the intestine which tend to move bacteria anteriorly could create an abnormally high

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TABLE 10. Mean amounts of the major constituents excreted in normal and scouring feces for calves on artificial diets.[a]

Constituent (g. per day)	Classification of Feces Samples			Ratio of "Diarrheal" to "Normal"
	"Normal"	"Loose"	"Diarrheal"	
Water	51.0	280.0	927.0	18.2
Dry Matter	12.5	42.5	93.5	7.5
Total Fat	4.1	17.5	37.4	9.1
N X 6.25	5.5	22.3	41.0	7.5
Ash	1.5	5.3	10.6	7.1

[a] Blaxter and Wood, 1953.

TABLE 11. Mean amounts of mineral elements lost in the feces of normal and scouring calves.[a]

Amounts of Mineral Excreted (mg. equivalent per day)	Classification of Feces Samples			Ratio of "Diarrheal" to "Normal"
	"Normal"	"Loose"	"Diarrheal"	
Calcium	21.6	31.2	98.8	3.7
Magnesium	11.4	16.0	24.0	
Sodium	5.0	9.5	41.6	11.3
Potassium	2.2	3.0	39.9	
Phosphorus	21.0	39.0	94.0	4.4

[a] Blaxter and Wood, 1953.

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number of E. coli in the upper intestine.

Cowie (1964) showed that acid treatment will prevent or render scours less severe in young calves provided the treatment begins at the acute indigestion phase and not after it has advanced. Acid solutions used were in the pH range of 2.9 to 3.2 and consisted of citric acid or a mixture of citric (32 gr) and dilute hydrochloric acid (5 minims) in water (10 oz.). These were administered twice daily. The pH of feces from 100 diarrheic and 17 normal calves was measured, and those calves responding to treatment with a drop in fecal pH had a drop from about 7.6 (6.1 to 9.1) down to 5.6 (4.6 to 7.1).

In summary of this section, it is evident that many researchers believe E. coli to be the major disease-causing factor in calfhood diarrhea. Also, several workers have stated that external environmental conditions as well as the conditions existing within the gastrointestinal tract play a significant role as to whether or not pathogenetic bacteria populate and cause disease. Mebus et al. (1969, 1972) have worked with a reo-like virus and found that this could also be a responsible diarrhea-initiating agent. Diarrhea causes gross changes in a calf's electrolytic balance, thus causing loss of water and poor absorption of nutrients and thus death.

Historical Perspectives of Immunoglobulins

Ehrlich in 1892 (as cited by Smith 1948) recognized the transfer of maternal antibodies to the newborn from the colostrum milk. Famulener (1912) referred to colostrum as having high concentrations of immune bodies, two to three times the content of maternal serum at parturition. He also noted very little if any hemolysin transfer into kids' serum while in utero. Immune bodies and hemolysin refer to agglutinins or antibodies or substances having antibody properties (Webster's New Collegiate Dictionary). Jenness et al. (1956) refers to two classes of immune proteins in milk, euglobulin and pseudoglobulin, based upon their water solubility. Smith (1948) conveniently refers to these colostrum and milk globulins which are associated with immunity as "immune lactoglobulins", although the actual antibody content may account for only a small portion of these fractions. Immunoglobulin is a general term assigned to a family of high molecular weight proteins that share common physico-chemical characteristics and antigenic determinants. They have gamma or slow beta electrophoretic mobility and occur in serum and other body fluids of animals. Three classes have been identified in the cow, IgG, IgM, and IgA (Butler 1969).

According to Smith (1948), Jameson in 1942 and San Clemente in 1943 utilized electrophoretic analysis to show that the newborn does not have any gammaglobulin and that the presence of slow-moving globulin occurs only after the ingestion of colostrum. In the 1920's Howe (1921) and Orcutt and Howe (1922) also observed the appearance of agglutinins in the post colostral calf serum associated with a globulin which was precipitated in 14.2 per cent sodium sulfate.

Smith's review (1948) discusses several properties of the bovine immune lactoglobulins. Their molecular weight is in the neighborhood of 180,000. By electrophoresis the immune proteins may equal 50 to 60 per cent of the total protein in colostrum and 85 to 90 per cent of the protein in colostral whey. Colostrum itself, shortly after parturition contains 15 to 26 per cent protein which is about two or three times the concentration in blood plasma (Smith 1948, Parrish et al. 1950, and Foley et al. 1972). About 85 to 90 per cent of serum and whey immunoglobulins are of the IgG class and less than 10 per cent of the IgM class (Butler 1969). According to Askonas et al. (1954), Larson (1958) and Feldman (1961) the bulk of protective immune components in colostrum come unmodified from the maternal blood.

Methods of Detecting Blood Levels of Immunoglobulins

A number of studies have been conducted to determine immunoglobulin levels in newborn dairy calves, their role in protection against disease and factors affecting these levels. Methods used in determining these levels have varied. McEwan et al. (1970c) used a modification of the zincsulfate turbidity test to estimate the immunoglobulin portion of calf serum. A correlation coefficient of .96 was obtained between values for the zincsulfate test and a quantitative immunodiffusion technique measuring IgM plus IgG combined. McBeath *et al.* (1971) used the zincsulfate test and found a correlation of 0.99 with a single radial diffusion test for IgM plus IgG. A simple refractometer was also used by McBeath *et al.* (1971) for a quick determination of immunoglobulin levels. The refractometer is a method to estimate serum protein concentrations and thus use of this method for the purpose of detecting levels of immunoglobulins in newborns assumes that the major variation in protein levels of neonatal calves is due to changes in blood gammaglobulin. The correlation of this test with the single radial diffusion test was 0.72 which is lower than correlations obtained between the $ZnSO_4$ method and radial diffusion cited previously.

Mungle (1972) used the single radial diffusion assay to quantitate serum IgG along with commercial antiserum and a standard IgG. He also employed the refractometer to determine total serum protein and to estimate per cent gammaglobulin he used a micro-zone electrophoresis system. Penhale *et al.* (1970) used the single radial diffusion system plus micro-Kjeldahl analysis to calculate total serum protein. Selman *et al.* (1971a) and Kruse (1970b) used cellulose acetate strips to electrophoretically

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determine immune lactoglobulin in whey. Lecce et al. (1961) employed immunoelectrophoretic techniques and reference antisera to egg white proteins and bovine whey proteins to detect these proteins in piglet blood after feeding the egg white and bovine proteins. Lecce et al. (1961) also used agar gel electrophoresis under similar conditions to separate egg protein fractions, colostral protein fractions, and for detection of polyvinylpyrrolidone (PVP) in piglets blood.

Protection Offered by Immunoglobulin Presence in the Calf

In 1922 Smith and Little (1922) showed that feeding colostrum greatly reduced calf losses. They successfully raised ten calves fed on colostrum while losing nine of eleven which were colostrum deprived. Ingram et al. (1956) reported similar results losing 59 of 225 colostrum fed calves and 94 of 103 colostrum deprived calves. Smith and Little (1922) stated that colostrum deprived calves lack something allowing intestinal bacteria to invade the body and multiply in various organs. Lecce and Reep (1961) found that pigs receiving gammaglobulin in their diets were most resistant to bacteremia and death.

Several workers have shown that calves with increased concentrations of blood immunoglobulin tend to have fewer deaths than those with low concentrations (Dam 1968, Penhale et al. 1970, Gay et al. 1965, McEwan et al. 1970b, and Fey and Mangadent 1961). Dam (1968) showed that deaths in four herds due to colisepticemia, a systemic infection caused by invading bacteria, were more likely to occur in calves with low blood levels of immunoglobulin. Penhale *et al.* (1970) had calves dying of septicemia with IgG and IgM levels of 0.8 and 0.2 mg/ml respectively. These levels were significantly different from those in surviving calves (7.5 and 0.8 mg/ml) which had no indications of illness except occasional diarrhea. Calves that died but were not bacteraemic had profuse diarrhea and intermediate IgG and IgM levels.

Several experiments determining immunoglobulin levels with the zincsulfate test show a positive relationship between turbidity of serum and the amount of colostral immunoglobulin in the calves blood, and negative relationship to sickness. Gay *et al.* (1965) sampled 178 Ayrshire market calves and found 30 per cent (54) had less than 10 zincsulfate turbidity units and of these 54 calves, 23 died. This test was successful in identifying calves likely to succumb to the septicemic form of colibacillosis. There was evidence that enteric disease (local G.I. infections) was also related to serum immunoglobulin and here again calves with low serum levels died. McEwan *et al.* (1970b) found all but two of 58 septicemia deaths occurred in calves having low serum zinc turbidity units (0-10). Fey and Mangadent (1961) found hypogammaglobulinemia in only 10 per cent of the healthy calves but low gammaglobulin levels occurred in 95 per cent of the dead calves where death was attributed to colisepticemia.

Logan and Penhale (1971a) and Lecce and Reep (1961) suggested colostrum has a dual protective function; locally against enteric disease within the gastro-intestinal tract and systemically in the circulation against colisepticemia. Logan and Penhale (1971a) mentioned this in light of the failure of colostral whey to influence diarrhea condition when given parenterally. Penhale et al. (1971) prepared a IgM rich injectable fraction from bovine serum, which was given intraperitoneally. The usual course of septicemia was modified regardless of the dose. However the fraction had little effect upon the development of enteric disease. To test the idea that colostrum has a local protective activity within the gastro-intestinal tract Logan and Penhale (1971b) used hypogammaglobulinemic market calves under one week of age. All calves were placed in an area previously contaminated by calves with colibacillosis. Calves were treated with IgM intravenously alone and in combination with feeding colostral whey orally. Other calves received only whey or were controls with no treatment. IgM I.V. plus whey orally provided the longest survival time ($P < 0.02$) with two of six calves surviving. Postmortem examination revealed these calves had mucoid E. coli in the small intestine and some mesentric lymph nodes at death as did the calves given only IgM I.V. Feeding whey alone did not raise the IgM serum levels (.17 mg/ml) and all these calves died of septicemia. Since whey was not being absorbed into the circulation when fed orally then the additional survival time in calves treated with both whey and IgM I.V. was concluded to be due to local benefits of whey in the gut.

IgM may be the principle immune component for protection against colisepticemia in the calf. IgM is present in normal bovine serum and possesses antibacterial activity, particularly against gram negative bacteria including pathogenic serotypes of _E. coli_ (Penhale 1965, Logan and Penhale 1971a). Ingram _et al_. (1956) however, suggested that certain strains of bacteria against which colostrum is non-effective, i.e., not containing specific agglutinins for antigens produced by strains of bacteria, may become dominant in colostrum-fed calves. Cartwright (1968) writes that colostrum or sow's milk must be in the piglets gut to neutralize the effect of a particular virus, transmissible gastro-enteritis (TGE), with which he was working because they soon died if they were removed from the sow and nursed artificially. Cartwright did not mention here what the artificial feeding system was. Roy (cited by Reid 1956) showed colostrum reduced the incidence of scours and deaths caused by localized intestinal infections even when the colostrum was administered after the time when the small intestine was no longer permeable to the transfer of intact globulins.

Wood (1955) stated septicemia to be more frequent in colostrum deprived calves, but local intestinal infections were more prevalent in those receiving an aqueous colostrum fraction (400 ml) as the first feed followed by a basic diet of synthetic milk. Lecce (1973) remarked that the local effects of colostrum in the gut during the first three days may be more beneficial than the immune level in blood. He also caused gut closure artificially without adding any immunoglobulin to the piglets system and prevented incidence of bacteremia which occurred in controls. Lecce (1973) theorized that the large globulin molecules and other molecules filled the absorptive sites in the neonate intestine and eventually caused closure.

There is some disagreement in the literature on the need for specificity of antibodies in colostrum to particular antigens which supposedly cause disease in calves and death. Dam (1968) reported that he previously found higher protective effect (this is assumed by the reviewer to be protection from disease within the calf) of sera containing specific agglutinating antibodies than of normal sera, and thus demonstrated the preferability of a specific prophylaxis aimed directly at the pathogenic organisms in question. He did not define the normal sera. Ingram *et al*. (1956) found that of 59 colostrum-fed calves that died, 45 had received colostrum devoid of agglutinins to strains associated with their death. Of 94 colostrum-deprived calves that died, 66 deaths were associated with strains against which agglutinins could be demonstrated in colostrum given to contemporary calves that survived. However the existence of strains of bacteria were not determined in surviving calves receiving colostrum in which agglutinins were present. Gay stated (Gay 1965, Gay *et al*. 1965) that the level of specific agglutinating antibodies to a "K" antigen of infectious *E. coli* strain did not relate to the incidence of colisepticemia but that mortality was related to a deficiency of serum gammaglobulin in the calf. Lecce and Reep (1961) reported that feeding of *E. coli* strain "08" to nine, two week old, colostrum-free, 08 agglutinin-free piglets resulted in no signs of the disease attributable to the *E. coli* fed at two weeks of age. This suggests presence of a resistance to infection that was not dependent on blood gammaglobulin containing antibodies for strain "08". Lecce and Matrone (1960) write that colostrum-free isolated pigs were eight weeks of age before they could synthesize antibodies in response to administered antigens, and the knowledge that after two weeks of age antibody-free pigs are "easy" to rear may indicate that more factors are involved in protection against disease in the early period than high blood levels of antibodies.

In summary, Barto (1972) points out that there may be bactericidial activity in calf serum before colostrum feeding and that a complete complex may be formed when colostrum is absorbed. Lecce and Reep (1961) as well as Logan and Penhale (1971a) describe colostrum as having the primary purpose of systemic and local gut protection and to this Lecce and Reep (1961) and Lecce (1973) adds that immunoglobulin may allow for rapid maturation of piglet serum profile and enhance gut closure which may be the first line of defense against bacterial disease.

Levels of Immunoglobulins Found in Calves

The idea that calves lack gammaglobulin until ingestion of colostrum has been discussed and levels achieved following colostrum absorption in various studies will be presented. However, researchers have verified that calves do not completely lack gammaglobulin at birth (Howe 1921, Klaus *et al*. 1969, McCoy *et al*. 1970, Bush *et al*. 1971 and Mungle 1972).

The condition of agammaglobulinemia in calves refers to this near complete lack of gammaglobulin detectable in the blood. Fey (1967) defined hypogammaglobulinemic calves as those with blood levels below 0.5 per cent gammaglobulin. Calves deprived of colostrum until 24 hours had .02g of gammaglobulin per 100 ml of serum (McCoy 1970). McBeath *et al*. (1971) using a refractive index found 14 colostrum deprived calves with an average serum protein concentration of 3.83 g/100 ml. With this technique they found five of 24 (20.8 per cent) market calves had values of 3.80 or less.

Klaus *et al*. (1969) found three of ten calves with less than 0.5 mg/ml IgM and below 4.0 mg/ml for IgG.

Staley et al. (1971) state 26 and 30 per cent of the calves in their studies remained hypogammaglobulinemic in spite of adequate levels in the ingested colostrum. Sixteen of the 30 calves in Mungle's (1972) work had serum gammaglobulin levels below 0.5 mg/ml which was stated to result from feeding low amounts of gammaglobulin. The calves consumed either 22.6g or 45.2g of colostral immunoglobulin per 50 kg of bodyweight within 24 hours. Low total immunoglobulin consumption may also have occurred in calves found hypogammaglobulinemic in experiments of both Klaus et al. (1969) and Staley et al. (1971) where the calves were allowed to nurse the dam. Colostrum intake was not known in either case and conceivably could be small in some nursing calves. Staley et al. (1971) in their second study fed colostrum at only 2.5 per cent of the calves birthweight on day one which may be an insufficient immunoglobulin mass to increase levels much above 0.5 per cent gammaglobulin in some calves even though the concentration is high. Adequate amounts of colostrum has not been well defined or substantiated. The reviewer does not overlook the fact that time to colostrum ingestion could also be a variable in Klaus and Staley's experiments but it was constant in Mungle's work. On the other hand Selman et al. (1971a) reported not one of 50 experimental calves were unable to absorb gammaglobulin. Colostrum was fed at the rate of 25 ml/lb. of birthweight in three equal feedings within nine hours postpartum.

Previous discussions have revealed that blood levels of gamma or immunoglobulin were related to calf livability. Table 12 summarizes reported gammaglobulin levels with rates of calf mortality. Methods used for quantitation of immunoglobulins varied and comparison between studies may not be accurate. However, fewer calves died with high gammaglobulin levels than with low levels in each report.

Further information on mortality and immunoglobulin levels is in Table 13. Surviving calves had more IgM and IgG than did calves with septicemia. The usual interpretation is that calves get septicemia because of low immunoglobulin levels but cause and effect are not proven by this type of data. In the data of Dam (1968), calves in the control herd, a herd without a septicemia problem, had lower levels than the calves dying from septicemia in herds having a high mortality rate. He also found that 25 per cent of the 20 surviving calves (one calf was not included in the average values because of very high immunoglobulin level, 3.0 gram of gammaglobulin/100cc) had lower per cent of gammaglobulin while 35 per cent had lower gammaglobulin concentration in serum than the average values for the six dying from septicemia.

The mean blood gammaglobulin concentration in young calves is below that in parturient cows. McCoy _et al_. (1970) found serum gammaglobulin concentrations

TABLE 12. Number of calves and mortality within four or five ranges of immunoglobulin levels, estimated by various techniques.

	Total Calves	Groups[a] 1	2	3	4	5	Reference
Units[b]		0-5	5-10	10-20	> 20		Dam 1968
No. Calves	32	12(2)	9(2)	8(2)	3(0)		
Units[c]		0-.25	.25-.5	.5-1.0	> 1.0		Dam 1968
No. Calves	31	12(3)	8(1)	8(1)	3(0)		
Units[d]		0-.5	.5-.99	1.0-2.0			Kruse 1970
No. Calves	523	221	233	69			Unpublished
Units[e]		0-.25	.25-.5	.5-1.0	> 1.0		Mungle 1972
No. Calves	30	0(0)	16(0)	13(0)	1(0)		
Units[f]		0-4	4-8	8-12	12-18	18-22	Mungle 1972
No. Calves	30	8(0)	14(0)	5(0)	2(0)	1(0)	
Units[g]		0-4	4-8	8-12	12-18	18-22	Penhale
No. Calves	61	33(27)	14(6)	8(2)	5(2)	1(0)	*et al.* 1970
Units[h]		0-10	10-20	20-30	30-40	> 40	Klaus
No. Calves	10	3	1	3	2	1	*et al.* 1969
Units[i]		0-.5	.5-1	1-2	> 2		Klaus
No. Calves	10	4	1	2	3		*et al.* 1969
Units[j]		0-10	10-20	20-30	30-40	40-50	McBeath
No. Calves	80	23(1)	16(1)	20(0)	10(0)	11(1)	*et al.* 1971

TABLE 12. Cont'd.

	Total Calves	Groups^{a} 1	2	3	4	5	Reference
Units^{j}		0-10	10-20	20-30	30-40	40-70	McEwan
No. Calves	415	182(107)	80(20)	60(4)	55(2)	37(0)	et al. 1970b
Units^{k}		0-10	10-20	20-40	> 40		Kruse and Neimann
No. Calves	181	42	43	53	43		Sorensen 1966
Units^{j}		0-10	10-20	20-30	30-40	40-70	Gay et al.
No. Calves	178	53(22)	33(7)	26(1)	35(1)	31(0)	1965
Units^{l}		0-20	20-40	40-60	60-80	80-100	Smith
No. Calves	230	65(1)	53(0)	61(0)	30(0)	21(0)	et al. 1967

[a] Immunoglobulin concentration increases with group numbers, and the number of calves that died is in parenthesis.

[b] Dam 1968, per cent gammaglobulin, paper electrophoresis of serum.

[c] Dam 1968, grams of gammaglobulin/100cc, paper electrophoresis of serum.

[d] Cited from Kruse, 1970c, grams of gammaglobulin/100g serum, protein analysis and electrophoresis.

[e] Mungle 1972, maximum gammaglobulin level in blood (gm/100 ml), microzone electrophoresis.

[f] Mungle 1972, maximum IgG level in blood (mg/ml), microimmunoelectrophoresis.

[g] Penhale et al. 1970, IgG (mg/ml), single radial diffusion.

[h] Klaus et al. 1969, IgG (mg/ml), radial gel diffusion.

[i] Klaus et al. 1969, IgM (mg/ml), radial gel diffusion.

[j] McBeath et al. 1971, McEwan et al. 1970b, Gay et al. 1965, the relative concentration of immunoglobulin determined by a modification of the zincsulfate method of Aschaffenburg, 1949. Turbidity units based on Barium sulfate standard.

TABLE 12. Cont'd.

[k] Cited from Kruse 1970c, Method of Aschaffenburg 1949, units: Extinction x100; 0.634.

[l] Smith *et al*. 1967, Method of Aschaffenburg 1949, units: absorptiometer reading.

TABLE 13. Relationship between colisepticemia and blood immunoglobulin levels.

		Penhale *et al.* 1970					
	No. of Calves	IgG (mg/ml)			IgM (mg/ml)		
		$\bar{X}$	±SE	Range	$\bar{X}$	±SE	Range
Survived	24	7.5	±1.0	1.4-18.6	0.8	±0.1	0.2-2.6
Died							
Non-sept[a]	18	5.0	±1.0	.7-12.6	0.6	±0.1	0.1-1.9
Septicemia	19	0.8	±0.3	0-5.3	0.2	±0.1	0-1.0

		Dam 1968 group means	
	No. of Calves	% gamma-globulin	grams of gammaglobulin[b]
Surviving	21	10.7	.51
Septicemic	6	7.7	.33
Control herd[c]	6	6.3	.26

[a] Non-sept = calves died but not from septicemia.

[b] Grams of gammaglobulin/100cc of serum.

[c] Control calves were taken from a herd not having a septicemia problem.

increased linearly ($P < 0.01$) from 0.02 to 0.19g/100 ml during a 7.5 hour period after feeding colostrum. He also noted an increase in albumin ($P < 0.05$) but not in alpha 1, alpha 2 and Beta globulins. Bush et al. (1971) found peak levels at 24 hours in calves hand-fed colostrum after birth.

Process of Absorption and Closure

Many researchers have studied the processes involved in colostral immunoglobulin absorption and the mechanism of closure to these immune proteins in the newborn in hopes of enhancing immunoglobulin uptake into the circulation.

The time from consumption until the colostral immunoglobulins have been detected in the circulation varies from one-half to three hours according to reports by Fauconneau and Michel (1970), McCoy et al. (1970), and Staley (1971). The peak immunoglobulin levels in calf serum occurred about 24 hours after birth (Bush et al. 1971 and Staley 1971). The newborn calf can absorb a variety of bovine proteins because the intestine does not yet act as a selective filter (Lecce 1966a and Fauconneau and Michel 1970). The piglets gut is also unselective for constituents of pig and cow colostrum and even polyvinylpyrrolidone (PVP) molecules (Lecce and Reep 1961), Klaus et al. (1969) found the two immunoglobulins IgM and IgG absorbed with equal efficiency from the gastro-intestinal tract of the calf.

The mechanism for immunoglobulin absorption is thought to be similar to pinocytosis found in macrophages, planaria and ameoba (Lecce 1966a and Fauconneau and Michel 1970). These proteins cross the intestinal wall in the jejumum and to some extent in the ileum (Fauconneau and Michel 1970). Ultra-structure studies have shown a characteristic cellular organelle in intestinal absorptive epithelial cells in newborn of all species which absorb undigested proteins, i.e. dogs, pigs, horses, and calves (Staley 1971). This organella is tubular and engulfs colostral proteins from the digestive lumen. Globulins are transported into the cell through invaginations and colostral vacuoles are formed to transport globulins through the cell and discharge them into the lamina propria (Staley 1971). From here they pass through the lymphatic endothelium into the general circulation (Fauconneau and Michel 1970 and Staley 1971).

In the discussion of Lecce et al. (1964) they proposed that charged nutrients absorb to the surface membrane with subsequent pinching off of the membrane and vesiculation occurring. Using an in vitro technique Lecce (1965) indicated the transfer of gammaglobulins was energy coupled and not simple passive diffusion. Inhibition to absorption was noted and was reversible indicating that a specific metabolic block could prevent absorption rather than non-specific generalized damage or death of the cell. Information to support this idea was indicated when Lecce (1966a) found reversible inhibition by several metabolic antagonists from the transport system of small molecules such as glucose in mature intestinal epithelium.

Gay *et al*. (1965) speculated that the usually quoted period of absorption in the calf, up to 24 to 36 hours of age, may be an over estimation because they found calves lacking capacity to absorb colostral globulins by four to six hours after birth. Their method for determining absorption ability was not mentioned. Studies by Selman *et al*. (1971b) do not support the idea of early closure since three groups of ten calves not allowed to nurse until six hours postpartum averaged 18.3, 24.9 and 31.2 zincsulfate turbidity units. Only two remained below ten units (six and eight units). Lecce and Morgan (1962) report starved piglets retained absorption capacity until 52-86 hours of age while nursing piglets lost absorption ability after 24 to 28 hours. They also found absorption of PVP possible at 24 and 48 hours in three starved lambs.

Deutsch and Smith (1957) attempted to prolong gut permeability in calves by giving intravenous transfusions of maternal blood. During the 24 to 48 hour postpartum test period three feedings of mature milk (2500 ml total) was also administered. Gut permeability was then tested with proteins from other species, which passed the intestinal barrier during the first 24 hours but failed to do so after 36 hours. These workers also used diethylstilbestrol (100-300 mg), progesterone (200-500 mg) and a combination of these two, cortisone (200-350 mg) and ACTH (120 IV) given either intermuscularly, intraperitoneally or subcutaneously. None of these prolonged the period of permeability. Perhaps the feeding of mature milk during the 36-40 hour pretest period caused the gut to close regardless of the treatments. Deutsch and Smith (1957) also found a mixture of amionic fluid and mature milk would not prolong absorption. Amounts were not mentioned. El-Nageh (1967) suggested amnionic fluid in the gut at birth may hinder immunoglobulin absorption.

Lecce and Morgan (1962) utilized PVP, which has similar weight and osmotic properties as serum proteins, as a test for gut closure. From their experiments they noted that a number of particules and colostrum constituents could cause gut closure (Lecce 1966a, Lecce and Morgan 1962, Lecce 1966b, and Lecce _et al_. 1964). Compounds causing closure were glucose, sow and cow colostrum, lactose, xylose, galactose, and sucrose. Particules lower than 20,000 molecular weight were effective and not just macromolecules. Lecce (1966a) found closure activity could be associated with a fat-free, protein-free colostral fraction and with a dialyzate of either sow's colostrum or non-fat milk solids. Therefore results of Lecce _et al_. (1964) indicated that the absorption of large molecules and closure could be independent. Lecce and Morgan (1962) also found closure in piglets was more dependent on amounts of material fed than on age in the piglet. Newborn piglets eating more than 300 ml of cow's colostrum in the first 24 hours had gut closure while those eating less had guts still permeable to PVP (Lecce and Morgan 1962, and Lecce 1966a). Piglets that were fed more than 300 M Eq (54 grams) of glucose within 18 to 24 hours postpartum were unable to absorb a following 40 ml test dose of egg protein indicating closure and that closure was probably related to amounts consumed. However it was not possible to cause closure in less than 12 hours postpartum with glucose feeding (Lecce 1966b). El-Nageh (1967) remarked that traces of marked protein can still be absorbed in apical villi, in calves in 52-53 hours which have been previously fed glucose solution or colostrum.

Kruse (1970c) from unpublished data suggested calves are exposed to a "cortisol shock" at birth and this may trigger some mechanism causing changes in cell population of the small intestine producing a decline in absorbing ability. Vochover, 1967, (cited by Fauconneau and Michel 1970) stated absorption ceases when epithelial cells of the fetal type are replaced by the adult type but the animal species or evidence was not mentioned. Staley (1971) remarks that the apical tubular system responsible for globulin uptake is present in the absorptive cell only during the postnatal period. The disappearance of this system occurs at 36 hours in fed piglets (Staley *et al.* 1969). Staley (1971) writes that the process of closure is apparently retrograde in that first the basal cell membrane ceases to release the evacuolated product then transport ceases and finally uptake by the tubule system stops.

According to Reid (1956) in 1950 Laskowski and Laskowski found a tryptic inhibitor in colostrum which may act to limit protein hydrolysis in intestines of newborn calves and partially explain the large amounts of absorption of intact globulins during the first two days of life. However Deutsch and Smith (1957) failed to lengthen intestinal permeability by preventing gastric digestion of immune proteins with AL $(OH)_3$ gel. Staley (1971) remarks that proteolytic activity contributes little to intestinal closure mechanism. Parrish and Fountaine (1952) noted the pH in the omasum-abomasum of the unsuckled calf was 4.4 but was pH 6.6 in the small intestine. Staley (1971) further states that colostrum fed will raise the pH in the stomach by neutralizing the HCl.

Hardy (1969) found that bovine serum gammaglobulin mixed in sodium lactate or sodium pyruvate showed a high absorptive pattern into calf serum, characteristic of serum immunoglobulin levels when colostrum is fed. There was poor absorption of serum gammaglobulin in NaCl or HCl solutions. Metabolic energy for the epithelical cells was thought to be increased by the presence of lactate or pyruvate.

Lecce and Morgan (1962) suggested that one of the other benefits of colostrum, other than its antibody contents, is the ability of colostrum to enhance gut closure. Then this "non-permeable gut", like the mature intestine, may be more resistant to invasion by usual gut micro-organisms. However, Staley (1971) writes that *E. coli* antigens were absorbed in one study by older animals supposedly after closure had occurred. Tlaskaloua *et al.* (1970) surmised from their experiment that small amounts of IgM had passed through the intestinal wall of four to six day old piglets and prevented infection from *E. coli* strain 055. From these two pieces of information Staley (1971) states that closure may only occur to a degree which is also dependent on the absorbable material. Closure could be extremely advantageous to the newborn and Staley (1971) suggested that invading bacteria may carry antigens into the circulation, and any lack of continuity of the intestinal epithelium may allow easy passage of organisms and their toxins into the circulation. Gay (1965) speculates that endotoxin also may be absorped causing enteric-toxemia in calves.

Factors Affecting Levels of Immunoglobulins in Newborn Calves

A considerable variation in calves immunoglobulin levels has been reported and mentioned in this review. Klaus *et al.* (1969) relates that much of this difference may be due to different amounts of colostrum consumed by calves during their first 36 hours. Bush *et al.* (1971, 1973) substantiate this in two experiments. In the first experiment they found a correlation of .82 ($P < .01$) between 24 hour immunoglobulin levels in 19 calves and the amount of immunoglobulin consumed in the first 12 hours in two colostrum feedings. Sixty-eight per cent of the variation in 24 hour blood immunoglobulin levels was attributed to differences in the amount of colostral immunoglobulin consumed per unit weight of calf. In their second experiment they report the absolute amount of IgG consumed by 30 calves, but not its concentration in colostrum, had a significant effect on blood IgG levels. Approximately 50 per cent of the variation in blood serum IgG was due to total IgG consumed. Mungle (1972) reports 50 per cent of the variation in serum immunoglobulin levels were also attributable to the level fed in terms of grams of immunoglobulin/Kg of bodyweight. Kruse (1970c) found more than 50 per cent of the variation in the change of immunoglobulin level from birth to 24 hours was due to the mass of immunoglobulin consumed.

Kruse (1970d) used data from previous experiments to build a computer simulation program. He used the program to generate immunoglobulin levels in calves by using parameters of bodyweight, concentration of immunoglobulin in colostrum, amounts of colostrum, and age at first feeding. Results indicated that low levels of serum immunoglobulin in calves is not necessarily associated with malabsorption because this hypogammaglobulinemia condition could occur with certain values of the parameters used. With the wide variation noted in immunoglobulin content in colostrum, Kruse (1970a,d) suggests that practical recommendations should place importance on the amount of colostrum ($>$ 2Kg) given and on early feeding (<5 hours).

Klaus *et al*. (1969) remarked the wide range in percentages of immunoglobulin appearing in serum of ten calves may be related to different amounts of colostrum consumed during the first 36 hours. However, they did not think this would account for the marked hypogammaglobulinemia in three of the calves, nor the lack of relation between colostral and calf serum immunoglobulin levels. Calves were allowed to nurse their dams and the amounts of colostrum consumed are unknown. If a calf consumed only a small amount of colostrum from the dam there is little probability that it would have high immunoglobulin levels regardless of colostral concentration.

McEwan *et al*. (1970a) states calves with high levels of immunity may have 2-4 g per 100 ml of immunoglobulin in serum more than colostrum-deprived animals. With a plasma volume of seven per cent this would be 50-100 g in a 35 Kg calf. Using their regression equation for absorption efficiency ($r = .62$, $P < 0.02$ for $y = 0.16 X + 0.58$, where y = amount of gammaglobulin absorbed as g/Kg of bodyweight and x = amount of colostral gammaglobulin presented as g/Kg of bodyweight) one can calculate that 2.7 liters of colostrum whey with a gammaglobulin concentration of 8 g per 100 ml would provide a 35 Kg calf with 50 g of immunoglobulin. Three and one quarter liters (±6.4 lb.) of whole colostrum is then required if their correction factor for the volume occupied by the casein clot is used to adjust the whey volume needed.

Precaution against overfeeding calves is a typical recommendation and Reisinger (1965) remarks that overfeeding can dilute the acid condition in the stomach, cause sluggish peristalsis and result in upward migration of E. coli in the lower gut. However it is not known if this complex would exist on the first day of life. One, because the frequency of which E. coli occur in the gut at birth is not known, and secondly what is overfeeding in a newborn? Selman et al. (1971b) found a mean intake of 10.8±3 per cent of the birthweight in calves allowed to nurse once at six hours and again at 12 hours postpartum. Calves at the six hour nursing consumed 5.1 lb. of colostrum. They also found a significant negative relationship ($r = -.78$, $P < 0.001$) between birthweight and colostrum intake as a per cent of birthweight in these 20 calves. Wise and LaMaster (1968) and Mylrea (1966) presented evidence that overfeeding alone is not a contributory factor in digestive disturbances.

Smith et al. (1967) fed 30 calves colostrum in buckets at various times postpartum. They remarked that five of nine calves (55.4 per cent) fed 10-12 hours postpartum had serum gammaglobulin under ten units while only seven of 21 (33.3 per cent) fed within eight hours postpartum had less than ten units and they concluded longer times to feeding initial colostrum decreased the amount of immunoglobulin absorbed into the blood. In a farm survey Selman et al.

(1971c) recorded that 76 calves fed within six hours had ZST units of 10.7 ± 6.6 and 88 calves fed after six hours had 6.7 ± 4.5 units with $P < 0.001$. Selman *et al*. (1970a) also calculated a significant negative correlation ($r = -.49$, $P < 0.05$, $N = 15$) between time of first suckling and immunoglobulin levels at 48 hours. Concentration of immunoglobulins and amount of colostrum consumed were not known. Kruse (1970c) also showed with one feeding of colostrum a significant decrease in immunoglobulin absorption as time to first feeding increased up to 20 hours postpartum using 141 calves. The ΔIg per cent by 24 hours was 1.49 for calves fed at two hours, 1.40 for those fed at four hours, 1.15 for those at ten hours, 0.89 for those at 14 hours and 0.86 for those at 20 hours. Howe (1921) reported that colostrum ingestion after a period of 21 hours resulted in globulin absorption but McCoy *et al*. (1970) and Hansen and Phillips 1947 (cited by Reid 1956) found no uptake when colostrum was fed after 24 hours. McCoy apparently fed .7 Kg of pooled colostrum at 24 hours but concentration was not known. Insufficient information was given in these articles for the reviewer to properly evaluate differing results.

Gay *et al*. (1965) remarked that many dairymen wait until the fresh cow is milked at the next regular milking time before they fed the newborn. Many times this may be more than six hours resulting in low immunoglobulin levels according to their findings that some calves may lose the ability for globulin absorption by four to six hours after birth. They did not remark on the method used to quantitate absorption. They stated that some mortality may be prevented if adequate amounts of colostrum are fed immediately after birth. They did not define "some", "adequate" or "immediately". These parameters need to be defined for dairymen.

Concentrations of immunoglobulins in the dam's serum and colostrum has been investigated in a number of experiments. Larson (1958) indicated that two months prior to parturition protein blood levels increase due to increased $Beta_2$ and gammaglobulins. At about five weeks prepartum these start filtering into the mammary gland somewhat faster than new protein are restored to the circulating plasma as indicated by weekly samples. Bush <u>et al</u>. (1971) reports the concentration of immunoglobulin in colostral whey at parturition was considerably higher than in blood serum in cows and Klaus <u>et al</u>. (1969) states this is particularly true for IgG. No meaningful relationship existed between blood serum immunoglobulins of 19 cows and colostral whey immunoglobulin content, however breed differences may have interferred (Bush <u>et al</u>. 1971). Also blood values in cows are probably not normal because of a physiological hypoglobulinemia in the cow at parturition (Dixon <u>et al</u>. 1961). Bush <u>et al</u>. (1971) published values on total protein in colostrum of 19 cows at parturition (13.7 per cent), 12 hours postpartum (10.0 per cent) and 24 hours postpartum (7.0 per cent).

Immunoglobulin levels also declined; 6.03 per cent, 4.25 per cent and 2.40 per cent respectfully. The range of colostral immunoglobulin at parturition was 1.7 to 8.7 per cent on a whole colostrum basis. Samples were apparently taken from that withdrawn to feed the calf at birth at 2.5 per cent of birthweight. Cows were then milked out completely at 12 and 24 hours. Parrish _et al_. (1950) found a variation in total protein of colostrum from 4 to 24.6 per cent in first lactation Jerseys milked completely at first milking. Average total protein at first milkings were 14.0 per cent for eight Holsteins, 14.2 per cent for 11 Jerseys, 15.7 per cent for nine Ayrshires and 20.0 per cent for four first lactation Guernseys. Kruse (1970b) found large individual variations in colostrum yield, immunoglobulin per cent, and immunoglobulin yield and (Kruse 1970a) noted colostrum and immunoglobulin yield were significantly lower in first-calf heifers ($P < 0.01$).

Mungle (1972) was unable to relate the small concentration of total gammaglobulin and IgG in the blood serum of the newborn at birth to the concentration in their dam's serum. Bush _et al_. (1971), with 27 hand-fed calves and Staley _et al_. (1971) also with hand-fed calves plus Smith _et al_. (1967) in 42 calves remaining with the dam, found the calves had much lower Ig blood serum levels than their dams. Klaus _et al_. (1969) found no relation between presuckling colostrum immunoglobulin concentration and levels obtained in calves allowed to nurse. However Staley (1971) reports there was a positive linear correlation (r value was not mentioned) between colostral immunoglobulin concentration and calf serum concentration attained in calves. In this case calves received colostrum on a bodyweight basis (2.5 per cent on day one). This means the total mass of immunoglobulin consumed by each calf would be related directly to colostral immunoglobulin concentration which Staley measured and thus the total mass of immunoglobulin consumed would correlate to serum concentration as was the case in Mungle's study (1972). Smith <u>et al</u>. (1967) noted that in the case of six cows with low concentrations of immunoglobulin in colostrum by sampling time, which was usually within eight hours, could be associated with calves which obtained high blood levels. In these cases he is suggesting the calves had nursed significant amounts of colostrum thus decreasing the concentration by sampling time and increasing the calves blood values. Conversely no calf with low serum values was associated with dams with low colostrum concentrations by sampling time.

Lower immunoglobulin levels were more commonly found in 30 calves that received colostrum by bucket alone than in 70 calves that suckled the dam or in 38 calves that both suckled and were fed by bucket (Smith <u>et al</u>. 1967). No statistics have been applied to Smith's work. McCoy <u>et al</u>. (1970) found significantly higher blood levels ($P < 0.05$) at seven hours in hand-fed calves receiving

.7 Kg of pooled colostrum at zero and 5.5 hours later (.13 g/100 ml) than in calves remaining with their dam (.04g/100 ml). However by 24 hours values were reversed (.29g/100 ml for hand-fed and 0.57g/100 ml for nursed) and they interpreted this as due to smaller amounts of colostrum consumed in the first seven hours by the nursing calves.

Selman et al. (1971a,b,c) examined the effect on immunoglobulin uptake in calves when left with the dam vs separation after birth. Data in Table 14 shows the ZST units for calves left with the cow are significantly higher than in calves separated from dams and hand-fed.

Selman et al. (1971a) attempted to determine if there was an increase in immunoglobulin levels in calves purely due to being in the presence of their dam (mothered). They fed two groups of calves equal amounts of pooled colostrum at one, five, and nine hours postpartum totalling 25 ml/lb. of birthweight. Ten muzzled calves left with the dam (mothered) had an average ZST units of 17.7±3.1 and the other ten calves that were separated at 15 minutes postpartum had only 10.3±2.4 ZST units ($P < 0.001$). Selman et al. (1971b) found similar results between calves when both non-mothered and mothered groups were allowed to nurse the dam at six and 12 hours postpartum. The colostrum intake was measured by weighing calves and intake was similar for both groups. Serum ZST units at 48 hours for ten non-mothered calves, which were returned to nurse, was 18.3±7.6 and 31.2±6.6 for ten mothered calves ($P < 0.001$).

TABLE 14. Comparison of ZST units in calves left with dam vs separated calves.[a]

Month	Time with dam	r	ZST units[b] Mean	SD	
March	12 hours	16	12.7	±7.9	P .05
	Calves separated at birth or when found	96	8.3	±5.7	
April	12 hours	17	16.2	±9.0	P .05
	Calves separated at birth or when found	69	9.4	±5.9	

[a] Selman *et al*. (1971c).

[b] ZST; Optical density of $BaCl_2$ standard is divided into 20 to set scale at 20 units. Then the optical density of a zincsulfate reaction with serum gammaglobulins is multipled by 20/$BaCl_2$ standard. McEwan *et al*. (1970c).

Ten muzzled, mothered calves were allowed to nurse only at six hours and their ZST value was just 24.9±7.7. In this trial there was an increase in immunoglobulin due to the second feeding as evidenced by higher ZST readings in the mothered calves nursing twice. This is contrary to Kruse's (1970d) suggestion that a second colostrum feeding would not lower the incidence of hypogammaglobulinemia in calves because it would not increase blood immunoglobulin levels significantly. In piglets Lecce (1973) remarked that the period of nursing time required for maximum immunoglobulins levels was to six hours postpartum.

From a farm survey in Pennsylvania, Ace (1973) found that nearly one-half of the dairymen removed calves from cows immediately following birth but herds where the cow and calf were left together one or more days had slightly lower mortality.

Smith et al. (1967) found no seasonal variation in immunoglobulin levels in 280 calves. McEwan et al. (1970b) found immunoglobulin levels low from November through April and attributed this to indoor calvings where calves usually were separated and hand-fed. Selman et al. (1971c) found seasonal variation in ZST units that corresponded to the great seasonal variation in mortality in West Scotland.

Selman et al. (1971c) found higher mortality and lower ZST units when calves were born to cows tied in the barn (byre) than when calvings occurred in box stalls or in the field, Table 15.

The differences were attributed to the opportunity the calf had to nurse and be "mothered". According to Selman when a calf is born where cows are tied in barns (byre) the calf is usually removed and fed by hand.

McEwan et al. (1970a) estimated the efficiency of absorption in 13 calves. They received 214.8 grams of gammaglobulin resulting in 55.36 grams of gammaglobulin absorbed into the blood or 1.57 grams/Kg bodyweight. This gives an absorption efficiency of 25 per cent. However taking into account the globulin estimated in the extravascular pool and the fact that the casein clot occupies about 17 per cent of the initial volume of colostrum, the calculated absorption efficiency was then 65 per cent. Klaus et al. (1969) found the mean IgM concentration in calves was 49 per cent (four to 118 per cent) and IgG was

TABLE 15. The effect of place of birth on mortality and immunoglobulin levels.[a]

Place	Number	Serum immunoglobulin concentration (ZST units) Mean	SD	Mortality Rate %
Barn (cow tied)	194	9.0[a]	±5.8	18
Box stall	64	12.0[b]	±7.9	8
Field	69	24.4[c]	±7.9	3

[a]Selman *et al.* 1971c. Significance: a vs b $P < 0.01$
b vs c $P < 0.001$
a vs c $P < 0.001$

60 per cent (six to 106 per cent) of the corresponding colostrum concentrations. This estimate of absorption efficiency does not allow for the amount of colostrum fed or the decreased concentrations in colostrum as more is extracted from the cows. Therefore it is not accurate. Bush *et al.* (1973) found efficiency of IgG absorption to be 66 per cent during the first 24 hours.

Smith *et al.* (1967) remarked that the length of gestation period, the number of pregnancies and the breed of a cow did not appear to influence the immunoglobulin levels in their calves.

Penhale *et al.* (1971) mentioned that severe scours could influence the level and duration of systemic immunity provided. Marsh *et al.* (1969) found serum proteins in the digesta and MacDougall and Mulligan (1969) noted an increased catabolic rate of immunoglobulin IgG in scouring calves. Thus lower immunoglobulin levels could be partially due to degradation of immunoglobulin after several days of scouring.

This review has covered a number of factors responsible for the wide variation in immunoglobulin levels. It does appear that several variables including: time to first colostrum, amount of colostrum, place of calving and to some extent the mothering effect and concentration of immunoglobulins in colostrum fed to calves can be altered or controlled by dairymen to the benefit of newborn calves. Kruse (1970b) does remark that man must not act so that the transfer of immunoglobulins is blocked or unduly reduced.

Animal Behavior

Behavior of both the dam and newborn calf has been observed in several studies and indications are that immunoglobulins and/or mortality may be influenced by the responses of the dam and calf in the early hours of life of the newborn.

Donaldson *et al.* (1972) conducted a study relating maternal behavior of first calf heifers to the methods which as calves they were fed and housed in pens during the "milk" feeding period. After weaning all calves were grouped together and raised until they calved as two year olds. Observations when these animals calved showed that those fed and raised in individual pens as calves were superior mothers to those fed and penned in a group. Cows from the group pen system ignored or only partially cleaned their calves and failed to allow nursing. Also they tended not to protect the young and were extremely vocal toward them.

Selman *et al*. (1970c) assumed the amount of licking to be a measure of mothering intensity and quantitated this activity. He found differences due to the type of cow (Table 16). Three dairy cows (DC) and two dairy heifers (DH) were slow or completely failed to initiate the licking of their offspring. They were not included in the data. Dairy heifers spent the least time licking their offspring. Reisinger (1965) demonstrated that calves born outside in winter, not fed colostrum, not dried, but moved into a warm facility died of diarrhea, but those dried with cloth remained healthy. *E. coli* was found in the upper tract of dead calves, but nothing was mentioned regarding determining the presence of *E. coli* in live calves. Reisinger assumes this analogous to dams licking or grooming the calves.

Selman *et al*. (1970d) found the time for calves to stand was significantly different ($P < 0.02$) for those of dairy cows (DC) and beef cows (BC) whereas those from dairy heifers (DH) were extremely variable (Table 17). Selman *et al*. (1970c) found the shape of the underbelly of the dams was an important factor in deciding how quickly a vigorous calf suckled its dam. Teat seeking activity by

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TABLE 16. The duration of initial licking of calves by dams after birth.[a]

Dams	N	Mean	SD
		min.	min.
Beef cows (BC)	10	48.3	±37.1
Dairy Heifers (DH)	8	11.0	± 8.5
Dairy Cows (DC)	7	32.9	±18.5

[a] Selman *et al.* 1970c.
Signifance: DH vs BC $P < 0.01$
DH vs DC $P < 0.01$

calves was largely directed toward high points of the dam, behind the forelegs or in the groin area (Selman *et al.* 1970d). Therefore high udders as in the beef cows and dairy heifers made it easier for calves to find the teats (Table 18).

Five dairy and two beef calves did not suckle within the eight hours postpartum observation period. Two dairy heifers did not stand for teat-seeking advances by calves but all beef cows did (Selman *et al.* 1970c). Small calves 70 lb. were considerably more vigorous and easier (quicker) to feed than the very large calves (Selman *et al.* 1971a).

How well a cow licks and cares for a newborn calf and how the calf responds by standing, seeking and obtaining nurishment may influence mortality and immunoglobulin levels. It was previously mentioned that calves left with and fed in the presence of the dam had higher immunoglobulin

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TABLE 17. Time for calves to stand after birth, by groups of dams.[a]

Calves	N	Mean	SD
		min.	min.
Beef cows (BC)	10	35.4	14.8
Dairy heifers (DH)	10	72.7	71.6
Dairy cows (DC)	10	58.1	20.6

[a] Selman *et al*. 1970d.
Significance: BC vs DC $P < 0.02$

TABLE 18. Interval from birth to first suckling time for calves from their groups of cows.[a]

Calves	N	$\bar{x}$ interval	SD
		min.	
Beef cows (BC)	8	81.4	±52.2
Dairy heifers (DH)	8	218.3	±113.8
Dairy cows (DC)	7	261.1	±129.1

[a] Selman *et al*. 1970b,d.
Significance: BC vs DH $P < 0.01$
BC vs DC $P < 0.01$

levels than "non-mothered" calves fed equal volumes of colostrum or "non-mothered" calves returned to nurse at six and 12 hours postpartum (Selman *et al.* 1971a,b). Calves may also respond by consuming more colostrum or nurse sooner due to the behavior of dams either of rejection or positive stimulation as licking or grooming. Then also the calf's ability to stand and find the teats will also affect the time and amount of colostrum consumption. So it is evident that there may be many variables in these first few hours that may affect immunoglobulin levels and mortality. These variables may also create a large amount of variation between calves left with the dam during this early period.

Management and Environmental Factors

The purpose of this section is to briefly review a number of management and environmental conditions stated by researchers to influence calf mortality. Factors included are the calving area, temperature, ventilation, feeding regime, type of calf pens, weaning age, type of housing and personnel.

Selman *et al.* (1971c) and Ace (1973) found mortality related to the type of calving area. Selman found higher mortality among calves born to cows in stanchions (15 per cent) than among box stall born calves (eight per cent) and lowest in field born calves (three per cent). Ace (1973) stated greater than 50 per cent of dairymen surveyed in Pennsylvania used box stalls in cold weather,

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approximately 20 per cent had cows freshen in comfort stalls and about 30 per cent allowed calving in the free stall area or other available space. Their mortality for calves up to one year of age was 10 per cent, 14 per cent and 23 per cent respectively. In summertime grassy lots were used most frequently. Selman *et al*. (1971c) stated that these differences occur because calves born outdoors are usually permitted to suckle, however in colder months calves are born inside in barns and removed from their dam and fed fixed amounts of colostrum. This is particularly true for calves born to cows tied in stanchions. This seasonal management difference may be responsible for lower serum globulin concentrations in calves born between November and April in Scotland.

Excessively high and low environmental temperatures is thought to produce stress on young calves. The temperature of the calving area in 191 herds surveyed by Speicher and Hepp (1973) was approximately the same as outside temperature and winter and annual death losses of 19.6 and 15.4 per cent up to weaning were recorded. For the 168 herds where cows were freshened in heated facilities, there were winter and annual death losses of 13.6 and 10.9 per cent. All differences were significant ($P < 0.01$). But average herd size was 51.8 cows for herds calving at outside temperatures and 38.3 cows for herds with heated facilities.

Supplemental heat in calf housing has been reported by Ace (1973) and Speicher and Hepp (1973) in surveys to be related to reduced mortality. Data from Ace's survey is reproduced in Table 19.

TABLE 19. Relationship of mortality to heated and unheated calf housing.[a]

Type of housing	Dairymen using system	Calf losses
	%	%
Cold, no heat added	31	23.3
Cold, heat lamps added	3	16.1
Warm, barn temperature	57	15.4
Warm, heat added	3	14.9
Combination cold and warm	6	19.8

[a] Data from Ace 1973.

Speicher and Hepp (1973) report winter and annual mortality in 195 herds with supplemental heat was 15.9 and 12.7 per cent and in 176 herds without supplemental heat respective losses were 18.6 and 14.6 per cent (heat vs no heat, $P < 0.01$).

Selman *et al*. (1971a) stated calves subject to cold environment (-9.0 to $+5.5^{\circ}$ C) were less vigorous and more difficult to feed than control animals. Appleman and Owen (1971) remarked about a definite climate-nutritional interaction in calves reared in the cold. Gonzalez and

Blaxter (1962) found the critical temperature in three day old calves to be 13° C (55° F) below which heat production increases in response to a fall in air temperature. Jorgensen _et al_. (1970) compared daily gains in calves to six months and found no difference at six months in calves reared in heated barns and those reared outdoors in South Dakota. The outdoor temperatures and type of calf units were not mentioned.

Appleman and Owen (1971) write that raising the humidity will decrease heat loss of calves and can increase the heat stress on an animal in cold environmental temperatures. Water vapor cannot escape from surfaces causing dampness of the hair coat, bedding, floors and walls thus increasing the unfavorable effect of low temperature. High temperature increases water consumption and urine output which may double water vapor production.

Controlling the temperature and humidity then become very important and require controlled and effective ventilation in calf houses. Smith (1973) listed five key factors for calf barn ventilation. 1) Insulation is needed to retain available heat. 2) Ventilation rate must be equal to rate of moisture production by animals in winter and in warm weather rate of heat removed by ventilation should equal total heat production minus heat loss through building structure. Boyd (1970) and Smith (1973) differ in their recommended ventilation rates. Boyd suggests for a 50° F calfhouse temperature, a winter ventilation rate of 1/10 cfm/lb. of animal (10 cfm/100 lb.) and a summer rate of 2 cfm/lb. of animal (200 cfm/100 lb.). Smith suggests that ventilation rate should be 14 cfm/calf (100-300 lb. bodyweight) at ambient temperatures less than 20° F, 32 cfm/calf at ambient temperatures of 20-50° F and 120 cfm/calf when ambient temperatures exceed 50° F. Smith and Boyd recommend calf house temperatures of 65 to 55° F and 50° F respectively and both recommend the use of two-speed fans to achieve flexibility in a system to maintain uniform temperatures. Smith mentioned various methods for air intakes but dwelled on a system using forced air throw tubes with punched holes to provide even distribution of air throughout the calf house. This would eliminate drafts from incoming air.

Boyd (1970) suggests the amount of heat required to maintain calf house temperatures when adequate ventilation removes moist heated air can be calculated from the following equation.

Pounds of calf x 4 _____
Square feet of wall x 5 _____
Square feet of glass x 10 _____
_____ Total BTU's required

Appleman and Owen (1971) and Oxender _et al_. (1973) mentioned that calves are now housed in greater densities in both new and adapted buildings than in previous years when herds were typically smaller in cow numbers. Oxender _et al_. (1973) believe this may be contributing to the

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presence of bacterial and virus infections. Anderson (1973) comments that increased movement of animals through channels of trade has contributed to the general dissemination of many diseases. Appleman and Owen (1971) and Anderson (1973) submit that organisms become more virulent as they sequentially pass from calf to calf and thus in larger groups of calves the organisms may become more "infectious". Roy _et al_. (1955) commented that the occurrence of infections in their calf house increased with time after reoccupation of the house and as the number of calves successively reared increased. This resulted in higher frequency of diarrhea and mortality. Also the growth rates became less.

Oxender _et al_. (1973) reported a significant increase ($P < 0.05$) in survival rates (by 4.6 per cent) of calves raised in an area separate from the maternity stalls. Speicher and Hepp (1973) surmised from their survey that use of individual pens until weaning had no measurable effect on calf mortality. Those using individual stalls had 47.9 cows and annual losses of 13.6 per cent and dairymen using group pens had 43.5 cows and annual losses of 13.3 per cent.

Ace's (1973) survey indicated that calves raised in free stalls to be most favorable, followed closely by individual tie stalls, and then box stalls. The heaviest losses occurred when calves were tied in any location (24 per cent or seven to eight per cent greater than other systems). The number of dairymen and size of herds were not mentioned by Ace. A statistical evaluation was not available.

Appleman and Owen (1973) reported that calves raised in individual wooden pens 4 feet by 6½ feet had a significantly lower incidence of scours than calves raised in individual metal stalls 4½ feet by 4½ feet (Table 20).

TABLE 20. Effect of type of pen construction on scour incidence.[a]

	days of age		
Pen	2-21	22-42	43-60
	mean[b]		
Metal 4½x4½	1.49	1.88[c]	1.75
Wooden 6½x4	1.35	1.73	1.64

[a] Data from Appleman and Owen 1973.
[b] Mean scour index: 1=normal, 2=soft, 3=very loose, 4=watery.
[c] Significant for 78 calves at $P < 0.05$.

Appleman and Owen (1971) remarked that a 4½ by 4½ foot pen was satisfactory even if a built litter system is used for six weeks. They also believed that the principal problem with raised stalls was maintaining control of drafts.

Since Appleman and Owen indicate stall size may be a factor in scour incidence the survey reports by Speicher and Hepp (1973) may show little or no better results with individ

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individual stalls due to inadequate space for calves which are tied in 2 by 4 foot or 2 by 5 foot stalls. The square feet of bedding a calf has may be important enough to cancel any desirable effect of isolating calves in tie stalls compared to rearing them in groups where dry bedding may be more plentiful. Outdoor hutches used by Jorgensen _et al_. (1970) required less labor and bedding and although the exact size of the stalls were not mentioned the stall space may well be 32 square feet. In this situation a longer time would be required to dampen bedding thus providing more dry pack to lie on and less bedding turnover.

Weaning age of calves varies from three weeks to several months and Ace (1973) listed mortality from herds weaning calves at different ages. This data is found in Table 21. The higher mortality in the group weaning at six weeks is not readily explainable. Ace remarks this could occur because these dairymen are weaning just because calves have reached six weeks of age and not giving consideration to calves ability to eat sufficient feed.

Appleman and Owen (1973) and Jorgensen _et al_. (1970) have both successfully weaned calves at three weeks of age. However Appleman and Owen report that weaned calves at day 42 were heavier at day 42 and 57 than were calves weaned at day 21 ($P < 0.01$). Difference between groups disappeared by six months and they remarked early weaning significantly increased starter consumption between day 21 and 42. Reasons for early weaning at day 21 are that calves spend

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TABLE 21. Weaning age of calves in 545 Pennsylvania dairy herds and the per cent calf mortality by weaning age.[a]

Age weaned (weeks)	% dairymen	% loss
4	14	15.2
6	43	19.9
8	34	15.2
More than 8	9	14.2

[a] Data from Ace (1973).

less time in the calf barn so smaller units can be used and rotated in shorter intervals and there is smaller bedding build up with less labor required for changing bedding. Also less of the more expensive liquid feeds are fed.

The feeding regime is one subject that has been extensively reviewed in the literature where feeding practices have been related to calf illness. Speicher and Hepp (1973) found no effect on calf mortality in their survey due to the length of time the calf was allowed to remain with and nurse its dam. This is contrary to the findings of Selman <u>et al</u>. (1971c) where place of calving and usual time the calf was allowed to nurse appeared important. Information on the time of first colostrum feeding after birth and the duration of colostrum feeding was obtained in the survey of Oxender <u>et al</u>. (1973) and both significantly affected mortality ($P < 0.05$) Table 22.

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TABLE 22. The use of colostrum in raising calves and its effects on survival.[a]

Treatment	No. of herds	Died 0-14 days	 15-60 days	Total mortality
		%	%	%
First feeding of colostrum less than 6 hours	267	7.6^{c}	2.6	10.2^{c}
6 to 12 hours	151	10.5	2.9	13.4
Days colostrum fed				
0	6	19.7^{a}	2.4	22.1
1	22	8.4^{ab}	2.7	11.1
2	89	10.9^{ab}	3.2	14.1
3	345	7.8^{b}	2.7	10.5

[a] Data from Oxender _et al_. 1973.
[ab] Values with different letter superscripts are different $P < 0.05$.
[c] Each difference in column is significant at $P < 0.05$.

This reviewer would question whether dairymen know how soon their calves are getting colostrum as many leave the calf with the cow for at least 12 hours with little observation on suckling.

Ace (1973) reported three per cent of the dairymen did not feed any colostrum and had 24 per cent mortality, 75 per cent fed colostrum one to three days and had 20 per cent losses and 32 per cent fed colostrum more than three days and had 13 per cent death rate.

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Speicher and Hepp (1973) found 20 per cent of the surveyed herds fed milk until weaning age, 27 per cent began to feed milk replacer immediately after the feeding of colostrum and 53 per cent started calves on milk and then changed to milk replacer. Differences in mortality were not significant. Similarly, Oxender et al. (1973) found a non-significant difference of 2.1 per cent less mortality in herds feeding milk instead of milk replacer. Ace (1973) reported 75 per cent of surveyed dairymen fed milk replacer but those feeding whole milk had less losses. Reid (1956) writes that when a high level of infection existed a higher rate of mortality was found in calves fed synthetic milks than those reared on whole milk, even though all calves originally had the same level of passive immunity. Aschaffenburg et al. (1949) found less scours and higher daily gains and no mortality in ten calves fed untreated colostrum where five of seven calves died which were fed a colostrum substitute.

Swannack (1971) raised home bred British Friesian calves on cold milk substitute or 13 day old sour or fermented colostrum. This colostrum had a stable pH of 4.0 after 12 days. It was readily accepted by dairy heifer calves. When fed in place of the milk substitute the feeding costs to weaning were reduced 78 per cent. Calves on all treatments achieved the same live weight at 84 days.

Roy (1970) writes (pg. 127) that in infants, fermentative diarrhea, which is probably similar in many respects

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to so-called 'nutritional scours' in calves, is associated with excessive carbohydrate in the diet, or a deficiency of enzymes to degrade the carbohydrate. The only sugars that can be utilized by the young calf are glucose and lactose and yet too large a quantity of these in the diet may cause diarrhea.

Pettyjohn *et al.* (1963) and Burt and Irvine (1972) relate high dry matter (greater than ten per cent) liquid diets to increased incidence of scours. Work of Pettyjohn *et al.* (1963) indicated poor utilization of dry matter when calves were fed 20 and 25 per cent dry matter while 15 per cent dry matter gave better utilization than 5 or 10 per cent dry matter.

Owen and Brown (1958) found no difference in bodyweight gain or efficiency with respect to temperature of liquids (47-52° F vs 97-100° F). Diarrhea was not a problem.

Wise and LaMaster (1968) and Mylrea (1966) both have experimental results that indicates calves can handle large amounts of liquid when fed ad libitum twice daily. In both trials calves consumed milk to about 20 per cent of their bodyweight. Wise and LaMaster used only seven calves from four through seven days of age. Calculated per cent calf days of diarrhea was 19 for calves fed by nipple and 25 for those fed in open pails. Seven other calves restricted to 14 to 18 per cent of bodyweight intake had 0 and 13 per cent days of scours for nipple and open pail feeding. Mylrea noted few adverse effects with ad libitum intake. Calves were abruptly changed from a restricted intake to ad libitum and reversed again several times during a period from day 9 to 38. During four of ten sub-periods of ad libitum feeding a gross change of feces did occur and some variability of appetite occurred. No calves in their experiment with re-entrant cannulae of the small intestine had gross fecal changes when subject to the ad libitum regime. Mylrea also found by use of x-ray opaque material that even when feeding large amounts of liquids all passed to the abomasum which was highly distensible giving it the capability to hold these large amounts of liquid milk. Mylrea concluded the high levels of intake are not a major cause of digestive disorders which is contrary to the belief of Reisinger (1965) and others.

The complete passage of the milk may be affected by the methods of feeding. Tiedemann and Gmelin in 1826 and Schalk and Amadon in 1928 and Wise and Anderson in 1939 (all cited by Reid 1956) pioneered work discovering that in suckling calves liquid is shunt via the esophogeal groove to the abomasum but when drank from a pail, much entered the reticulo-rumen. Thus suckling vs drinking is the reason given by most investigators for lower scour incidence, as is possibly the case in Wise and LaMaster's (1968) work, when calves were fed by nipple bottle as compared to the pail fed calves. This effect may be less when restricted amounts are fed. Ace (1973) reports that 43 per cent of 545 herds used nipples to feed and had two per cent less mortality and Oxender *et al.* (1973) found no mortality difference between 158 herds using pails and 126 herds using nipples.

The personnel responsible for feeding and caring of calves is thought by many to be rather important in determining the rate of mortality. Ace (1973) from survey information ranked these in order of decreasing mortality as the mother, hired man, dad, and youngsters. Oxender *et al.* (1973) report no significant difference in mortality due to personnel responsible for feeding calves. Table 23 contains data from Speicher and Hepp (1973) giving creditability to the hypothesis that increased herd size and use of hired labor dilute the effects of good herd management.

In summary surveys and experimental trials relate many factors to calf mortality. However the presence of interactions is not easily detected with these methods alone. In other words the factors easily related to mortality may not really affect mortality but may be related consistently from farm to farm to particular practices that are influential. Herd size is evidently related to mortality rate but reasons for this relationship appear complex. Whatever interactions exist have not been clearly identified.

It is a tedious process for many cattlemen to make sure that the newborn calf receives adequate levels of

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TABLE 23. Relationship between persons caring for calves and calf mortality on 378 Michigan dairy farms.[a]

Person(s) caring for calves	No. of farms	Mean herd size	Calf mortality		
			Seasonal		
			Winter[b]	Summer	Annual[b]
			%	%	%
Operator	171	46.0	16.2	10.0	12.8
Hired labor	25	53.2	28.1	12.4	20.1
Mother or wife of operator	25	38.2	15.0	9.4	12.3
Children of operator	66	44.1	16.0	10.0	13.1
Operator with assistance	67	46.1	16.2	10.9	13.5
All other combinations	24	44.9	16.3	11.1	13.4

[a] Data from Speicher and Hepp 1973.
[b] Significant difference ($P < 0.01$) in calf mortality, with person caring for calves, both annual and winter data.

immune protein via colostrum and then maintain the calf and the environment to the best advantage of the calf. In this rearing process many interacting factors are involved which may tip the balance favorably or unfavorably and thus result in survival or death of the calf. The successes and failures of this procedure is a puzzle to many cattlemen and scientists alike.

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CHAPTER III

MATERIAL AND METHODS

Experimental Plan - Trial I

Nine Holstein calves in the University herd were allowed to remain with their dam for approximately 36 hours postpartum. Calves were not assisted in nursing during this period. Following their removal calves were weighed and placed in individual pens 4 feet by 6 feet with sawdust bedding. Calves then received four pounds of whole milk twice daily from an open pail. These calves are referred to as mothered calves. Nine other Holstein calves were permitted to remain with their dam for only one-half hour during which time the dam was allowed to lick the calf clean. Calves were weighed upon removal and placed in pens of the same type as the mothered calves. These calves were fed by nipple bottle 2 lb. of their dam's colostrum one hour postpartum. This colostrum was hand milked from the dam after the calf was removed. Calves then received 4 lb. of their dam's colostrum at 12, 24 and 36 hours postpartum from a nipple bottle. This colostrum was taken from subsequent machine milkings of the dams. After 36 hours calves were fed whole milk at 4 lb. two times daily from an open pail. These calves are referred to as separated or non-mothered calves.

Blood samples for serum immunoglobulin determination were taken at 24, 48 and 72 hours and two weeks postpartum in the nine mothered calves and just prior to feeding at one hour, again at 2, 6, 12, 24, 36, 48 and 72 hours and at two weeks postpartum in the nine separated calves.

TRIAL II

Calves from 32 Holstein cows in the M.S.U. herd were blocked into two groups according to date born, February through March or April through May 1973, and within these two groups they were blocked into two genetic groups, best or worst. The best breeding group is those cows in the M.S.U. herd who were sired by two newly proven young sires each year found to have the highest predicted difference for milk among a group of young sires progeny tested by Select Sires Inc. These cows were also from dams who were sired by similarly chosen young sires. Those cows in the worst breeding group were sired by two young sires having the lowest predicted difference for milk among this same group of young sires and these cows were also from dams who were sired by similarly chosen young sires. This blocking for genetic capability would provide information on genetic influences upon immunoglobulin absorption. These calves were then randomly assigned to a treatment combination in a 2 by 4 factorial scheme. Two initial feeding levels of colostrum were given: 1 and 3 lb., and four initial times to first colostrum; 1, 2, 6 or 12 hours

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postpartum. The object was to evaluate the effect of the initial amount of colostrum given and the time it was given on the estimated serum immunoglobulin levels in these newborn calves. Figure 1 shows a diagram of the split plot 2 x 4 factorial design used.

Treatment of Calves

Calves were permitted to remain with the dam for 15 to 30 minutes allowing the dam to lick the calf clean. The calf was then removed, weighed and placed in an individual 4 feet by 6 feet pen with sawdust bedding. These pens prevented contact between calves and were scrubbed between use by calves.

Colostrum Feeding

Calves were fed pooled colostrum to remove the effect of variation due to colostral immunoglobulin concentration. Four groups of approximately ten cows were used to make four pooled batches.

Colostrum collected from cows at the first and second milkings was frozen in one gallon containers at -20° C. When sufficient colostrum was collected from approximately ten cows to make a sizeable batch it was thawed, throughly mixed and placed in one gallon containers and refrozen until use. Thawing was at room temperature or in warm water. Lots of first milking were designated batches 1, 3, 5 and 7 and lots of second milkings were designated batches 2, 4, 6 and 8.

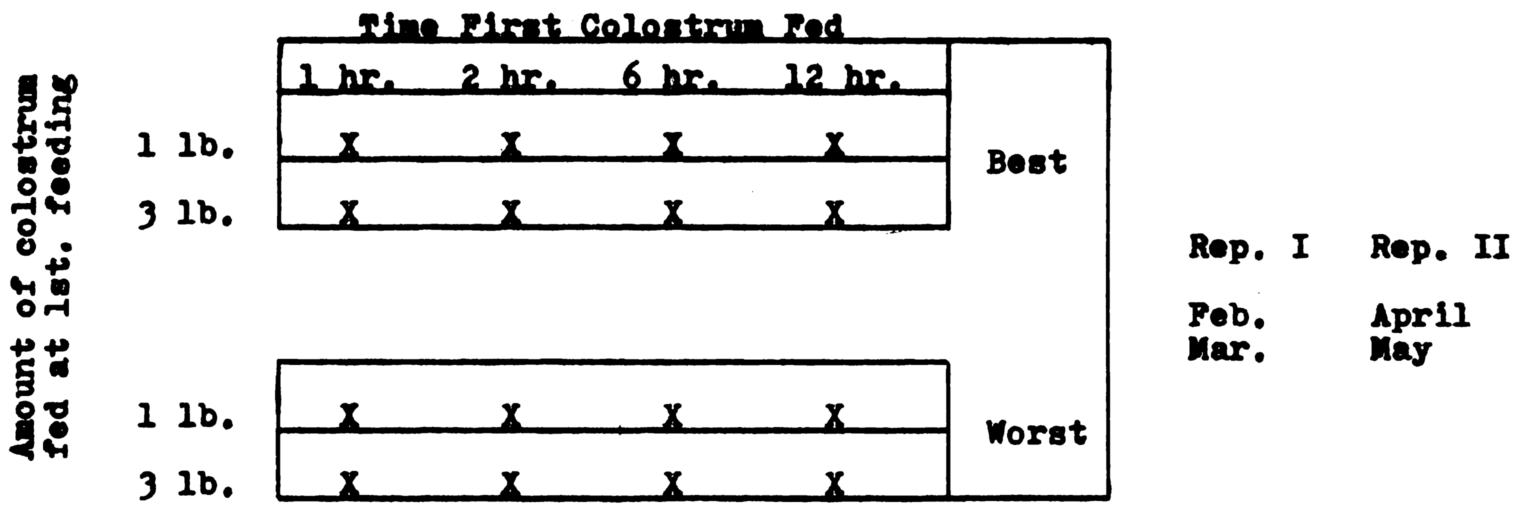

Figure 1. Experimental design for Trial II using 32 Holstein calves with two colostrum amounts and four times postpartum in two breeding groups at two calendar times.

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Batches 1 and 2, 3 and 4, 5 and 6, 7 and 8 were paired batches. That is batch 1 was from the first milkings and batch 2 was from the second milkings of the same 10± cows. Each calf received all its allotted colostrum from the same paired batches. As one paired batch was used up by sequentially born calves then the next paired batch was used. All calves then received the allotted amount (1 or 3 lb.) for the first feeding from one of the four batches of first milking. All feedings except the final feeding in the 38 hour postpartum period was from first milking colostrum while the final feeding was from second milking colostrum. Table 24 indicates the times of feeding and total amounts of colostrum received in the 38 hour period postpartum.

After the 38 hour period calves were fed 4 lb. of whole milk twice daily from an open pail. Water and dry feeds were withheld for several days after birth.

Analysis of Serum for Immunoglobulin Levels

All serum samples from Trial I and II were taken from the jugular vein of calves by using 10 ml vacutainer tubes. Samples were refrigerated for 12 to 24 hours then centrifuged for 15 minutes at 800 Xg. A sample of serum was then frozen at -70° C and later stored at -25° C until tested for immunoglobulin content.

The estimation of immunoglobulin content of blood serum was determined by the zincsulfate turbidity method outlined by McEwan *et al*. (1970c). This test is based on

TABLE 24. Amounts of colostrum and times for colostrum feedings within each treatment combination.

Amount of colostrum at first feeding	Time of first feeding				Colostrum from milking no.
	1 hr.	2 hr.	6 hr.	12 hr.	
1 lb.	1[a] at 1[b]	1 at 2	1 at 6	1 at 12	1
				2 at 18	1
	4 at 13, 25	4 at 14, 26	4 at 18	4 at 24	1
	4 at 37	4 at 38	4 at 30	4 at 36	2
	Total[c] 13	13	9	11	
3 lb.	3 at 1	3 at 2	3 at 6	3 at 12	1
	4 at 13, 25	4 at 14, 26	4 at 18	4 at 24	1
	4 at 37	4 at 38	4 at 30	4 at 36	2
	Total[c] 15	15	11	11	

[a] Lb. of colostrum for that feeding.

[b] Hour postpartum that feeding occurred.

[c] Total lb. of colostrum fed in 38 hours postpartum.

a turbid reaction of a zincsulfate solution and the gammaglobulin fractions in blood serum. Zincsulfate solution is made by adding 208 mg of $ZnSO_4 \cdot 7H_2O$ to one liter of distilled water which had been boiled for 10-15 minutes to remove dissolved carbon dioxide. This solution was made fresh each time. It was dispensed from a repipette bottle with the CO_2 removed from incoming air by using ascarite. The repipette was set to deliver .1 ml serum and 6 ml of zincsulfate solution into a test tube. Blank determinations were made with every fifth serum sample which included 6 ml of distilled water plus .1 ml of serum. Blanks were not determined on every sample since blanks for different serum did not differ significantly to affect accuracy.

Each day determinations were made, a standard of barium sulfate was prepared so that results obtained may be compared to those found in other laboratories and on a day to day basis within this study. This suspension was prepared by dissolving 1.15 g of barium chloride ($BaCl_2 \cdot 2H_2O$) in 100 ml of distilled water and then 3 milliliters of this solution was mixed with 97 ml of 0.2 N sulphuric acid to make 100 ml of barium sulfate suspension whose turbidity was very constant when prepared on different days. The serum:zincsulfate mixture was incubated for one hour at 20° C as were test blanks and the standard solution. These solutions were then sequentially paired in one of a set of matched 1 cm light path cuvettes. One cuvette contained water and was arbitrarily set at 100 per cent transmittance when read using a wavelength of 650 mu on a Beckman DB spectrophotometer. The reading of the sample was then converted to optical density using a table based on optical density = 2-log of transmittance of the sample contained in the second cuvette. The per cent transmittance for the barium sulfate standard varied between 14 to 16. All test blanks with 6 ml of distilled water and .1 ml of serum had 98 to 99 per cent transmittance and were therefore negligible and not considered in any calculation. Relative turbidity units were then calculated assuming a value of 20 units for the $BaSO_4$ standard. For instance the standard had a transmittance of 14 or an O.D. of 0.854 therefore 20 divided by 0.854 = 23.42. This value (23.42) was used as the multiplicand for the optical density of each sample to give relative turbidity units for each sample.

Serum samples taken at 48 hours in Trial II were also analyzed using cellulose acetate electrophoresis which is a procedure frequently used on human serum. Procedures used were somewhat modified from those outlined in a manual provided by the Gelman Instrument Company of Ann Arbor, Michigan. The Cellulose Polyacetate (Sepraphore III) strips were placed in a cold Tris-Barbital-Sodium Barbital buffer (pH 8.8) which had been lowered to pH 8.6 for bovine serum by use of HCl. Serum (3-4 ul) was applied to each strip by a wire applicator. The strips were then placed

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placed in a Gelman electrophoresis chamber. Three hundred volts were maintained with 2.5 milliamps per strip. After one hour strips were then placed in Ponceau S stain for five minutes. They were then destained and dehydrated by usual procedures. The strips were placed in clearing solution and then put on 4 inch cleaned glass slides.

Density of the stained bands of protein were then determined on a Gelman Gelscan densitometer using the 620 mu filter. Tracings of density were recorded on a Goertz Electro recorder which had an integrator to measure the area under the curves. The percentage of proteins in the albumin, alpha, beta and gamma areas was then determined.

Total serum protein was determined by refractive index using a Goldberg refractometer. From a table provided the total protein in the serum was calculated and recorded. Micro Kjeldahl procedures were also used for total protein. The total protein value was then used to express the quantity of each protein fractions in terms of gram/100 ml of serum.

Analysis of Protein and Immunoglobulins in Colostrum

Colostrum given to calves in Trial II was pooled in order to remove variation between dams in immunoglobulin concentration. Samples from the four first milking batches and four second milking batches were analyzed for immunoglobulin content.

One milliliter of commercial cheese rennet was added to 20 ml of a thawed colostrum sample and incubated in a

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water bath for two hours at 37° C. Samples were centrifuged for 15 minutes at 800 Xg. and the whey was decanted and frozen at -20° C until analyzed. Total protein was determined on the whole whey by semi-micro Kjeldahl procedure. A 10-20 ml portion of the whey sample was dialyzed for 1 to 1½ hours to remove much of the water. These samples were then electrophoresed on cellulose acetate strips as were blood serum samples except that the dye used was Naphthol blue black. The dye was prepared by adding 100 mg of Naphthol blue black to 100 ml of saturated aqueous picric acid. Density of the protein bands was determined using a Gelman Gelscan densitometer and Gortez Electro recorder and the percentage of gammaglobulin was calculated. Total gammaglobulin in each colostrum batch could be expressed quantitatively by multiplying percentage distribution by total nitrogen content per 100 ml of serum.

FIELD STUDY

Various informants were used to obtain a list of potential dairymen either having good success in raising calves or having high calf mortality. These dairymen were then contacted by phone to determine if they would be willing to provide information and animals for this field study and to verify their calf mortality rate. Herds smaller than 40 milking cows were excluded from this study since too few calves would be born during the observation period to provide usable information. Thirty-five cooperator herds were selected and sufficient data was collected from 30 herds.

Each herd owner was asked to complete a questionnaire upon the initial visit to provide background information and mortality statistics for the year of 1972. From the 1972 data herds having calf losses from birth to two months (excluding those born dead) greater than 15 per cent were classified as high mortality herds (17 herds) and those with losses less than 10 per cent were classified as low mortality herds (13 herds). A sample of the questionnaire forms Table 25.

Dairymen were asked to phone whenever a cow calved so that I could take a blood sample as near as possible to 48 hours postpartum. Samples were taken from the jugular vein using a vacutainer tube and handled and analyzed the same as those in Trials I and II. Sampling of calves started in January of 1973 and continued through May of 1973. Dairymen were given a data sheet to record the time the calf was born, its identification number, its dam's number, date born, date died, and sex. Then for estimating some management effects the high mortality herds were arbitrarily split into two groups. One group (nine herds) along with the 13 low mortality herds were asked to record the time after birth the calf first received colostrum and the hours it spent with the dam when they were known. The reason for separating high mortality herds into two groups was to determine if the dairymen who were to record how soon the calf received colostrum would

TABLE 25. Questionnaire for calf mortality study - January 1973.

The purpose of this questionnaire is to gain information on your calf problems and help us develop research projects that may solve your calf raising problems.

Information is for the calendar year 1972.

NAME______________________________ COMPLETE MAILING ADDRESS
____

Circle the correct answer.

YES NO 1. Do you use maternity (box) stalls for cows calving?
2. Calf raising pens are:
YES NO a) in separate building from calves older than 2 months?
YES NO b) in separate building from maternity pens?
YES NO 3. Are dry cows kept separate from the milking herd?
YES NO 4. Do you dip the navel of newborn calves with iodine?
YES NO 5. Do you take body temperature of sick calves?
YES NO 6. Do you supply supplemental heat to your young calf raising facilities?
YES NO 7. Do you use fans for ventilating your calf housing?
YES NO 8. Do you routinely use antibiotics on calves at birth?
YES NO 9. Do you routinely use antibiotics for scouring calves?
10. Are there any other treatments or supplements given to calves?
YES NO a) at birth? What? __________
YES NO b) when scouring? What? __________

Place the correct number or letter for answer in space at left edge of page.

_____ 11. Do you vaccinate calves for: A) IBR; B) BVD; C) PI-3; D) None of these.
_____ If so, at what age in months do you vaccinate calves?
_____ 12. Have the cows been vaccinated for: A) IBR; B) BVD; C) PI-3; D) None of these.
13. If cows have been vaccinated for IBR
_____ a) were they vaccinated as calves? A) Yes; B) No; C) Some were.
_____ b) If they were vaccinated as cows, at what stage of lactation? A) Dry; B) Just prior to calving; C) Fresh to 3 months in lactation;

D) 3 to 9 months in lactation.

_____ 14. If you use antibiotics for calves, which ones? A) Combiotic; B) Tetracycline; C) Neomycin; D) Sulfas; E) Furacin; F) Penicillin; G) Chloromycetin; H) Vetsulid; I) Other _______

_____ 15. Number of cows milked.

_____ 16. Number of heifers and female calves for replacements (all females never fresh).

_____ 17. Average milk production per cow per year.

_____ 18. Type of housing for cows: A) stanchion or tie stalls; B) free stalls; C) loose housing; D) Other __________

_____ 19. Type of stalls for young calves to 2 months of age: A) individual pens; B) individual tie; C) group pens; D) other __________

_____ 20. How many maternity (box) stalls do you use?

_____ 21. How long do calves usually remain with cow after birth? A) calves not left with cow; B) less than 3 hours; C) 3 to 12 hours; D) 1 to 2 days; E) longer

_____ 22. Number of calves born <u>live</u> during 1972?

_____ 23. Number born dead during 1972?

_____ 24. How many calves died between birth and 14 days?

_____ 25. How many died between 14 days and 2 months?

_____ 26. Do you supply calves with fluids when they have scours or diarrhea by: A) oral administration; B) intravenous; C) none

_____ 27. How soon after the calf is born do you usually feed colostrum? A) not fed; B) less than 6 hours; C) 6 to 12 hours; D) 12 to 24 hours

_____ 28. Which of the following calf raising problems cause you the most trouble? A) scours; B) respiratory (coughing, etc.); C) navel infections; D) other __________

29. Complete the following table where method of feeding is: A) automatic nurser; B) bucket; C) nipple bucket; D) nipple bottle; E) other __________

	Age of calves (in days) during feeding	Times fed per day	Method of feeding (A,B,C,D,E)
Colostrum	______________	__________	____________
Whole milk	______________	__________	____________
Replacer	______________	__________	____________
Mixture___	______________	__________	____________

30. Rank the following in regard to helping you successfully raise herd replacements. 1=very helpful; 2=helpful; 3=not helpful.

_____Feed Salesman

_____Veterinarian

_____Magazine articles

_____Neighbor

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_____County Extension Agent _____DHIA tester
_____University Extension Specialist

31. If you attended the meeting last winter on preventing calf mortality, please answer the following questions.

_____ a) How many calves have you saved as a result of attending the meeting?

_____ b) What other benefits were gained from the meeting?

secondarily reduce mortality due to closer observation, and particularly explore the possibility that they may make some effort for calves to receive colostrum sooner after parturition during this study than was usually the case in their herds.

During numerous visits to the 30 herds data were also collected on the temperature and humidity of the calving area and the calf facilities. Bedding samples for dry matter and other observations were taken from both the calving area and calf pens in most of these herds. Several herds used raised steel constructed stalls with steel barred floors and no bedding for the young calves.

The size and type of calf pens were recorded as was the number of calves in the calf facilities. Notes on the type of calving facility and the number of cows sharing this facility was recorded and other general information was noted.

CHAPTER IV

RESULTS AND DISCUSSION

TRIAL I

The nine mothered calves had higher estimated immunoglobulin levels as estimated by zincsulfate turbidity units, at 24, 48 and 72 hours and at two weeks than did the calves separated from their dam at birth. Table 26 gives values for each calf at 48 and 72 hours and at two weeks. Figure 2 graphically shows the difference between the two groups and the immunoglobulin pattern from birth to two weeks for the nine separated, hand-fed calves. Only six of the nine mothered calves had serum sampled at 24 hours. Maximum concentrations occurred near 24 hours, as was found by Bush _et al_. (1971). Also levels in mothered and hand-fed calves remained rather constant between 24 and 72 hours, then by two weeks levels decreased to 77 per cent of their 72 hour level. Mean values for hand-fed calves for one hour to two weeks are given in Table 27 with the amounts of colostrum fed. Hand-fed calves received 6 lb. of colostrum (2 lb. at one hour and 4 lb. at 12 hours) prior to the 24 hours when concentration reached a plateau. The second feeding probably had a large contribution to the 24 hour or maximum level because calves

TABL

Calf
No.

Moth

1343
1188
1345
1021
972
1346
1347
1348
900
Mean

Sepa

1192
1119
1344
1349
1351
1352
135
1354
1189
Mean

---

[a] Ger
[b] C
Cal
let

TABLE 26. The estimated immunoglobulin levels in newborn mothered and separated calves at fixed times postpartum.

			Time After Parturition		
Calf No.	Dam No.	Genetic Group[a]	48 hr.	72 hr.	2 weeks
Mothered group			-------ZnSO$_4$ turbidity units--		
1343[b]	967	B	27.05	30.47	20.75
1188A	1188	C	2.16	2.27	3.21
1345	1199	B	12.93	12.50	10.12
1021A	1021	B	18.64	18.03	9.84
972A	972	W	4.38	4.01	2.93
1346	1133	C	20.75	11.92	18.03
1347	1133	C	10.68	11.29	5.36
1348	900	B	6.18	7.26	6.37
900C	900	B	20.00	24.50	17.45
Mean ± S.E.			13.64± 2.83	13.58± 3.10	10.45± 2.25
Separated group					
1192A	1192	C	3.42	4.31	3.63
1119A	1119	B	9.20	11.29	4.71
1344	1129	B	12.60	9.84	9.32
1349	1070	B	5.04	11.13	7.26
1351	923	B	19.30	21.17	16.37
1352	1047	B	9.58	6.84	6.65
1353	1140	C	6.84	6.09	4.77
1354	1194	C	4.87	7.92	4.87
1189A	1189	W	7.68	6.70	7.68
Mean ± S.E.			8.73± 1.62	9.48± 1.66	7.24± 1.29

[a] Genetic groups in MSU herd, B = Best, W = Worst, C = Control.

[b] Calves with numbers in 1300's are heifers, those with letter following dam's number are bulls.

Figure 2. Serum immunoglobulin levels from one hour to two weeks of age as estimated by zincsulfate turbidity (ZST) units for nine calves hand-fed colostrum up to 36 hours postpartum and nine calves remaining with their dam to 36 hours postpartum. Standard errors are represented by vertical lines.

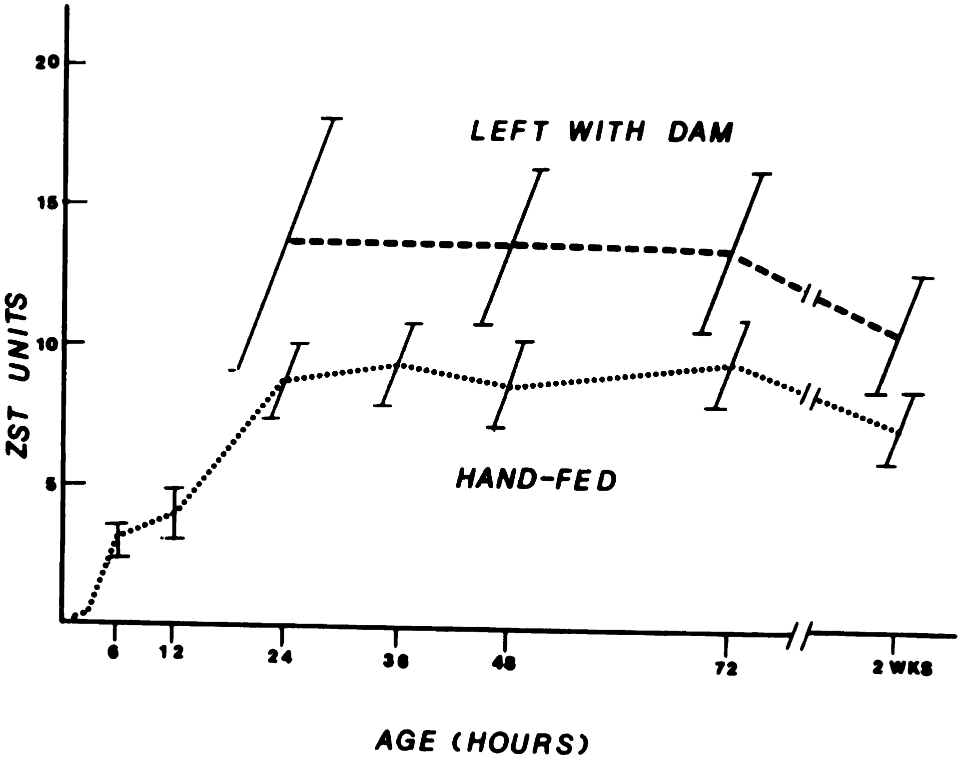
20
15
10
5
ZST UNITS
LEFT WITH DAM
HAND-FED
6
12
24
36
48
72
2 WKS
AGE (HOURS)

FIGURE 2

TABLE 27. Estimated immunoglobulin levels for nine calves separated from dams and fed fixed amounts of colostrum at fixed times postpartum.

Time postpartum	Total colostrum fed to this hour[a]	Immunoglobulin Level	
		-----ZST units------	
Hour	lb.	Mean	± S.E.
1	0	.167	0.02
2	2	.175	0.02
6	2	3.162	0.62
12	2	3.997	0.95
24	6	8.835	1.33
36	10	9.246	1.53
48	14	8.725	1.62
72	14	9.475	1.66
2 weeks	14	7.245	1.29

[a] Calves were fed 2 lb. at one hour postpartum and 4 lb. at 12, 24 and 36 hours, whole milk fed after 36 hours.

sampled at six and again at 12 hours showed little increase during this time indicating that most of the 2 lb. of colostrum fed at one hour postpartum was absorbed before the second feeding at 12 hours. Then the large increase in immunoglobulin level from 12 to 24 hours is likely due to absorption from the 4 lb. of colostrum fed at 12 hours. This is in agreement with data from Selman et al. (1971b) which indicates that calves with two nursings had higher ZST units (31.2) than calves with only one nursing (24.9). In the hand-fed calves little or no absorption had occurred at two hours postpartum or one hour after feeding. Calves were not totally void of serum immunoglobulin at birth as was also found by Bush et al. (1971) and Mungle (1972).

The mean differences for serum immunoglobulin between the mothered calves and hand-fed, separated calves were not statistically significant at 24, 48 or 72 hours or 14 days postpartum even though the mean and maximum value for the mothered calves was consistently greater. Table 28 contains the one way analysis of variance for 48 and 72 hour and two week immunoglobulin levels.

The reason for the non-significant difference between the mothered and separated calves was due to the large variation between the mothered calves. This is evident when examining the standard errors and range of calves in Table 26.

The possible reasons for the large variation that existed when calves were allowed to remain and nurse their

TABLE 28. One way analysis of variance for immunoglobulin levels in mothered and non-mothered calves at 48 and 72 hours and two weeks postpartum.

Source	d.f	SS	MS	f value	Level of significance
		48 hours			
Treatment	1	108.74	108.74	2.27	.25
Error	16	767.42	47.96		
		72 hours			
Treatment	1	75.95	75.95	1.36	.50
Error	16	891.12	55.70		
		2 weeks			
Treatment	1	46.25	46.25	1.53	.25
Error	16	484.31	30.27		

dams are: 1) time to nursing is obviously variable, 2) differing and unregulated amounts of colostrum would be consumed, 3) difference in immunoglobulin concentration of dam's colostrum, 4) difference in mothering intensity, 5) differences in birthweight, and combinations of above listed variables.

Selman *et al.* (1970c,d) have shown that time to first suckling is influenced by size of calf, shape of the dam and in particular the height of the udder in relation to the shape of the underbelly. Selman *et al.* (1970b,d) reported the average time to first suckling was 218.3± 113.8 minutes for calves of dairy heifers and 261±129.1 minutes for calves of dairy cows. This information plus observations made during these experiments indicate little possibility that the interval from birth to nursing in the mothered calves was less than the one hour to first feeding for the hand-fed calves. The actual interval was not recorded but general observations were made. In this experiment then the importance of time may be questionable.

Selman _et al_. (1971b) reported calves allowed to nurse at two fixed times postpartum consumed 5 to 8 lb. within 12 hours postpartum. Very likely mothered calves in this experiment and particularly those with the highest serum immunoglobulin levels consumed more colostrum than the 6 lb. fed by 12 hours or the 14 lb. total fed by 36 hours in the hand-fed calves. Also probably some of the mothered calves found to have low immunoglobulin levels did not receive much colostrum.

In this trial all calves received their dam's colostrum and the difference in concentration of immunoglobulin in their colostrum could be responsible for variation in both groups.

Bush _et al_. (1971, 1973) and Mungle (1972) found strong relationship between serum immunoglobulin levels in calves and the absolute amount of immunoglobulin or IgG fed when fed at a rate based on birthweight. There was not a strong relationship however to concentration alone.

Selman _et al_. (1971a) also reported that calves fed equal amounts in the presence of the dam had higher ZST units (17.7±3.1) than those which were separated soon after birth (10.3±2.4). They postulate a maternal effect on immunoglobulin absorption. This maternal influence could not likely occur in the separated calves unless the effect was established in the first 15-30 minutes before the calves were removed from the dam.

Since the calves bodyweight, and the concentration of immunoglobulin in colostrum were random in both groups these variables would probably not contribute significantly to the difference between treatment groups. Therefore one must conclude that the greatest contributors to the differences in immunoglobulin levels between mothered and non-mothered calves and the variation within the mothered calves was the amount of colostrum consumed and possibly the maternal effect. In other words when the amount of colostrum fed was constant and mothering was not permitted as in the hand-fed calves less variation between calves existed than when these two variables were permitted to vary in the mothered calves. Thus a careful consideration of the difference in variation within the two groups does provide more understanding of factors affecting immunoglobulin levels in newborn calves.

TRIAL II

Allocation of calves to treatments and experimental design are in Table 29. Individual values for zincsulfate turbidity (ZST) units at first feeding and at 12, 24, 36, 48 and 72 hours and two weeks postpartum are listed for each calf in Appendix Table 1. Serum immunoglobulin estimates for 48 hour samples are shown in Table 30. Analysis of variance of the 48 hour ZST values indicates that the time of first feeding of colostrum (1, 2, 6 or 12 hour postpartum) and the initial amount fed (1 or 3 lb.) were not significantly different (Tables 30 and 31). Figures 3a and 3b represent the increase in ZST units from birth to 72 hours for each time and feeding level treatment combination. Calves fed 1 lb. initially had very little increase by 12 hours as compared to those fed 3 lb. and therefore the levels at 12 and 24 hours appear to be more affected by the initial feeding level than the 48 hour values. The calves fed 1 lb. had a considerable increase at 24 hours as a result of the second feeding of 4 lb. Those initially fed 3 lb. also increased from the 12 hour to the 24 hour sampling time as a result of the second feeding of 4 lb. On a percentage basis the increase for those calves fed prior to 12 hours was less for those initially fed 3 lb. than 1 lb. (two-fold vs six-fold increase). Analysis of variance on the 12 and 24 hour samples are in Table 32. Level of initial feeding is significant; $P <.001$ at the 12 hour and $P <.005$ at the

TABLE 29. Allocation of calves by treatment combination with two blocks for seasons and two genetic groups.

Genetic group	Amount of colostrum at first feeding	Time to first colostral feeding (hours after birth)				Season
		1	2	6	12	
	lb.					
Best[b]	1	1210A[a]	1374	1181A	1369	I[c]
	3	1221A	1368	1072	1375	
Worst	1	1366	1190A	1362	1195	
	3	1358	1355	1367	1356	
Best	1	1377	1141A	1142B	1373	II
	3	1147A	1376	1381	1225A	
Worst	1	1232A	1222A	1138B	1379	
	3	1214A	1380	1371	1378	

[a] Calf number, those with letters are males.

[b] Herd genetic group.

[c] Block I calves born 1-26-73 to 4-26-73
Block II calves born 4-7-73 to 5-29-73

TABLE 30. Mean 48 hour serum immunoglobulin levels for calves fed first colostrum at 1, 2, 6 or 12 hours after birth. Two levels were fed at these times, 1 and 3 lb.

Amount first feeding	Hours after birth 1	2	6	12	Average
lb.					
1	9.44[a]	8.13	5.58	9.53	8.17
3	10.26	12.59	9.75	8.69	10.32
Average	9.85	10.36	7.66	9.11	9.25

[a] Values are estimated serum immunoglobulin levels expressed as zincsulfate turbidity units (ZST) and each value is a mean of four calves.

TABLE 31. Analysis of variance of ZST values at 48 hours for 32 Holstein calves in Trial II.

Source	d.f.	SS	MS	f	Level of Significance
Genetic groups (G)	1	35.343	35.343	2.713	.25
Feeding levels (F)	1	37.083	37.083	2.847	.25
Time (T)	3	33.128	11.059	0.849	.50
G X F	1	32.004	32.004	2.457	.25
G X T	3	153.747	51.249	3.934	.025
F X T	3	40.206	13.402	1.029	.50
Blocks (season)	1	27.372	27.372	2.101	.25
Error	18	234.494	13.027		
	31				

Figure 3a. Serum immunoglobulin levels from 0 to 72 hours postpartum as estimated by zincsulfate turbidity (ZST) units for calves receiving 1 lb. of colostrum initially at 1, 2, 6 or 12 hours of age as indicated by different lines. Each value represents the mean of four calves. Numbers 2, 3, 4 on each line represent time of 2nd, 3rd and 4th colostrum feeding.

Figure 3b. Serum immunoglobulin levels from 0 to 72 hours postpartum as estimated by zincsulfate turbidity (ZST) units for calves receiving 3 lb. of colostrum initially at 1, 2, 6 or 12 hours of age as indicated by different lines. Each value represents the mean of four calves. Numbers 2, 3, 4 on each line represent time of 2nd, 3rd and 4th colostrum feeding.

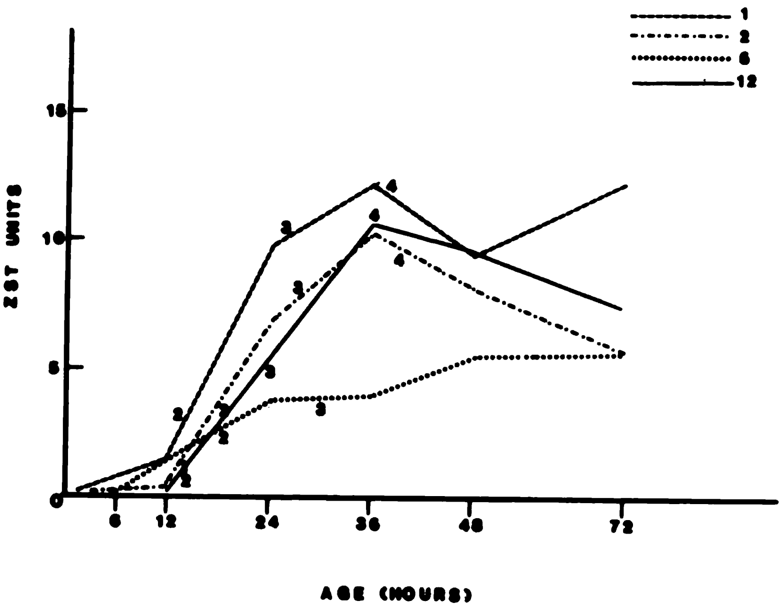

FIGURE 3a

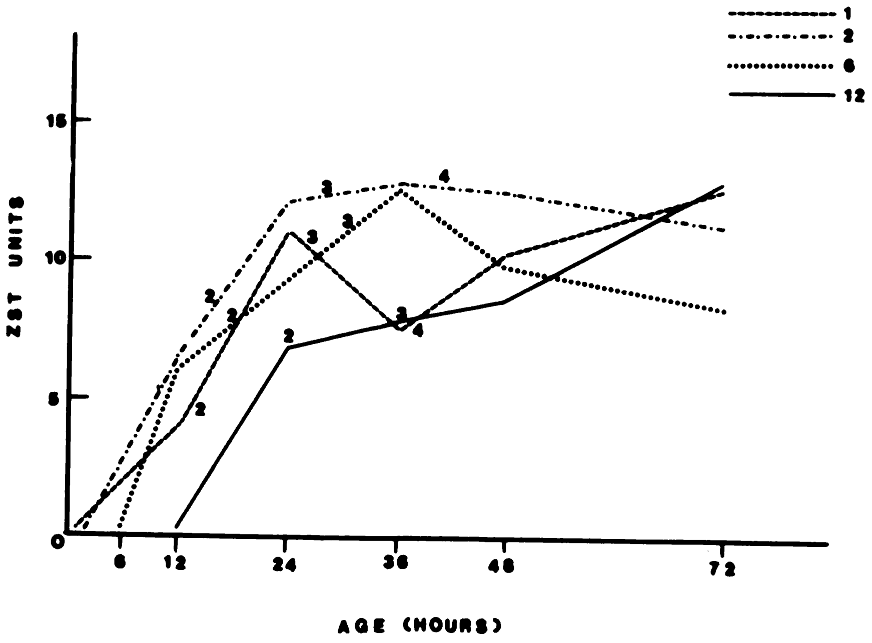

FIGURE 3b

TABLE 32. Analysis of variance of ZST values at 12 and 24 hours for 32 Holstein calves in Trial II.

	12 hours				
Source	d.f.	SS	MS	f	Level of Significance
Genetic group (G)	1	4.150	4.150	0.972	.50
Feeding level (F)	1	95.437	95.437	22.345	.001
Time (T)	2	8.895	4.448	1.041	.50
G X F	1	0.185	0.185	0.043	NS
G X T	2	2.349	1.175	0.275	NS
F X T	2	5.40	2.70	0.632	.75
Blocks (season)	1	4.546	4.546	1.064	.50
Error	13	55.523	4.271		
	23				
	24 hours				
Genetic group	1	22.882	22.882	3.091	.1
Feeding level	1	88.658	88.658	11.976	.005
Time	3	101.534	33.845	4.576	.025
G X F	1	0.306	0.306	0.041	NS
G X T	3	17.443	5.814	0.785	.75
F X T	3	33.794	11.265	1.522	.25
Block (season)	1	13.320	13.320	1.799	.25
Error	18	133.253	7.403		
	31				

24 hour time. These analysis indicate that time of initial colostrum consumption is significantly related to 24 hour ZST values ($P < .025$). Peak ZST levels occur after 24 hours (Figure 3a and 3b).

Table 33 shows the gammaglobulin content of eight batches of colostrum used. Second milking had markedly less nitrogen than first milking but about the same percentage distribution of gammaglobulin. Grams of gammaglobulin per 100 ml second milking averaged 57 per cent (range 44 to 65) that of first milking colostrum. For each calf the total grams of gammaglobulin fed in the 38 hour postpartum period was calculated from grams of gammaglobulin/100 ml (g.gl./100 ml) whole colostrum multiplied by the amount fed. These values along with serum gammaglobulin values for each calf at 48 hours and other general information about the calves are in Appendix Table 2. Analysis of variance of the serum gammaglobulin levels at 48 hours show no highly significant relationship (Table 34). There is some difference in the significance levels between values in Table 31 and 34. The genetic group and the GxT interaction terms are nonsignificant and time approaches significance in Table 34 while in Table 31 the term GxT is significant ($P < .025$) and time is nonsignificant ($P < .50$).

Comparison of techniques to determine serum immune levels shows the correlation between gammaglobulin levels at 48 hours and ZST values at 48 hours is .37, $P < .05$.

TABLE 33. Analysis of eight colostrum batches used in Trial II.

Batch	Total protein in whey[a]	Gamma globulin in whey	g gl/100 ml whey[b]	g gl/100 ml whole colostrum[c]
	%	%	g	g
1[d]	8.25	63.2	5.21	4.06
2	4.69	67.0	3.14	2.45
3	7.81	68.0	5.31	4.14
4	3.63	64.7	2.35	1.83
5	7.75	62.4	4.84	3.78
6	4.75	66.0	3.14	2.45
7	6.50	71.2	4.63	3.61
8	3.81	68.8	2.64	2.06
Ave. 1st milk	7.58	66.2	5.00	3.90
Ave. 2nd milk	4.22	66.6	2.82	2.20
2nd ÷ 1st	.557	1.01	.564	.564

[a] Nitrogen from kjeldahl analysis X 6.25.

[b] Grams of gamma globulin/100 ml of whey.

[c] Grams of gamma globulin/100 ml whole colostrum = g gl/100 ml whey X 0.78 (per cent of whole colostrum in whey fraction).

[d] Odd numbers are first milkings even numbers are second milkings, each set of two samples 1 and 2, 3 and 4, etc. are from same group of about 10 cows.

TABLE 34. Analysis of variance of serum gamma globulin levels (g. gl./100 ml serum) at 48 hours postpartum in 32 Holstein calves in Trial II.

Source	d.f.	SS	MS	f	Level of Significance
Genetic group (G)	1	.0043	.0043	0.041	NS
Feeding level (F)	1	.1668	.1668	1.602	.25
Time (T)	3	.8083	.2694	2.588	.10
G X F	1	.0148	.0148	0.142	.75
G X T	3	.1192	.0397	.0381	NS
F X T	3	.2988	.0996	0.957	.50
Blocks (seasons)	1	.2468	.2468	2.371	.25
Error	18	1.8741	.1041		
	31				

This correlation is much lower than the correlation found by McEwan *et al*. (1970) between zincsulfate turbidity units (x) and the concentration of IgG + IgM (y) in serum ($r = .96$, $N = 53$, $y = 107x - 2.17$). McEwan *et al*. (1970) used a more quantitative immunodiffusion technique to determine the IgG and IgM concentrations in calf serum whereas the present study employed cellulose acetate electrophoresis to quantitate total serum gammaglobulin. The relation of this electrophoretic value to total serum IgG + IgM is not known but is assumed to be high.

Studies by Bush _et al_. (1971 and 1973) and Mungle (1972) found the absolute amount of gammaglobulin or IgG fed per unit of birthweight to be highly correlated to serum immunoglobulin levels at 24 hours and to account for 50 to 68 per cent of the variation. Similar results by Staley _et al_. (1971) and Kruse (1970) also indicate the mass of gammaglobulin fed is highly related to the increase in serum immunoglobulin levels. In Kruse data the amount fed was more significant than time to first feeding. Kruse (1970) as well as Bush _et al_. (1971, 1973) and Mungle (1972) based their evaluation on the 24 hour serum samples. Staley _et al_. (1971) does not state the hour of samplings that were evaluated. The difference in significance of time and amount of colostrum between these studies and the present study evaluation of 48 hour sampling may be due to this difference in time of samples as well as the fact that the present experiment did not account for variation in bodyweight when allotting colostrum amounts to calves.

To determine if the absolute amount of gammaglobulin fed to the calves in this study significantly influenced the 48 hour ZST values a covariate was calculated. The covariate was the total grams of gammaglobulin fed during the 38 hour colostrum feeding period per Kg of birthweight (g. gl./Kg b.wt.). Total grams were used because the 12, 24 and 36 hour level appear to be affected by each previous feeding of colostrum (Figure 3a and 3b). Analysis of variance for the 48 hour ZST values with the covariate adjustment appears in Table 35. Comparison of Table 31 and 35 shows the covariate adjustment decreased the level of significances for genetic groups, feeding level, time, FxT interaction and season while increasing the significance of the GxF term. The GxF interaction was negatively related to the covariate and in Table 35 approaches significance ($P < .1$). Only the FxT interaction is highly significant ($P < .025$) in both analysis.

By graphing the mean values for the GxF interaction (Figure 4) the calves from the worst genetic group are more efficient in absorbing gammaglobulin when only 1 lb. if fed than are the calves in the best genetic group. However the calves receiving 3 lb. initially appear to have similar absorption efficiency as reflected in 48 hour ZST values.

The GxT interaction is graphically depicted in Figure 5. As the age of calf to first colostrum increases to 12 hours the 48 hour immunoglobulin levels increase for the worst genetic group. A simple regression equation indicates the trend is not significant ($y = 9.274 + .194x$, $r = .21$ NS; where y = 48 hour ZST value, x = hours to first colostrum). There appears to be no consistent time trend for this relationship in calves of the best genetic group. However the worst genetic calves had higher levels when colostrum was initially fed at 12 hours. These interactions suggest that calves of different genetic potential may have

TABLE 35. Analysis of variance for 48 hour $ZnSO_4$ turbidity values when covaried on total grams of gammaglobulin fed within 38 hours per kg of birthweight.

Source (adj)	d.f.	SS	MS	f	Level of significance
Genetic groups (G)	1	15.235	15.235	1.37	.75
Feeding level (F)	1	0.038	0.038	0.003	NS
Time (T)	3	15.537	5.179	0.466	.75
G X F	1	46.754	46.754	4.204	.1
G X T	3	150.695	50.232	4.517	.025
F X T	3	9.613	3.204	0.288	NS
Blocks (seasons)	1	3.529	3.529	0.317	.75
Error	17	189.062	11.121		
	30				

Figure 4. Interaction between genetic group and initial feeding level after covariate (grams of gammaglobulin fed within 38 hours/kg of birthweight) adjustment. Values are 48 hour ZST values as influenced by amount of colostrum at first feeding (1 or 3 lb.) for the "worst" and "best" genetic group. Each value is the mean of eight calves with standard errors indicated by vertical lines.

Figure 5. Interaction between genetic group and time of initial feeding after covariate (grams of gammaglobulin fed within 38 hours/kg of birthweight) adjustment. Values are 48 hour ZST values as influenced by the age of calves when fed first colostrum for "worst" and "best" genetic group. Each value is a mean of four calves and standard errors are represented by vertical lines.

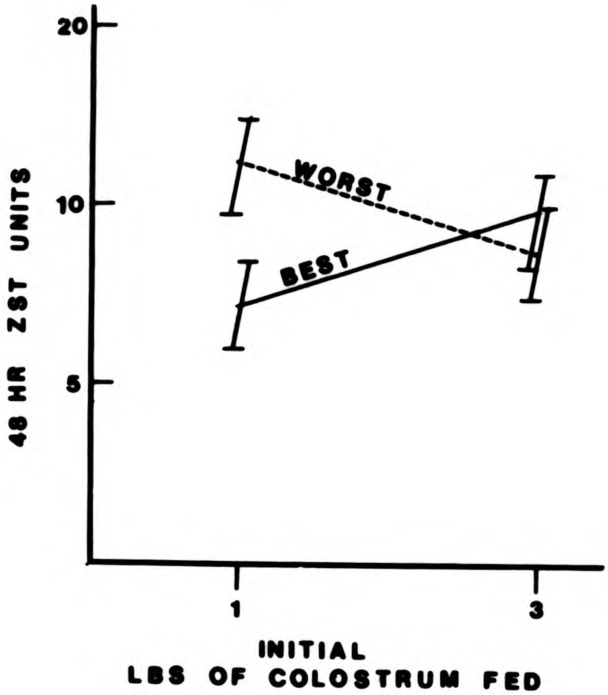

FIGURE 4

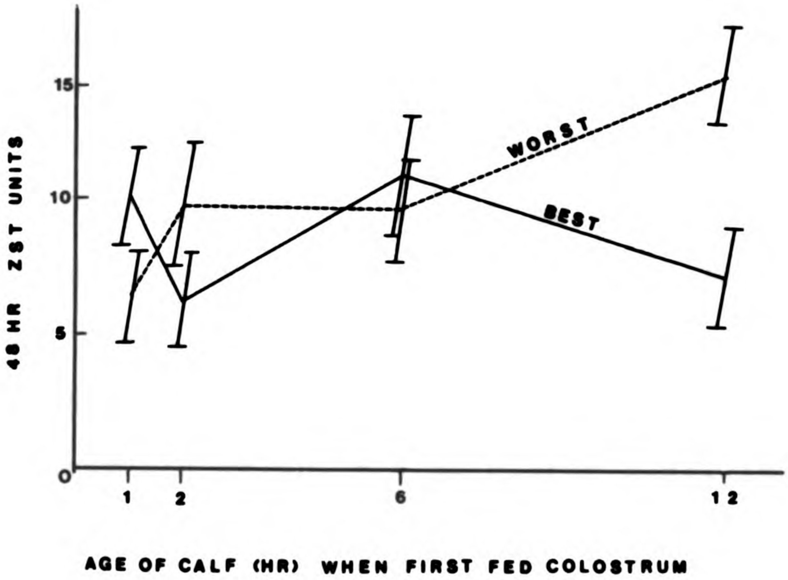

FIGURE 5

have different abilities to absorb immunoglobulins.

The covariate (g. gl./Kg b.wt.) was found to approach significance. The f value is calculated by f = SSr/adj MS_E, where SSr = $SP_E^2/SS_E(x)$, SSr = Sums of squares of regression, SP_E = error sums of squares for x and adj MS_E = adj error mean square (Snedecor and Cochran 1967) and was found to be f = 4.085 with $P < .1$.

Covariance analysis of the serum gammaglobulin levels (g. gl./100 ml serum) decreased the significant levels (Tables 34 and 36) for feeding levels, time, GxF interaction, FxT interaction and seasons but increased slightly the level of significance for genetic groups and GxT interaction. However none of the variables were highly significant (Table 36). Test of significance for the covariate gives f = 2.0305, $P < .25$ which is not significant but the trends indicate again that this type of covariance should be taken into account in the experimental design.

The efficiency at which gammaglobulin is absorbed can be evaluated. The estimated grams of gammaglobulin/Kg b.wt. fed in the present study ranged from .61 to 1.69 g. The regression for ZST units on g. gl./Kg b.wt. fed (column 4 and 5, Appendix Table 2) was $y = .61 + 9.10x$, where y = 48 hour ZST value, x = g. gl./Kg b.wt. fed ($r = .50$, $P < .01$). A regression of grams of gammaglobulin/100 ml serum (Y) and g. gl./Kg b.wt. fed (x) (column 7 and 4, Appendix Table 2) gave $y = .78 + .72x$, $r = .50$, $P < .01$. In comparison McEwan et al. (1970) fed

TABLE 36. Analysis of variance for 48 hour serum gammaglobulin levels when covaried on total gammaglobulin fed within 38 hours postpartum expressed as gram per kg of birthweight.

Source	d.f.	SS	MS	f	Level of significance
Genetic group (G)	1	.0306	.0306	.3107	.75
Feeding level (F)	1	.0003	.0003	.003	NS
Time (T)	3	.450	.150	1.5228	.25
G X F	1	.002	.002	.0203	NS
G X T	3	.1984	.0661	.6711	.75
F X T	3	.1783	.0594	.603	.75
Blocks (seasons)	1	.0706	.0706	.7168	.50
Error	17	1.674	.0985		
	30				

calves two colostrum feedings with an average of 6.18 grams of gammaglobulin/Kg b.wt. The whey protein concentrations estimated by McEwan and coworkers were 10.6 g/100 ml (average) which is higher than in the present study (Table 33) and accounts for higher estimated grams of gammaglobulin/Kg b.wt. fed. Their regression equation which is an estimation of absorption efficiency is $y = 0.16x + 0.58$ where y = the grams of gammaglobulin absorbed/Kg bodyweight and x = the amount of gammaglobulin presented (g./Kg bodyweight). The coefficient r is 0.62

with $P < .02$, $N = 13$, which is similar to the values ($r = .5$) in the present study. The serum values were also adjusted by McEwan *et al*. (1970) on a bodyweight basis (g/Kg bodyweight) and this was not done in the present study.

FIELD STUDY

The division of herds into two groups was based on their calf mortality rate during the 1972 calendar year. H_1 and H_2 herds had similar mortality in 1972 and also during the sampling period of this trial thus indicating that having the dairymen in H_1 record, when known, the hours to first colostrum and hours the calves spent with the dam did not influence the mortality rate. Table 37 contains the analysis of variance for the mortality rate of the 30 herds by groups for 1972 and 1973. The mean values were similar for all three herd categories during both time periods. Herds were selected on the basis of high or low mortality in 1972 but all herds did not continue with the same mortality rate for the sampled calves in 1973 (Appendix Table 3). Herds B and M were exceptions on selecting on the 1972 mortality rate where they had 19 and 15 per cent mortality respectively for the year but they currently were not having any losses and it was therefore decided to place them into the low mortality group. The variation from 1972 to 1973 mortality is indicated by the change in significance from $P < .001$ in 1972 to $P < .1$ for mortality rates between high and low mortality herds in 1973. In 1973 only calves from which blood samples were obtained were considered in these calculations and perhaps the few calves sampled in several herds over this period of time were not completely

TABLE 37. **Analysis of variance for calf mortality[a] of 30 Michigan dairy herds. Herds were assigned to L (low) or H (high) category based on rate of calf mortality in 1972.**

Variable	d.f.	Level of significance	Treatment means ± SE			
			L[b]	H	H_1	H_2
1972 calf mortality %	1 and 28	$P < .001$	7.5±1.4	22.6±1.6	-	-
1972 calf mortality %	2 and 27	$P < .001$	7.5±1.4	-	21.2±1.9	24.2±2.6
1973 calf mortality %[c]	1 and 28	$P < .1$	6.8±3	21.1±5.8	-	-
1973 calf mortality %[c]	2 and 27	$P < .25$	6.8±3	-	21.2±9.4	21.0±6.9

[a] Calf mortality is the per cent of calves born alive that died within two months of age.

[b] L = low mortality < 10%, H = high mortality > 15%, based on figures for 1972 calendar year. H is divided into two subgroups H_1 and H_2 for comparison.

[c] 1973 mortality was for calves sampled for ZST values during January to May 1973.

representative of the 1972 and existing mortality rate. Five high mortality herds had no sampled calves die and conversely one low mortality herd (x) had three of eight or 37 per cent die that were sampled. Except for herds R, T, V, X, FF, HH, II, JJ and KK, almost all of the calves born in each herd between February and May 1973 were sampled. Poor sampling occurred in herds R, T, V and X and Herds FF through KK did not start on the trial until March.

The average ZST units for the three herd groups and the calves that lived and died are in Table 38. There is a slight trend with higher ZST units in low mortality herds but these differences were not significant as indicated by the analysis of variance in Table 39. This is due to the great variation in average herd ZST levels within each herd group as indicated by $P < .001$ for herds within groups. This variation in mean herd ZST units within groups can be seen in Appendix Table 3.

The difference in ZST units was significant ($P < .05$, $7.75 \pm .53$ vs $5.69 \pm .53$) between calves that lived and those that died by two months postpartum (Table 39). This indicates that ZST readings are related to the survival of calves as was indicated by McEwan *et al*. (1970b) and Gay *et al*. (1965). However in this data if all three herd groups had similar average ZST units then all groups had calves with low ZST units but more calves with low ZST units died in the H_1 and H_2 groups than in the L group (Table 40). Only 11 of 176 sampled calves died in L herds.

TABLE 38. Means for 48 hour ZST units in three herd groups and in surviving and dying calves in 30 Michigan dairy herds.

	ZST units[a]		Range		
Herd group	$\bar{x}$	±SE	Low	High	Calves
H_1 high mortality 1	5.92	.67	0	30.24	158
H_2 high mortality 2	6.70	.71	.12	30.26	117
L low mortality	7.50	.86	.12	26.84	170
					445
Live[c]	7.75	.53	.12	30.26	380
Died	5.69	.53	0	25.60	65

[a] Zincsulfate turbidity (ZST) units for serum samples taken as near to 48 hours postpartum as possible.

[b] Herd group H_1 and L were asked to record, when known, the time to first colostrum and hours calf remained with dam.

[c] Status of calves by two months postpartum.

TABLE 39. Least squares analysis of variance for immunoglobulin levels in 30 Michigan dairy herds.

Source	d.f.	SS	MS	f	Level of significance
[a]Treatment (group)	2	86.117	43.058	1.137	.322
[b]Mortality	1	142.406	142.406	3.759	.053
Herds/group	27	2259.023	83.667	2.207	.001
T X M	2	44.702	22.351	.590	.555
Error	412	15607.657	37.883		
TOTAL (about mean)	444	18485.540			

R^2 for regression of above variables = .16.
a = three herd treatment groups, H_1, H_2, L.
b = live or dead by two months of age.

TABLE 40. Raw mean values, standard errors and ranges for calves that lived and died in each of three herd groups.

		Calves	ZST units[c]				
					Range		
		[a]	$\bar{x}$	±SE	Low		High
H_1[b]	Live	(127)	6.35	.559	.12	-	30.24
	Died	(34)	4.53	.956	0	-	21.78
		161					
H_2	Live	(92)	7.23	.709	3.25	-	30.26
	Died	(26)	4.80	1.301	.12	-	25.60
		118					
L	Live	(165)	7.66	.491	.12	-	26.84
	Died	(11)	2.68	.992	.17	-	9.84
		176					

[a] Several values were added to data in this table therefore the number of calves in each treatment is different than in Table 38.

[b] H_1 = high mortality 1, H_2 = high mortality 2, L = low mortality.

[c] Zincsulfate turbidity units for serum samples taken as near to 48 hours postpartum as possible.

These calves averaged 2.68 ZST units while 34 calves in H_1 and 26 calves in H_2 died and averaged 4.53 and 4.80 ZST units respectively (Table 40). This indicates that a greater number of calves with low ZST units succumb in the high mortality herds than in low mortality herds. On the other hand surviving calves had average ZST units of 6.35 in H_1, 7.23 in H_2 and 7.66 in L which indicates that calves with higher levels have a greater chance of survival than low ZST calves regardless of herd group. This is particularly important for calves in the high mortality herds because the data suggest that calves with high ZST levels are less frequently affected by factors causing death, i.e. environment, management practices or presence of disease organisms. Therefore a possible interrelationship exists between low ZST values and the "environment" of the calves.

Correlations for both time to first colostrum and hours the calf remained with the dam versus mortality are in Table 41. In H_2 herds, by design, time to first colostrum and hours with the dam were not obtained thus data in Table 41 are for H_1 and L herds only. Even though there was a correlation of $r = .35$ ($P < .05$) for mortality vs time to first colostrum in H_1 herds the values used in this calculation may not have been sufficiently representative of high mortality herds being from only 39 calves from just four herds. More extensive data will be needed to actually demonstrate that such a relationship exists. The positive

TABLE 41. Correlation coefficients for time to first colostrum or hours with dam with mortality rate in field study.

Item correlated with mortality rate	Herds considered		r	Time to first colostrum		Number of calves	
	Number	Group		Mean	Range	Lived	Died
				hr	hr		
Time to first colostrum	5	H_1+L[a]	0.16	3.36	.3-14	44	8
	4	H_1	0.35*	2.72	.5-10	32	7
				Hours with dam Mean	Range	Lived	Died
Hours with dam	7	H_1+L	-0.14	14.85	0-48	81	25
	5	H_1	-0.08	11.72	0-36	67	22

*Significance $P < .05$.

[a] Herd groups H_1 = high mortality 1 and L = low mortality, these two groups, 9 and 13 herds respectively, recorded information for each calf, when known, as to time to first colostrum and hours the calves remained with the dam. Correlations were obtained by coding live or dead calves as numbers 1 or 2.

relation of a longer time to first colostrum and higher mortality ($r = .35$) is not due to lower ZST units since Table 42 indicates no relation between time to colostrum and ZST units. This result is similar to the non-significant influence of time in Trial II on 48 hour ZST values and is contrary to data of Selman *et al*. (1970a) where time to first suckling versus 48 hour ZST units was negatively related ($r = -.49$, $P < 0.05$, $N = 15$). However the average time to first colostrum observed and recorded by dairymen in the present study was about 3½ hours (Table 41 and 42) and the range was 0.2-14 hours indicating that most of these calves recorded were receiving colostrum within six hours. Therefore differences in ZST units may not be strongly related to how soon they receive colostrum within this short time period. Within a longer period of time to first colostrum consumption (0-20 hours) the influence of time could be more important on mortality and ZST values. More data are needed on this relationship.

Selman *et al*. (1971a,b,c) noted higher ZST values in calves remaining with their mother which he termed a "mothering effect". Such a maternal effect was evident by the positive correlations between the hours with the dam and the 48 hour ZST values in the sampled calves from 19 herds (Table 42). This relation was significant for all 237 calves and for the 119 calves in the low mortality herds ($r = .30$, $P < .01$). The correlation of $r = .13$ for H_1 herds and $r = .30$ for L herds were not significantly

TABLE 42. Means and correlation coefficients for time to first colostrum and hours with dam with ZST value for calves from field study herds.

Item correlated with ZST units	Herds considered			Mean ZST units	Calves	Time to first colostrum	
	Number	Group	r			Mean	Range
					no.	hr	hr
Time to first colostrum	15	H_1+L	0.05	7.58	138	3.25	0.2-14
	7	H_1	0.01	7.33	62	3.05	0.2-10
	8	L	0.07	7.79	76	3.42	0.3-14
						Hours with dam Mean	Hours with dam Range
Hours with dam	19	H_1+L	0.23**	7.47	237	10.3	0-48
	8	H_1	0.13	7.44	118	11.1	0-48
	11	L	0.30**	7.50	119	9.5	0-48

**Significance $P < .01$.

[a] Herd groups H_1 = high mortality 1, and L = low mortality, these two groups, 9 and 13 herds respectively, recorded information for each calf, when known, as to time to first colostrum and hours the calves remained with the dam.

different and thus caution should be used in interpreting the data in the bottom two lines of Table 42 as indicating differences in effect of maternity environment on ZST values in high and low mortality herds. This will be mentioned later.

Examination of relationships of several items measured as influenced by methods used to feed colostrum to newborn calves was performed. To do this herds were grouped regardless of mortality into three treatments. Treatment A were herds that left the calf with the dam for more than 24 hours and who depended on the calf to receive its first colostrum from the dam as well as the rest of the time it remained with the dam (column 4 and 5, Table 43). Treatment B was composed of dairymen who generally left the calves with the dam for 12 hours (column 4, Table 43) and who believed that 80.7 per cent (50-100 per cent) of their calves were receiving colostrum from the dam for the first time and thus only 19.3 per cent (0-50 per cent) were believed to be hand-fed for the first colostral feeding. Treatment C included dairymen who left the calf with the cow for 1 to 12 hours and generally believed that only 13.4 per cent (0-40 per cent) received colostrum for the first time from the dam and believed that 86.6 per cent (60-98 per cent) received colostrum first by hand-feeding. The average ZST units for the three treatments were A = 8.56±.52, B = 4.93±.70 and C = 7.30±.82 ($P < .025$, Table 43).

TABLE 43. Average ZST units and colostrum feeding data for 30 Michigan dairy herds grouped by method of feeding colostrum to newborn calves.

Method[a]	Herd code	Calves	ZST units[b]	Minimal time with dam[c]	Nurse cow first[d]
		no.		hr/%	%
A-nurse the dam	A	11	8.59	24/100	100
	B	18	9.35	24/ 80	66
	F	17	6.38	24/100	100
	L	19	7.84	24/100	95
	II	9	9.58	48/100	100
	KK	9	9.67	48/100	97
	Ave		8.56		93
	±SE		.52		
B-nurse dam & hand-fed	G	9	2.45	12/100	97
	H	12	6.38	12/100	50
	J	13	6.88	24/ 85	50
	V	9	7.00	12/100	80
	X	8	2.11	12/100	75
	Z	43	3.91	12/100	80
	AA	24	8.73	12/100	80
	FF	10	5.03	10/100	100
	HH	23	3.57	12/ 95	95
	JJ	11	3.27	12/100	100
	Ave		4.93		80.7
	±SE		.70		
C-hand-fed	C	12	3.56	2/100	10
	D	13	7.81	1/100	15
	M	4	14.79	12/100	25
	N	8	7.65	12/100	10
	Q	31	9.03	12/100	10
	R	8	3.71	4/100	10
	T	7	9.42	3/100	5
	U	18	5.19	4/100	30
	W	27	9.03	1/100	0
	BB	14	5.77	12/100	40
	CC	23	5.93	1/100	2
	DD	12	3.44	2/100	5
	EE	9	7.01	2/100	20
	GG	25	9.96	12/100	5
	Ave		7.30		13.4
	±SE		.82		

Significance A vs B vs C $P < .025$
A vs B $P < .005$
B vs C $P = .05$
A vs C NS

TABLE 43. Cont'd.

Method[a]	hand-fed first[e]	Colostrum hand-fed in 36 hours[f]	Colostrum hand-fed first feeding[g]
	%	lb.	lb.
A-nurse the dam	0	-	-
	34	10	4
	0	-	-
	5	-	-
	0	-	-
	3	12	6
Ave	7		
B-nurse dam & hand-fed	3	10	4
	50	10.6	4
	50	8.3	3
	20	6.0	4
	25	6.8	3
	20	7.2	4
	20	8.0	4
	0	6.0	-
	5	2.0	1
	0	5.2	-
Ave	19.3	7.01	3.4
C-hand-fed	90	11	4
	85	11	4
	75	5.5	2
	90	12.3	3.5
	90	12.3	4
	90	6.4	1.5
	95	8.4	3
	70	8.1	3
	100	11	4
	60	8.4	3
	98	8.4	2.5
	95	6.0	2
	80	19	4
	95	14	8
Ave	86.6	10.1	3.5

TABLE 43. Cont'd.

[a] Herds were divided into three groups according to method they most frequently depended on for calves to receive colostrum during the first 36 hours postpartum, i.e. nurse the dam for most of colostrum received-A, nurse dam and hand-fed-B, and hand-fed most colostrum-C.

[b] Zincsulfate turbidity units average of calves sampled.

[c] Minimal time with dam postpartum in hours and per cent of calves remaining this length of time as estimated by dairymen.

[d] The per cent of calves which are thought by dairymen to receive their first colostrum by nursing the dam.

[e] The per cent of calves which are thought by dairymen to receive their first colostrum by hand-feeding.

[f] Average colostrum hand-fed to calves in 36 hours. When hand-feeding was practiced.

[g] Average amount of colostrum fed to calves at the first feeding when suspected not to have nursed the dam.

Interpretation of these differences is difficult and the actual explanation may be in what the dairymen think is happening in regard to how the calves are first getting colostrum. Those dairymen who left the calf with the cow for less than 12 hours in general believed the calf had not nursed during this period and therefore were hand-feeding the calf thus assuring that it received colostrum (Treatment C). Dairymen in Treatment A were leaving the calf with the cow for 24 hours or more thus gave the calf plenty of opportunity to nurse and they depended on the calf to nurse. These calves had the highest ZST values but not significantly higher than Treatment C. These results are similar to those in Trial I where nine calves were allowed to remain with the dam for 36 hours and nine were separated at birth and hand-fed colostrum. Treatment B herds had low ZST values in calves and these dairymen believed many of these calves were nursing the cow for their first colostrum which suggests that they depended on the calf to nurse the cow during this period and perhaps hand-feeding colostrum some time later or upon removal from the cow. Therefore these calves received less hand-fed colostrum within 36 hours than calves in Treatment C. This interpretation is substantiated by the average amounts of colostrum hand-fed 7.01 lb. for B but 10.1 lb. for Treatment C. The total amount of colostrum received by calves must be assumed to be more when calves are hand-fed or left with the cow for "longer" periods than when left with the cows for only 12 hours.

Selman *et al.* (1970a,b) recorded the time required to first nurse the dam for each of 20 calves born to dairy cows (10) and heifers (10) in box stalls (refer to Table 18). Five of 20 dairy calves (25 per cent) did not nurse within the eight hour observation period and those that did took an average time of about 4±2 hours to nurse the first time. If this is the case then calves in Treatment A could make up for "lost time" by consuming reasonable amounts during their extended stay with the cow. But calves that do not nurse during their stay with the dam in Treatment B only receive what is hand-fed which may be less than they could eventually nurse from the cow. These results may offer an explanation to the findings of McCoy *et al.* (1970) where calves hand-fed colostrum had higher gammaglobulin levels at seven hours than calves remaining with the dam but by 24 hours calves remaining with their dam had values that exceeded those levels in calves that were hand-fed colostrum. Emphasis should be placed on the fact that the per cent of calves which nurse the dam for first colostrum or are hand-fed first colostrum in Treatment B and C are merely reflections of each dairyman's thoughts and not recorded facts.

Correlation coefficients between the estimated pounds of colostrum hand-fed within 36 hours and the average ZST units for each herd are in Table 44. No highly significant correlations were found for any of the five categories

TABLE 44. Correlations between estimated amounts of colostrum hand-fed in 36 hours postpartum and the average ZST units for each of several herd categories.

Group	Herd	r	Significance
Depended on both nursing the dam and hand-feeding colostrum (combination)	10	0.24	NS
Depended on hand-feeding colostrum most frequently	14	0.08	NS
Depended on hand-feeding[a] colostrum most frequently but removed calves by or shortly after 4 hours postpartum	8	0.24	NS
Low mortality herds, hand-fed and combination, excluding herd M[b]	8	0.55	NS
All low and high mortality herds using box stalls, hand-fed and combination excluding herd M[b]	12	0.46	NS

[a] Calves left with the dam have an opportunity to nurse and thus increase ZST units regardless of the lb. fed in 36 hours, therefore only herds which removed the calves by or soon after four hours were included in this group.

[b] Herd M had only four calves sampled and the average ZST value was unusually high consequently this herd average was excluded.

tested but the number of observations in each category were low. However the coefficients for the low mortality group which all used box stalls was .55 and for all herds hand-feeding colostrum and using box stalls it was .46.

Table 45 contains correlation coefficients for variables relating to calf mortality, population density and maternity areas in the herds studied. The correlation between 1972 mortality and mortality in calves sampled in 1973 was $r = .52$, $P < .01$. The correlation between herd size and mortality was not significant; $r = .05$.

The highest correlation to the 1972 mortality rate was the dry matter per cent (DM per cent) and estimated dry matter per cent of the bedding in the maternity area, $r = -.67$ for $N = 23$ herds with $P < .001$ for both. A regression for the first was $y = 32.5-.31x$. The estimated dry matter (Appendix Table 3, column 18) was used for some herds because maternity bedding samples were not obtained but DM per cent was estimated from personal observations during a number of visits. Also some samples taken from herds N, JJ, D, and U were not judged representative of usual conditions and these values were omitted and new estimates were obtained. This did not affect the average DM per cent for the herd groups (Appendix Table 3, columns 17 and 18) but more accurately reflected the average situation. Since only one to three bedding samples per herd were analyzed for dry matter content average values were easily affected by the "non-normal" extremes. The

TABLE 45. Correlation coefficients between several sets of variables relating to calf mortality, population density and maternity areas in 30 Michigan dairy herds.

	1 Ave ZST units	2 Mortality % 1972	3 Mortality % 1973	4 Calves /barn	5 Sq ft/ calf in stall	6 Maternity area sq ft/cow	7 Maternity area bedding DM%
3 Mortality % 1973		(30) .52^{d}	-				
4 Calves/barn		(30)-.11	-	-			
5 Sq ft/calf in stall		(30)-.06	-	-	-		
6 Maternity area sq ft/cow		(29)-.18	(29)-.36^{a}	-	-	-	
7 Maternity area bedding DM %	(23).16	(23)-.67^{e}	(23)-.42^{b}	-	-	(23) .50^{c}	-
8 Sq ft/calf in individual stall		(17)-.17	-	-	-	-	-
9 Calf stall bedding DM%		(20)-.13	-	-	(20).42^{b}	-	-
10 Sq ft/animal in barn		(30)-.37^{b}	(30)-.20	(30)-.31^{a}	(30).23	-	-
11 Estimated maternity bedding DM		(29)-.72^{e}	(29)-.47^{d}	-	-	-	-
12 No. cows in maternity area^{f}	(16).02	(29) .49^{d}	(29) .63^{e}	-	-	(29)-.57^{e}	(23)-.72^{e}
13 Herd size		(30) .05	-	-	-	-	(23) .05

Values in parenthesis are number of herds and values to the right are correlation coefficients.

TABLE 45. Cont'd.

1 Average ZST units for each herd.
2-3 Mortality is the per cent of calves born alive that died within two months.
4 Number of calves under three months of age in barn where calves were housed.
5 Sq. ft. per calf in individual or group pens includes all calves not weaned.
6 Maternity area sq. ft. per cow, includes box stalls and group areas.
7 Maternity area bedding dry matter.
8 Sq. ft. per calf in individual bedded stalls (excludes raised steel stalls and group pens).
9 Bedding dry matter of calf pens, individual and group pens (excludes raised steel stalls).
10 Sq. ft. per animal (all calves and cows) in calf barn.
11 Estimated dry matter for maternity areas (values for 6 of the 29 herds are estimates).
12 Number of cows in maternity area.
13 Herd size is the number of milking cows.

a,b,c,d,e = level of significance ($P < .1$) = a; ($P < .05$) = b; ($P < .02$) = c; ($P < .01$) = d; ($P < .001$) = e.

[f] Includes 16 of the 17 high mortality herds. One herd calved cows in tie stalls.

correlation coefficient between the estimated bedding DM per cent and 1972 mortality in the 13 L herds using box stalls was also $r = -.72$, $P < .01$, $y = 27.4 - .29x$. These correlations are high and not only significant for all herds but significant even in herds with low mortality. The correlations between bedding DM per cent and mortality of calves sampled in 1973 were also significant but not as high. This may be due to small sampling of calves in some herds and abnormal mortality rates of that small sampling.

The square feet per calf in bedded stalls, individual or group, was significantly correlated to bedding DM per cent ($r = .42$, $P < .05$, $N = 20$). This is similar to the finding of Appleman and Owen (1973) where incidence of scours was significantly higher in smaller bedded stalls and this difference was thought to be related to the dry matter of the bedding.

The number of cows in the maternity area was highly related ($r = .49$, $P < .01$) with 1972 mortality and this number of cows is also related to the maternity area bedding DM per cent ($r = -.72$, $P < .001$).

The number of herds using box stalls and group calving areas is in Table 46. A difference between high and low mortality herds is very apparent in that the low herds were all using box stalls and 13 of the high mortality herds were using group calving facilities with three to 60 cows in a large pen.

Table 47 shows that the mortality rate for both 1972

TABLE 46. Number of herds using box stalls and group calving area in 30 Michigan dairy herds.[a]

Type of maternity area	Mortality group Low	 High	
	(N)	(N)	(%)
Box stalls	13	4	59
Group maternity area[b]	0	12	41
Average (%)	43	57	100

[a] One high mortality herd calved cows in tie stalls.
[b] Calving cows in groups of three to 60 cows.

TABLE 47. Analysis of variance relating two types of maternity calving areas (box stalls vs. group or loose[c]) in 30 Michigan dairy herds.[a]

Variable	d.f.	Level of significance	Treatment means ±SE Box stall	 Group[c]
1972 mortality[b] %	1 and 28	$P < .001$	9.6±1.5	24.9±9
1973 mortality[d] %	1 and 28	$P < .005$	5.5±2.4	28.6±7.3

[a] One high mortality herd had cows calve in tie stalls.
[b] Mortality is the per cent of the calves that are born alive which die within two months of age.
[c] Calving cows in groups of three to 60 cows.
[d] Mortality of calves from which blood samples were obtained Jan-May. Also in some herds an indeterminate number of other calves were not sampled and not included in these figures.

and 1973 are significantly different for herds using box stalls and group calving facilities. Differences in bedding dry matter per cent for high and low mortality herds and herds using box stalls and group calving area are apparent in Table 48 with all differences significant at $P < .001$.

The negative relationship of mortality rate and usual dry matter content of bedding in the maternity area is speculative but may be related in three ways. One, the wetter maternity areas may allow more body heat transfer to the contact area and thus tend to lower calves body temperature which could become a stressful situation. Two, the maternity areas in the high mortality herds were wet because of a high concentration of animals and the areas were usually unclean and could provide a desirable environment for bacteria and a higher concentration of bacteria. Three, the group situation may also cause a different maternal behavior by the dam than when a cow is isolated in a box stall or calving away from the group when on pasture. The dam may be more interested in competing for food. Other animals may hamper the dam and calf thus interferring with "mothering" activity. This hampering had been noticed in several of the herds. The calf may have more trouble locating its dam among a large confined group of cows especially when the dam leaves to eat. Such phenomena may be responsible for the lower correlation between hours a calf remained with the dam and

TABLE 48. Analysis of variance for dry matter of maternity area bedding to mortality group and type of calving area in 30 Michigan dairy herds.

Variable	d.f.	Level of significance	Treatment means ± SE			
			L[a]	H	Box stall	Group[b]
Maternity area DM %	1 and 21	$P < .001$	66.1±4.3	42.8±5.6		
Est. maternity area DM %	1 and 27	$P < .001$	68.5±3.4	42.0±4.7		
Maternity area DM %	1 and 21	$P < .001$			65.5±4	33.4±4
Est. maternity area DM %	1 and 27	$P < .001$			67.4±3.4	34.7±3.2

[a] L = low mortality herds $<10\%$, H = high mortality herds $>15\%$ based on figures from 1972 calendar year.

[b] Calving cows in groups of three to 60 cows.

the ZST units for calves born in group pens (or high mortality herds) than for calves born in box stalls (or low mortality herds) (Table 42).

Mean values for low and high herds as related to population density in the calf barn and maternity area are in Table 49. Statistical significance for several of these differences are in Table 50. Differences in herd size were not significant and differences in area per calf (total square feet in building housing calves ÷ all calves all ages) only approached significance. Difference between high and low herds in square feet per animal in the barn where calves were housed (total square feet in building housing calves ÷ all animals) approached significance at $P < .1$ and data in Table 45 indicated a negative correlation ($r = -.37$, $P < .05$) between square feet per animal in the calf barn and 1972 mortality rate. Both these measurements indicate that population in calf facilities may be biologically important.

Data in Table 51 relate to the mortality rates stratified by type of calf barn, type of stalls and bedding material. Mortality was not lower in herds using a specialized calf house as compared to herds using old barns but a higher mortality was noted for two herds using group pens within a loose housing barn. The average number of milking cows per herd was higher for herds using specialized calf barns than for herds using all other types and for herds using old barns but these differences were

TABLE 49. Mean values for low and high calf mortality groups as related to population density in calf barn and maternity area.

	Mortality group[a]			
	Low		High	
	No. herds	Means ±SE	No. herds	Means ±SE
Usual no. of calves/barn[b]	13	26.4±6.8	17	21.4±2.8
Sq. ft/calf in stalls[c]	13	19.4±4	17	20.0±3.6
Sq ft/calf in individual stall[d]	8	18.0±4	9	12.8±3.0
Sq. ft/calf in group pens[e]	3	32.3±10	6	34.8±5.5
Calf stall bedding, DM %	9	74.3±4.4	11	65.8±3.8
Maternity area sq. ft/cow	13	156.0±16	17	120.0±18
No. cows in maternity area	13	1	17	20.0±5.0

[a] Low mortality herds with< 10%, high mortality >15%, mortality is the per cent of calves born alive that died within two months of age and was based on 1972 calendar year.

[b] The average number of all calves in barn where young calves are raised.

[c] Calf stalls for pre-weaned calves, individual and group pens.

[d] Does not include raised steel stalls.

[e] One herd in both high and low group used a group pen the first few days then moved calves to raised steel stalls.

TABLE 50. Means and analysis of variance for variables relating to population density in 30 Michigan dairy herds divided in herds having low or high mortality.[a]

Variable	d.f.	Level of significance	Treatment means ± SE			
			L[a]	H	H_1	H_2
Herd size (milking cows)	2 and 27	$P < .75$	138 ±38		172±19	152±20
Sq. ft./calf[b]	1 and 28	$P < .25$	152 ±51	88 ±25		
Sq. ft./animal[c]	1 and 28	$P < .1$	77.1±15	48.1±6		
Sq. ft./Ind. stall[d]	1 and 14	$P < .75$	18.0±4.4	12.8±3		

[a] L = low mortality < 10%, H = high mortality > 15%, based on figures for 1972 calendar year. H is divided into two subgroups H_1 and H_2 for comparison.

[b] Sq. ft. per calf in entire barn where newborn calves are raised (no. of animals represents all calves but not adult animals, space includes sq. ft. of barn housing calves).

[c] Sq. ft. per animal in entire barn and no. of animals includes all calves and all adults.

[d] Sq. ft. per calf in individual bedded stalls, excludes raised steel stalls.

TABLE 51. Mean mortality categorized according to type of calf barn, type of stalls and bedding.

	No. of herds	No. of milking cows	Mean mortality ± SE 1972	 1973
			%	%
Specialized calf barn[a]	12	172±33[d]	16.2±3.1	21.0±7.3
All other	18	137±19[d]	16.1±2	10.8±3.7
Old barns	12	147±22[d]	16.0±2.8	8.4±4
In cow barn[b]	4	131±71	7.8±2.6	3.2±2.0
Group pen in loose housing	2	165±85	24.5±1.5	40.5±3.5
Other[c]	2	132±68	12.5±2.5	40.0±4
Straw bedding	22		15.2±2.0	11.0±3.0
Sawdust	2		21.5±8.5	43.0±43
Steel stalls no bedding	6		17.5±4.0	19.8±8.5

[a] Barns constructed or completely remodeled especially for raising young calves.

[b] Calves raised in barn with milking herd, two herds move calves after a few days to a specialized calf barn.

[c] Two herds had calves in a room within herd facilities which was not intended for young calves.

[d] No significant difference by analysis of variance for herd size between herds using specialized calf barns and all others or specialized vs. old barns.

not significant. Only two herds used sawdust and one dairyman noted that newborn calves would eat the sawdust. This sawdust eating behavior was also noted in the calves in Trial I and II in the M.S.U. herd. Whether sawdust could be a carrier for bacterial invasion is not known but more definitive information would be needed before incriminating sawdust bedding as an agent causing increased mortality rates in calves.

Table 52 gives the average temperatures and relative humidity in the calf barn and maternity area. Average calf barn temperatures and their deviation from the outside temperature indicate no differences between high and low mortality herds. However heated calf barns averaged six degrees higher than non-heated barns. The average relative humidity readings were six per cent lower (60.7 per cent vs 66.8 per cent) in low than in high mortality herds and four per cent lower (62.3 vs 66.2) in heated barns than in unheated barns.

The maternity area had slightly lower temperatures (2.2°) and greater relative humidity (2.9 per cent) for high mortality herds than did low mortality herds. Enclosed maternity areas were judged as those with all doors and windows closed during colder weather and no air movement through cracks in the walls while open maternity areas were those with just doors and windows open as well as those with one side of the building open. Enclosed maternity areas were 4° warmer and slightly warmer relative

TABLE 52. Average temperature and relative humidity in calf barn and maternity areas in 30 Michigan dairy herds.[a]

	Herds[b]		Calf barns	
	Low mortality (13)	High mortality (17)[c]	Heated (16)[d]	Not heated (14)
	Temperature °F[f]			
Calf barn	55.3	54.4	57.4	51.8
range	50-60	49-60	54-62	44-58
Calf barn - outdoor	6.1	6.6	8.7	3.6
range	13-3	10-1	14-3	10-1
	Relative humidity %[g]			
Calf barn	60.7	66.8	62.3	66.2
range	46-75	57-80	50-74	53-83
Calf barn - outdoor	-2.4	-4.9	-6.5	-0.1
range	-17 -5	-24 -4	-13 -3	-17 -7
			Maternity areas	
			enclosed (9)[e]	open (21)
	Temperature °F			
Maternity area	52.5	50.3	54.0	50.1
range	47-59	44-58	48-60	44-58
Maternity - outdoor	3.7	3.5	5.7	2.3
range	.5-9	0-5	1-12	0-5
	Relative humidity %			
Maternity area	63.5	64.4	63.5	65.9
range	49-81	52-84	50-79	50-84
Maternity - outdoor	-1.6	-1.2	-1.7	-1.3
range	-16 -8	-9 -4	-21 -6	-8 -6

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[a] Temperature and relative humidity values are averages and the range values are averages of low values and of high values for each group.

[b] Mortality = per cent of calves which are born alive that died within two months, Low = < 10%, high = > 15% based on 1972 calendar year.

[c] The number of herds are in parenthesis.

TABLE 52. Cont'd.

[d] Calf barns with heating unit being used in colder weather.
[e] Enclosed maternity areas were judged as those having all doors and windows closed and no air movement through cracks in the walls during colder weather and the remainder judged as open were those with just doors or windows open as well as those with one side of the building completely open.
[f] Temperature in degrees Fahrenheit.
[g] Per cent relative humidity measured with a sling psychrometer.

to outdoor temperatures than were the more open maternity areas.

Table 53 includes data on the personnel involved in feeding the calves with regard to mortality and herd size. Only three herd owners depended completely on hired labor and two others on a herdsman to feed calves indicating that they place herd replacements low on their list of priorities or they would be involved with rearing these calves, particularly in a crisis (high mortality) situation. Average mortality and herd size where highest and square feet per animal in the calf barn was the lowest in these two categories (Table 53). Speicher and Hepp (1973) stated that as herd size increases the effects of good herd management may be diluted. From their data they suggest that mortality is high when calf care is delegated to hired labor. The average herd size is much larger in the present study (152) than in Speicher and Hepp's (1973) survey (45) but herds with hired labor caring for calves had a larger average herd size than other categories in both these studies (270 and 53 cows). As in the survey by Speicher and Hepp low mortality was noted when the wife fed calves (Table 53). The wife is usually praised for great success in raising calves but perhaps her success is partly due to much lower herd size which was only 38 in data of Speicher and Hepp and 52 in this study. Where the wife fed calves there was also less dense populations in calf barns (Table 53). The high mortality in herds fed by

TABLE 53. Stratification of mortality, herd size and population density by personnel feeding the young calves.

Personnel feeding	No. of herds	Mortality[a] 1972	Mortality[a] 1973	No. of milking cows	Sq. ft./animal[b] in calf barn
		Mean ± SE			
Wife	3	6.6±4	0	52±15	81±7
Wife & Owner	2	18.0±12	47.0±39	75±0	79±43
Owner	14	17.7±21[c]	9.9±4	158±21	64±14
Owner + hired	6	12.2±4	10.6±3	146±26	49±11
Herdsman	2	20.5±4	36.0±7	176±74	49±7
Hired	3	21.6±8	26.0±11	270±115	40±9
	30				

[a] Mortality is the number of calves that are born alive and die within two months, expressed as a per cent of those born alive. 1973 mortality reflects only calves sampled for immunoglobulin levels.

[b] Sq. ft. of building per animal in the building housing newborn calves.

[c] Analysis of variance for 1972 mortality data between herd owner and all others combined is non-significant.

hired labor may be confounded with the simultaneous occurrence of high cow numbers, greater population density and less satisfactory facilities which all tend to increase stress and disease incidence. On the contrary it is obvious that mortality exists in herds where hired labor is not used (Table 53).

SUMMARY AND CONCLUSIONS

A zincsulfate turbidity test (ZST) was used to estimate immunoglobulin levels in serum of neonatal calves. The relationships of serum gammaglobulin or immunoglobulin levels in calves to the interval from birth to first colostrum feeding, the amounts of colostrum at this initial feeding, the presence of the dam and several environment factors were examined.

In Trial I nine Holstein calves in the M.S.U. herd were allowed to remain with their dam for 36 hours postpartum and nurse at will while nine other calves were removed from the dam at one-half hour after birth and hand-fed 14 lb. of the dam's colostrum during the first 36 hours. The hand-fed calves received 2 lb. of colostrum at one hour and serum ZST values increased from .167 ZST units at one hour to 3.162 ZST units at six hours. The 12 hour sample (3.997 ZST units) showed little increase from six hour sampling indicating that the gammaglobulin from the initial colostrum fed had been absorbed by six hours. These calves were again hand-fed at 12 hours and at 24 hours serum ZST values averaged 8.835 indicating a further increase in serum gammaglobulin levels resulting from the second feeding of colostrum.

In comparison the calves left with the dams had higher ZST values at 48 hours postpartum than the hand-fed calves (13.64±2.83 vs 8.73±1.62) but they had greater variation in their values. This was interpreted to be due to differences in amount of colostrum consumed and "mothering" effects of the dams that might influence gammaglobulin absorption. This difference was not statistically significant.

In a second trial 32 Holstein calves were removed from the dam at one-half hour postpartum and assigned to be fed initially at 1, 2, 6 or 12 hours after birth and to receive one or three lb. of pooled colostrum at one of these times. Calves were blocked for two genetic groups existing in the M.S.U. herd and for two calendar dates between January and May 1973.

Calves receiving 1 lb. of colostrum at the 1, 2 or 6 hour first feeding had only a slight increase in ZST units by 12 hours but a six-fold increase occurred from the 12th to the 24th hour due to the second feeding of 4 lb. at 12 hours after the initial feeding. Those calves fed 3 lb. of colostrum initially had significant increases in the ZST units by 12 hours and only a two-fold increase from 12 to 24 hours.

The 12 and 24 hour ZST values were significantly affected ($P < .001$ and $P < .005$ respectively) by initial feeding level of 1 or 3 lb. and the 24 hour values were also affected by the time interval to the first feeding (1, 2, 6 or 12 hours). Peak ZST units usually occurred after 24 hours. However ZST values at 48 hours were not significantly affected by the feeding level or time interval nor were the 48 hour serum gammaglobulin levels (g/100 ml) determined from total protein analysis and electrophoretic distribution. The correlation between ZST values and gammaglobulin levels (g/100 ml) at 48 hours was only .37 ($P < .05$).

Calves with lower values at 12 and 24 hours had a greater increase by 48 hours than did those with higher 12 or 24 hour values indicating that repeated consumption of colostrum tends to equalize serum gammaglobulin levels. The 48 hour ZST values had a significant interaction between genetic group and the interval to first feeding.

Calves fed initially at one and two hours postpartum received three more feedings of 4 lb. of colostrum within 38 hours totalling 13 or 15 lb. Calves fed at 6 or 12 hours received only two subsequent feedings within 38 hours totalling 9 or 11 lb. There was a trend toward higher 48 hour ZST values as the total lb. of colostrum fed increased. From this point a covariate was used to adjust the treatment means. The covariate, grams of gammaglobulin in the colostrum fed within 38 hours per Kg of birthweight, did not significantly change the levels of significance for the 48 hour serum ZST or gammaglobulin values but testing the covariate itself showed the covariate was approaching significance at $P < .1$.

Dairy herds in Michigan having high mortality rates ($>$15 per cent) (high) and herds with low calf mortality ($<$10 per cent) (low) were selected to study immunoglobulin levels in the neonatal calf and to relate these levels and several factors affecting them to mortality. Mortality was based on the 1972 calendar year and was calculated as the per cent of calves dying within two months of age that were born alive. Further an evaluation of any differences in management and environment that might differentiate high and low mortality were made in an effort to elucidate factors causing neonatal mortality in Michigan dairy herds.

Seventeen high mortality herds were divided into two groups, nine H_1 herds and eight H_2 herds. H_1 herds as well as the 13 low herds were asked to record, when known, the hours from birth to first colostrum and the hours the calves spent with the dam. Therefore there were three treatment groups, low, H_1 and H_2 herds.

Serum samples were taken as near to 48 hours postpartum as possible on 456 calves in the 30 dairy herds. The 48 hour ZST units, as well as the 1972 mortality and the mortality of the sampled calves in 1973 were not different for the H_1 and H_2 herds indicating that asking dairymen to record the additional information did not alter their mortality rate or ZST levels.

Correlations between mortality and the time to first colostrum for one low herd and four H_1 herds combined was .16 (NS) and .35 ($P < .05$) for the four H_1 herds alone. Values could only be used in herds where some of the calves died. Mortality versus the hours the calf remained with the dam had a low correlation -.12 for low and H_1 herds combined.

Correlations between 48 hour ZST values and time to first colostrum recorded was .01 for H_1 herds and .07 for low herds. The 48 hour ZST levels were more strongly correlated to the hours the calf remained with the dam in low herds $r = .30$, ($P < .01$) than in H_1 herds $r = .13$ (NS).

The average 48 hour ZST level for low, H_1 and H_2 herds was not significantly different but the average values of surviving calves (7.75±.53 ZST units) was significantly higher ($P < .05$) than those for calves dying within two months postpartum (5.69±.53 ZST units).

The mortality rate for 1972 was similar to the rate for calves sampled for ZST levels during the study in 1973; 7.5 vs 6.8 per cent for low herds; 21.2 vs 21.2 per cent for H_1 herds and 24.2 vs 21.0 per cent for H_2 herds but correlated at $r = .52$, $P < .01$.

To evaluate the methods dairymen employed to get colostrum to the newborn calf the herds were re-divided into three treatment groups regardless of mortality. Herds in Treatment A generally left the calf with the dam for 24 hours or longer and these herds had the highest average ZST levels (8.56±.52). Treatment B herds generally allowed the calves to remain with the dam at least 12 hours. These dairymen believed that over 50 per cent of the calves received colostrum first from the dam before they were hand-fed colostrum either during their stay with the dam, or upon or sometime after removal from the dam. Herds in Treatment B averaged only 5.31±.74 ZST units. Treatment C herds generally left the calf with the dam between one and 12 hours but believed that at least 70 per cent of the calves were receiving the first colostrum when they were hand-fed. Average ZST levels for Treatment C calves was 7.17±.88 units. Differences between A and B and between B and C were significant at $P < .005$ and $P = .05$ respectively, but differences between A and C were not significant.

An attempt to correlate the amount of colostrum hand-fed within 36 hours to the herd average ZST level showed a high but not significant correlation in herds using box stalls ($r = .46$, NS) however the number of herds was small ($n = 12$).

In conclusion the observations on the immunoglobulin levels in neonatal calves as estimated by serum ZST units indicate that average levels from herd to herd are not related to high and low mortality herds. However the individual calf levels within a herd are related to mortality and more calves with low ZST levels died in herds previously classified high mortality than in herds classified low mortality indicating the possible existence of a herd "environment" interaction with immunoglobulin level.

Based on observations 12 and 24 hour ZST levels are influenced positively by the initial feeding level (1 or 3 lb.) of colostrum. And interval to first colostrum consumption affects 24 hour ZST values. However, 48 hour ZST values and gammaglobulin concentration are not significantly influenced by the initial feeding level (within the limits of this study, 1 or 3 lb.) or the interval to colostrum (1 to 12 hours). Additional colostrum feeding within 38 hours did increase ZST levels particularly in calves with lower ZST levels at 12 hours. These additional feedings may be responsible for the non-significant differences in 48 hour samples. Calves left with their dams more than 24 hours have higher but more variation in ZST values than hand-fed calves.

Information covered in the literature review and in particular work of Selman et al. (1970c, 1971a,b,c), Kruse (1970c), Bush et al. (1971, 1973), and Mungle (1972) plus data from the present study indicate that to achieve higher ZST values in neonatal calves several practices can be employed. 1) Use a system where the calves are left with the cow for 24 plus hours in a box stall to achieve the "maternal" effect that increases immunoglobulin absorption. 2) Then hand-feed colostrum 6-8 lb. per feeding every 12 hours, or less amounts more frequent up to 36 hours to assure large intake of gammaglobulin, and possibly pool first colostrum from several cows to minimize the possibility of giving colostrum with a low gammaglobulin concentration. 3) Provide new dry bedding in maternity stalls for whatever reason dry matter percentage of bedding is related to mortality rate and possibly use a muzzle to prevent intake of foreign material.

The evaluation of low and high mortality herds indicated the maternity area to be of significant importance. All 13 low mortality herds were using box stalls but only four high mortality herds were. Thirteen other high herds had cows calving in a large pen in groups of three to 60. Correlation between estimated bedding dry matter per cent and 1972 mortality was -.72, ($P <.001$) for all herds and was also -.72 for low herds using box stalls ($P <.001$). Area per animal in the calf barn and the number of cows in the maternity area were also correlated to the previous years' mortality rate, $r = -.37$, $P <.05$ and $r = .49$, $P <.01$ respectively. Maternity area bedding dry matter per cent and number of cows per maternity area were also significantly correlated to herd mortality rate of calves sampled during the four month study.

No difference in the previous year's mortality rates occurred between herds using specialized calf facilities and makeshift set-ups in old barns but those herds with old barns had lower mortality of sampled calves in 1973. Perhaps if all herds had similar maternity areas the differences due to calf housing may become evident.

One of the objectives of this study was to determine the needs of the clients, i.e. the important farm problems related to calf mortality. Much emphasis has been and still is placed on calf housing. But this small sampling of two very distinct mortality groups indicates there is less difference in mortality rates between herds with specialized calf facilities and those with makeshift facilities such as old barns than exists between herds with different types of maternity areas, i.e. box stalls vs group calving facilities. Therefore more dairymen need innovations and improvements in maternity facilities than need improvement in calf housing facilities.

APPENDIX

APPENDIX TABLE 1. Serum immunoglobulin levels (ZST) for various hours postpartum Trial II.

Calf No.[a]	At first feeding[b]	Time after birth					
		12	24	36	48	72	14
		hours					days
		ZST units[c]					
1 1210A	.093	.953	6.605	10.907	9.768	9.510	11.837
2 1366	.00	1.171	10.305	14.848	11.827	13.607	9.157
3 1377	.209	2.254	6.995	13.595	11.829	8.297	9.000
4 1232A	.419	1.419	14.837	9.256	4.349	17.907	11.209
5 1374	.209	.628	6.233	6.419	4.512	5.674	5.861
6 1190A	.258	.304	10.180	14.731	12.389	10.188	12.038
7 1141A	.302	.512	5.512	9.768	3.465	3.047	8.768
8 1222A	.093	.419	5.674	10.326	12.163	4.349	7.000
9 1181A	.209	1.186	6.047	1.302	2.651	7.000	3.326
10 1362	.209	2.061	2.904	4.778	3.138	4.028	4.942
11 1142B	.209	1.419	6.047	6.605	7.00	6.047	4.349
12 1138B	.209	1.186	.302	3.510	9.519	5.674	4.349
13 1369	.209	--	3.465	8.070	5.674	7.000	5.163
14 1195A	.211	--	8.010	18.430	18.430	14.970	9.368
15 1373	.302	--	3.744	5.000	4.047	5.674	6.419
16 1379	.116	--	7.530	12.062	9.947	2.370	5.861
17 1221A	.093	6.605	12.163	11.512	19.163	17.326	11.512
18 1358	.094	2.295	10.890	10.773	7.167	14.310	16.371
19 1147A	.209	2.651	9.512	3.186	6.419	6.510	5.674
20 1214A	.209	4.837	11.512	4.837	8.302	11.837	3.186

APPENDIX TABLE 1. Cont'd.

Calf No.[a]	At first feeding[b]	Time after birth					
		12	24	36	48	72	14
		hours					days
		ZST units[c]					
21 1368	.209	5.163	8.767	12.572	10.326	11.512	10.605
22 1355	.164	6.839	15.996	16.652	18.642	15.176	9.977
23 1376	.418	8.297	13.585	11.829	12.155	10.040	7.837
24 1380	.209	6.047	10.326	10.326	9.250	8.302	7.000
25 1072B	.209	6.902	11.411	14.837	13.131	11.736	8.070
26 1367	.000	8.619	10.305	17.354	8.291	11.827	3.906
27 1381	.209	5.861	4.349	7.837	8.302	4.512	6.605
28 1371	.209	2.907	11.209	10.907	9.256	5.861	8.302
29 1375	.000	--	9.000	9.256	8.768	14.000	14.837
30 1356	.211	--	9.064	11.663	8.853	16.371	9.110
31 1225A	.209	--	4.047	4.209	3.907	7.209	10.326
32 1378	.209	--	5.508	6.042	13.224	13.595	7.209

[a] Calves 1-16 received 1.0 lb. of colostrum at the first feeding. Calves 17-32 received 3.0 lb. of colostrum at the first feeding. Calves with letters are males.

[b] Calves 1-4 and 17-20 were fed initially at one hour.
Calves 5-8 and 21-24 were fed initially at two hours.
Calves 9-12 and 25-28 were fed initially at six hours.
Calves 13-16 and 29-32 were fed initially at 12 hours.

[c] Zincsulfate turbidity units as estimate of serum immunoglobulin levels.

APPENDIX TABLE 2. General information on calves in Trial II.

	Birth weight	Colostrum fed	g. gl.^{a} fed	g. gl.^{b} fed/kg b.wt.	48 hr^c ZST units	g. gl.^{d} in serum 48 hr	g. gl./^{e} 100 ml 48 hr
	kg	kg	g	g		%	g
1210A	46.4	5.9	43.8	.94	9.768	29.4	1.88
1366	44.6	5.9	44.6	1.0	11.827	30.3	1.71
1377	35.5	5.9	43.8	1.23	11.829	27.8	1.53
1232A	43.7	5.9	43.8	1.0	4.349	35.3	2.08
1374	51.9	5.9	43.8	.85	5.512	27.5	1.46
1190A	45.5	5.9	46.4	1.02	12.389	27.0	1.49
1141A	47.3	5.9	40.1	.87	3.465	26.7	1.37
1222A	42.8	5.9	40.1	.95	12.163	10.6	.66
1181A	43.2	4.1	28.7	.66	2.651	26.0	1.24
1362	44.8	4.1	30.1	.68	3.138	18.2	.96
1142B	43.7	4.1	26.3	.61	7.00	26.0	1.37
1138B	41.9	4.1	28.7	.69	9.519	28.3	1.52
1369	40.5	5.0	36.3	.90	5.674	25.1	1.35
1195A	41.9	5.0	38.2	.91	18.430	25.2	1.17
1373	45.5	5.0	36.2	.80	4.047	22.3	1.17
1379	46.4	5.0	33.5	.73	9.947	25.7	1.25
1221A	40	6.8	51.3	1.29	19.163	36.5	2.28
1358	44.6	6.8	54.5	1.22	7.167	26.0	1.59
1147A	54.6	6.8	48.0	.88	6.419	19.3	.94
1214A	42.8	6.8	48.0	1.12	8.302	27.0	1.79

APPENDIX TABLE 2. Cont'd.

	Birth weight	Colostrum fed	g. gl.[a] fed	g. gl.[b] fed/kg b.wt.	48 hr[c] ZST units	g. gl.[d] in serum 48 hr	g. gl./[e] 100 ml 48 hr
	kg	kg	g	g		%	g
1368	41.9	6.8	52.9	1.26	10.326	28.8	1.69
1355	32.3	6.8	54.5	1.69	18.642	33.2	1.91
1376	40.0	6.8	51.3	1.29	12.155	29.1	1.64
1380	39.8	6.8	48.0	1.21	9.250	26.1	1.31
1072B	51.9	5.0	36.3	.70	13.131	25.7	1.51
1367	36.4	5.0	36.3	.99	8.291	23.7	1.30
1381	39.1	5.0	33.5	.86	8.302	24.0	1.23
1371	42.3	5.0	33.7	.80	9.256	28.1	1.69
1375	44.1	5.0	36.2	.83	8.768	30.7	1.73
1356	40.9	5.0	38.2	.94	8.853	24.0	1.50
1225A	45.5	5.0	36.2	.80	3.907	21.5	1.16
1378	56.9	5.0	36.2	.64	13.224	24.3	1.25

[a] g. gl. = gamma globulin. Amount fed in 38 hours was obtained by multiplying colostrum fed by its g. gl. content.

[b] Gamma globulin fed in grams per kilogram of birthweight within 38 hours.

[c] Zincsulfate turbidity units.

[d] Gamma globulin as per cent distribution from clinical electrophoresis.

[e] Grams of gamma globulin per 100 ml of serum.

APPENDIX TABLE 3. General information about 30 Michigan dairy herds participating in field study.

1	2	3	4	5	6
Herd Code	No. of milking cows	lb. of milk/cow per year	Ave. ZST level	Calves sampled	Mortality 1972 %
A	38	13,000	8.59	11	0
B	110	13,500	9.35	18	19
F	135	12,000	6.38	19	8
G	98	10,200	2.45	9	6
H	75	12,100	6.38	12	6
Low J	64	14,300	6.88	13	10
L	70	12,200	7.84	19	7
M	36	15,000	14.79	4	15
N	66	13,000	7.65	8	7
X	500	13,600	2.11	8	8
CC	170	12,500	5.93	23	4
EE	83	13,100	7.01	9	5
GG	344	14,600	9.96	25	3
Ave	138	13,008	7.5		7.5
±SE	38		.86		1.4
C	155	14,000	3.56	12	28
W	250		9.03	27	20
Z	250	11,000	3.91	43	23
AA	170		8.73	24	20
H1 BB	200	13,500	5.77	14	15
DD	110	9,500	3.44	12	12
FF	180	13,000	5.03	10	20
JJ	160	13,900	3.27	11	23
KK	75	14,600	9.67	9	30
Ave	172	12,785	5.9		21.2
±SE	19		.67		1.9
D	140	12,000	7.81	13	37
Q	180	14,600	9.03	31	28
H2 R	165	14,400	3.71	8	13
T	103	10,700	9.42	7	17
U	80	13,400	5.19	18	26
V	100	14,400	7.00	9	21
HH	250	15,200	3.57	23	24
II	200	14,000	9.58	9	28
Ave	152	13,587	6.7		24.2
±SE	20		.71		2.6
H1+ Ave	162		6.3		22.6
H2 ±SE	14		.62		1.6

APPENDIX TABLE 3. Cont'd.

1		7	8	9	10	11
Herd Code		Mortality 1973 %	Type calf barn	Usual calves /barn	Type of calf stall	Sq. ft. per calf in stall
	A	0	Old barn	12	I	24
	B	0	Special H	25	S	8
	F	20	Special H	21	I	8.7
	G	11	Special H	12	I	8
	H	8	Special	25	I	8
Low	J	8	Other	1	I	12
	L	5	Cow barn H	15	G	22
	M	0	Cow barn	12	I	15
	N	0	Old barn	10	I	44
	X	37	Special H	50	S	8
	CC	0	Special H	75	I	24
	EE	0	Old barn	10	G	53
	GG	0	Special H	75	G(S)	22
	Ave	6.8		26.4		19.7
	±SE	3		6.8		4
	C	17	Special H	10	I	34
	W	11	Old barn H	10	G	24
	Z	37	Open shed	30	G	30
	AA	4	Old barn	44	I(2)	20
H1	BB	0	Other	6	G	53
	DD	0	Special H	22	I	8
	FF	0	Old barn H	30	I(2)	14
	JJ	36	Special H	12	S	8
	KK	86	Special	18	I	8
	Ave	21.2		20.2		
	±SE	9.4		4.1		
	D	38	Special H	15	I	8
	Q	3	Old barn H	19	G(S)	42
H2	R	0	Special H	28	I	8
	T	29	Old barn	30	I	9.3
	U	44	Open shed	6	G	43
	V	0	Old barn	15	I	6.4
	HH	43	Old barn H	35	S	8
	II	11	Old barn	35	G	17
	Ave	21.0		22.3		
	±SE	6.9		3.7		
H1+	Ave	21.1		21.4		20
H2	±SE	5.8		2.8		3.6

APPENDIX TABLE 3. Cont'd.

1 Herd Code		12 Sq. ft. per calf in barn	13 Adult animals in calf barn N	14 Sq. ft./ animal in calf barn	15 No. cows in maternity area
	A	99	1	91	1
	B	35	0	35	1
	F	14	0	14	2 W
	G	44	0	44	1
	H	121	0	121	1 W
Low	J	446	1	223	1
	L	613	90	88	1 W
	M	266	35	68	1
	N	111	1	101	1 W
	X	49	0	49	1 W
	CC	59	2	58	1
	EE	93	1	84	1 W
	GG	26	0	26	1
	Ave	152	8	77.1	1
	±SE	51		15	
	C	68	0	68	21
	W	24	0	24	* W
	Z	280	90	70	45
	AA	50	0	50	1
H1	BB	106	0	106	23
	DD	38	0	38	1
	FF	82	0	82	20
	JJ	42	0	42	50
	KK	36	0	36	40
	D	22	0	22	20
	Q	42	0	16	3
H2	R	24	0	24	1 W
	T	55	0	55	60
	U	400	35	67	30
	V	31	0	31	1
	HH	42	0	42	4
	II	49	3	45	3 W
H1+	Ave	88	3	48.1	20.1
H2	±SE	25		6	5

APPENDIX TABLE 3. Cont'd.

1		16	17	18	19	20
Herd Code		Sq. ft./ cow in maternity area	Maternity bedding DM%	Maternity bedding estimated DM%	Calf stall bedding DM%	Personnel feeding calves
	A	90	-	82	82	Wife
	B	154	45 Sa	45 Sa	-	Owner
	F	113	59	59	-	Owner+hired
	G	100	73	73	81	Owner+hired
	H	200	-	70	79	Wife+owner
Low	J	280	49	49	42	Owner
	L	132	83	83	83	Owner+hired
	M	225	-	65	-	Wife
	N	187	57	70	77	Owner
	X	130	70	70	-	Hired
	CC	130	85	85	80	Owner+hired
	EE	187	76	76	80	Wife
	GG	100	64	64	65	Owner
	Ave	156	66.1	68.5	74.3	
	±SE	16	4.3	3.4	4.4	
	C	55	25	25	68	Owner+hired
	W	*	*	*	-	Owner+hired
	Z	73	30	30	62	Owner
	AA	173	84	84	-	Hired
H1	BB	117	33	33	70	Owner
	DD	216	80	80	57	Owner
	FF	58	30	30	69	Owner
	JJ	56	16	20	-	Owner
	KK	80	38	38	76 Sa	Wife+owner
	D	78	33	30	71	Hired
	Q	306	61	61	81	Owner
H2	R	100	48 Sa	48 Sa	48 Sa	Owner
	T	69	-	30	-	Herdsman
	U	71	35	30	81	Owner
	V	150	44	44	42	Owner
	HH	221	-	50 Sa		Herdsman
	II	100	-	40		Owner
H1+	Ave	120	42.8	42.0	65.8	
H2	±SE	18	5.6	4.7	3.8	

G	Group calf pens.
H	Heating units used in colder weather.
I	Individual calf pens with bedding.
S	Raised steel stalls.
(S)	Two herds keep newborns in a group pen for several days then moved them into raised steel stalls.
Sa	Sawdust was used for bedding.
(2)	Two herds frequently had two calves per individual stall, the square foot per calf was based on two calves per stall.
W	Warm maternity area i.e. all doors and windows were closed in cool weather and there was no air movement through cracks in the walls.
*	Herd calved cows in tie stalls.

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