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## Beef Cattle Handbook



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### Management Factors that Affect the Development of Passive Immunity in the Newborn Calf

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#### Introduction

A successful cow/calf operation requires that a large percentage of cows wean a live calf every year. A live calf at weaning time requires survival of the offspring from birth to weaning. USDA beef researchers and rancher surveys report that diseases including scours and pneumonia cause significant numbers of young calf deaths.

Resistance to disease is greatly dependent on antibodies or immunoglobulins and can be either active or passive in origin. In active immunity, the body produces antibodies in response to infection or vaccination. Passive immunity gives temporary protection by transfer of certain immune substances from resistant individuals. An example of passive immunity is the passing of antibodies from dam to calf via the colostrum (or first milk after calving). This transfer only occurs during the first 24 hours following birth.

#### Colostrum and Passive Immunity in Baby Calves

Lack of colostrum immunity continues to be a major predisposing factor to newborn calf diseases and economic loss in cattle. In recent years, our knowledge of colostrum feeding has advanced, but a completely reliable method for preventing hypogammaglobulinemia (low blood concentrations of immunoglobulins) has yet to be described.

Calves are born with incompletely developed host disease defense mechanisms, and colostrum protection plays an important role in early life. Feeding colostrum provides the newborn with a source of pre-formed immunoglobulin, some of which is actively absorbed across the small intestine and provides passive (because

the immunoglobulin was acquired, not synthesized by the neonate's own immune system) protection against systemic disease. Part of the immunoglobulin remains in the gut where it can neutralize pathogenic bacteria and help prevent the development of diarrhea.

In addition, colostrum contains "transferrin" and "lactoferrin", which bind iron and also restrict bacterial growth. These factors, together with immunoglobulin, help limit growth of bacteria in the gut.

#### Formulation and Composition of Colostrum

Cow colostrum contains about 22 per cent solids compared with the 12 per cent solids of normal whole milk. Much of this extra solid is immunoglobulin, but colostrum is also a rich source of casein, fat and vitamins—especially A and E. There is also a trypsin inhibitor, which helps protect immunoglobulin from digestion in the calf's gut as well as protein fractions that facilitate absorption of immunoglobulins in calves.

In cows, immunoglobulin "IgG<sub>1</sub>" is the principal colostrum immunoglobulin. In cows, immunoglobulin is concentrated in colostrum from about five weeks prepartum, probably in response to rising estrogen concentration in the dam. Special receptors on the mammary epithelium selectively bind serum IgG<sub>1</sub>, and this is taken into the cell by transcapillary exchange and transported to the lumen of the mammary gland, where it is released into colostrum. Serum IgG<sub>1</sub> concentrations fall to 50 percent, as colostrum concentrations rise to 3 - 12 times that of serum. Other colostrum immunoglobulins called "IgM" and "IgA" also reach higher concentrations than are found in serum, and they are derived partly

from the serum pool and partly from local synthesis by lymphocytes within the mammary gland.

A number of factors influence the total amount of immunoglobulin found in colostrum. The volume of colostrum produced is affected by breed, for instance, dairy cows produce much more colostrum than beef cows. Cows produce more than heifers. Feeding energy-deficient diets markedly reduce colostrum volume (Table 1 and Table 2). Also prepartum nutrition of the cow will affect colostrum quality as will be discussed later in this paper.

**Table 1. Volume of Colostrum Produced by Cows as First Milking or First Suckling by Calf.**

Breed	Management	Average Colostrum Yield (Liters)
Beef-Hereford-Cross*	Out wintered: poor nutrition	0.6
	In wintered: silage ad lib	1.7
Dairy-Ayrshire	Jersey	2.2
	Holstein-Friesian	2.2
		2.4

There are marked breed differences in colostrum immunoglobulin concentration. Low colostrum IgM and IgA concentrations in Guernsey's have led to the speculation that this may result in high calf mortality in this breed. Cows also affect the colostrum immunoglobulin concentrations and serum immunoglobulin concentrations of their one-day-old calves. An important factor that influences colostrum quality (immunoglobulin concentration) is the age of the cow. Heifers have poor quality colostrum while older cows have the best quality colostrum. Another very important factor is milking stage. In general, colostrum immunoglobulin content is halved with each successive milking; therefore, the first milking colostrum has twice the immunoglobulin content of the second milking colostrum. Colostrum leakage and premilking will both adversely influence colostrum quality. Administration of long-acting corticosteroids, which takes 9 - 19 days to induce parturition, will depress colostrum immunoglobulin concentration. Limited evidence suggests that the commonly used North American corticosteroid preparations, which take about two days to induce calving, do not adversely affect the immunoglobulin concentrations attained by calves if the cow was over 260 days into gestation at induction. However, in one study, both induced and control calves had a very high incidence of poor colostrum immunity.

#### Timing of Colostrum Feeding and the Principle of "Intestinal Closure"

Timing of colostrum feeding is important because the efficacy of absorption of immunoglobulin from

colostrum decreases linearly from birth. (See Table 2.) Immunoglobulins are fairly resistant to digestion by intestinal enzymes and are further protected by the presence of a trypsin inhibitor in bovine colostrum.

"Intestinal closure" occurs when macromolecules are no longer released into the circulation and this occurs before the specialized absorptive cells are sloughed from the gut epithelium. In calves and lambs, closure is about 24 hours after birth, although efficiency of absorption declines from birth, particularly after 12 hours and some calves fail to absorb immunoglobulin if fed after 12 hours of age. Feeding may induce earlier closure, but there is little colostrum absorption after 24 hours of age even if the calf is starved. This principle of timing of colostrum feeding holds true whether the colostrum is directly from the first milk of the dam, or supplied by hand feeding the newborn calf previously obtained colostrum.

**Table 2. Effect of Time of Colostrum Feeding (hours after birth) on Total Immunoglobulin Absorption in Calves.**

Time of Feeding (hours after birth)	Plasma	
	Concentration (mg/ml) 24 hours after feeding	Absorption (%)
6	52.7	66
12	37.5	47
24	9.2	12
36	5.4	7
48	4.8	6

If parturition is induced in cows using very slow-acting corticosteroids (9 - 19 days), the efficiency of absorption of colostrum immunoglobulin is reduced in the calf. However, there is no evidence that more rapid-acting corticosteroid preparations (two days) induce closure or that treating calves with ACTH or cortisone at birth affects immunoglobulin absorption.

#### Behavioral Factors

Behavioral factors are very important in determining the final immunoglobulin concentration attained by calves. Following birth the cow licks the calf dry and may eat the placenta. The calf nuzzles upwards, along the dark underside of the cow, and in this way ends up in the region of the udder. In cows with good conformation, the teats are set at a high point between the thighs and are in the calf's path. Cows with poor udder conformation have dropped teats, and the calf has trouble finding them as it nuzzles up into the darker region of the thighs. The initial licking dry of the calf appears to be very important to the cow-calf bond, and the dam will not allow the calf to suck if this phase of behavior has not been successfully completed. Calves born in stalls can mistake walls for the dam and orient to the dark corners. This is particularly likely to happen if the cow remains lying down. In general, beef cows mother their calves better than dairy cows, and cows have better maternal instincts than heifers. If the calf does not suck its dam in the first eight hours of

life, it will be hypoimmunoglobulinemic. Despite behavioral differences, calves born to dairy heifers attain serum immunoglobulin concentrations similar to calves born to cows—better mothering behavior in cows is compensated by better udder conformation in heifers. Calves born to beef and dairy animals also attain similar immunoglobulin concentrations, possibly because, while beef cows are better mothers, they do not produce as much colostrum.

Mothering has a tremendous beneficial effect on the efficiency of absorption of immunoglobulin. Mothered calves absorb 70 per cent more immunoglobulin from a standard feed than non-mothered calves. This benefit is still seen if the calf obtains the colostrum by sucking its dam, but is separated from its dam between feedings. Field surveys implicate separating the calf from its dam as one cause of hypoimmunoglobulinemia. Dairy calves kept with their dams attained higher serum immunoglobulin concentrations than hand-fed calves, even though the mothered calves may suckle less colostrum than hand-fed calves.

Temperature stress adversely affects colostral immunoglobulin absorption. Cold environments decrease calf vigor, although absorption is normal if the calf ingests colostrum. Heat stress lessens immunoglobulin absorption efficiency.

#### Calving Difficulty Affects Immune Response in the Newborn Calf

The effect of calving difficulty is shown in table 3. Calving difficulty had a significant influence on IgG<sub>1</sub> and IgM concentrations in blood of one-day old calves, even though cows that were assisted were milked immediately after calving, and their calves fed the colostrum. The amount of colostrum produced by these heifers average 1250.7 ml at one milk-out immediately after calving. Increased calving difficulty also resulted in less vigorous calves, as measured by interval from calving to standing, and a poorer mothering score.

Calves born after dystocia, are at high risk of failing to receive adequate colostrum by natural suckling, because of greatly decreased colostrum intake from natural suckling. Calves that are born to a prolonged stage II of parturition very often suffer from severe respiratory acidosis. Acidotic calves are less efficient at absorbing colostral immunoglobulins from even artificially fed colostrum, so every effort should be made to provide weak newborn calves with the best source of colostrum available via bottle suckling or tube feeding. This data suggests that reducing calving difficulty may be an important means of decreasing incidence of newborn disease problems. Properly developed heifers mated to “calving ease” sires will be a major first step toward reducing scours and pneumonia in newborn calves. In addition, providing early obstetrical assistance to cows or heifers in stage II of labor, will result in more vigorous calves that are more eager to obtain colostrum naturally, and will be more able to absorb immunoglobulins than calves that undergo lengthy, difficult deliveries.

**Table 3. Effect of Calving Difficulty on Serum Immunoglobulin Concentration 24 hours after Birth, Interval from Calving to Standing, and Mothering Score**

	Calving Difficulty Score*		
	1	2	3
Interval from Calving to Stand (minutes)	39.8	50.9	84.3
Mothering Score	1.2	1.5	1.5
IgG1 (mg/dl)	2401	2191	1918.5
IgM (mg/dl)	194.8	173.0	135.6

\*1=unassisted; 2=assisted after at least one hour of labor, easy pull; 3=assisted after at least one hour of labor, difficult pull

**Table 4. Effect of Time of Suckling and Calf Vigor on Immunoglobulin Absorption**

Suckling Management	No. of calves	Serum concentration of IgG1.
Calves born easily or given early assistance; nursed within 6 hours of birth	90	60.89 mg/ml
Calves born to prolonged stage II of parturition and not assisted with nursing until after 6 hours	29	34.41 mg/ml
Calves born to prolonged stage II of parturition and not assisted with nursing at all.	8	10.85 mg/ml

#### Pre-calving Cow Nutrition Affects Calf Immune Response

Nutritional deprivation in late pregnancy has not been conclusively shown to change immunoglobulin concentration. However, researchers in Virginia and Colorado have both shown that prepartum nutrition of the cow significantly affects the volume of colostrum produced. Therefore the total amount of immunoglobulin available to calf will be much less in the situation where the cow has been underfed in late pregnancy. Since many researchers determine the nutritional well-being of the beef cow by the body condition score, Colorado researchers examined the amount of disease protection newborn calves would receive from first-calf mothers that were very thin (BCS=3 or 4); average (BCS=5); or good body condition (BCS=6). Their findings are in table 5.

Calves born to heifers of condition score five and six stood sooner after birth than those of condition score three and four. Calves born to heifers of better

**Table 5. Effect of Cow Body Condition Score at Calving on Interval from Calving to Standing, Colostrum Production and Immunoglobulin Concentration in Newborn Calves**

	Body Condition Score at Calving			
	3 (very thin)	4 (thin)	5 (average)	6 (good)
Interval from Calving to Stand (minutes)	59.9	63.6	43.3	35.0
Colostrum Production (ml)	1525	1111.5	1410.9	unknown
IgG1 (mg/dl)*	1998.1	2178	2309.8	2348.9
IgM (mg/dl)*	194.8	173.0	135.6	304.1
Total IG	2192.9	2351.0	2445.4	2653.0

\*Concentration of immunoglobulin in serum of calf 24 hours after birth.

body condition also tended to have higher IgG<sub>1</sub> levels and had significantly higher IgM levels. The higher immunoglobulin concentrations seen in calves born to better condition cows may be due to increased immunoglobulin production by these cows or increased calf vigor, allowing the calf to take advantage of the immunoglobulin present. This in-depth look at the immunoglobulin presence in the blood of the newborn calf explains why Wyoming researchers (in the 1970's) found a 10 percent higher incidence of death at calving time and another 19 percent death loss from scours in calves from dams on low feed levels the last 100 days prepartum. Heifers and cows that are in thin body condition at calving time are slow to rebreed and are less likely to wean a live calf seven to eight months later.

#### How Much Colostrum Does a Calf Need?

the amount of immunoglobulin ingested is also a major determinant of final serum immunoglobulin concentration. The calf's final immunoglobulin status improves linearly with the amount of immunoglobulin fed. The upper limit for the volume of colostrum that has to be fed to saturate the absorption mechanisms has not been accurately determined. One study suggests that the best serum immunoglobulin levels are attained by feeding calves 4.0 liters of colostrum at their first meal. This volume of colostrum takes considerable time to bottle feed very young calves. A more practical "rule-of-thumb" is to feed five to six percent of the calf's body weight within the first six hours. Then feed the same amount again when the calf is about 12 hours old. For an 80 pound calf this will equate to approximately two quarts of colostrum per feeding. Feeding less than two quarts will increase the risk of insufficient antibody absorption because the total amount of immunoglobulin ingested could be less than 100 grams. High colostrum immunoglobulin concentration also improves the calf's serum immunoglobulin status. Interestingly, better results are obtained by feeding highly concentrated colostrum, than by feeding the

same total amount of immunoglobulin in a larger volume or more dilute colostrum. Nonetheless it is important to get the required minimum amount of (100 grams) immunoglobulins into the calf before it is six hours old.

#### Alternative Sources of Colostrum for the Beef Calf

Colostrum from the dam may not be available to the newborn calf for various reasons including death, milk fever, inadequate production, or a calf weakened by a prolonged and difficult parturition. Available colostrum also may contain inadequate amounts of immunoglobulins, especially if it is from first calf heifers in poor body condition. Both situations necessitate the use of alternative sources of colostrum to provide sufficient immunological protection for the calf. One such source is frozen colostrum from mature dairy cows or mature high milking beef cows. Colostrum is produced in excess on most dairy farms and, if available, is less expensive (per gram of immunoglobulin) than commercial colostrum supplements. The quality of the surplus dairy colostrum can be estimated with the use of a hygrometer; a specific gravity of less than 1.05 is associated with poor immunoglobulin concentration.

There is a need for products that can act as colostrum replacements in the frequently encountered situation in which no beef or dairy cow colostrum is readily available. Several colostrum supplement products are available that can provide substantial doses of immunoglobulin to newborn calves, although the immunoglobulin content is considerably less than that provided by natural colostrum. Approximately 100 grams of immunoglobulin must be available in an initial colostrum meal to provide the best chance that the calf will develop serum IgG1 concentrations that are associated with the best passive protection. Previously obtained colostrum must be kept frozen in order to protect the integrity of the large protein molecules that make up the various immunoglobulins.

Fermented colostrum offers a storage alternative to

frozen colostrum. Colostrum stored at room temperature ferments by the presence of the lactic acid in the milk. Dairies often store colostrum by using plastic garbage cans with lids for storage. Use 20 gallon cans or smaller. Larger ones are too heavy to handle. Have three cans available, one from which you are feeding, one full and ready to feed, and the third being filled. When one is empty, thoroughly clean and have it available for refilling. The fermented colostrum can be fed straight or diluted. Small amounts of mold on the top can be accepted; however if extremely large amounts of mold form, the entire contents of the can should probably be discarded. Do not store fermented colostrum for more than one month. Immunoglobulin is well preserved in fermented colostrum, but absorption is less effective than in fresh colostrum. Correcting the pH to 6.15 will partially correct this problem.

Commercial suppliers have sought to develop dried products labeled as colostrum-supplements which they market to prevent diseases in newborn calves. Based on scientific studies there is little doubt that feeding these colostrum supplements to newborn calves is better than no colostrum at all. However, the more relevant concern is a comparison between feeding colostrum-supplements versus natural colostrum collected from cows. Colorado State University researchers recently made that comparison. In one trial, Holstein calves were fed two one-quart meals of colostrum collected from cows at the farm or one of three colostrum-supplements within 12 hours of age. Calves fed natural colostrum had far higher serum IgG concentrations, more efficient absorption of colostrum IgG, and fewer episodes of disease within the first 30 days of life compared to calves fed colostrum-supplement products (See Figure 1.) . Although the colostrum products contained more immunoglobulin than was reported on the label and were fed at volumes that were three to four times that of the manufacturers recommendation, they were far inferior to natural colostrum for achieving passive transfer and disease protection. While colostrum supplements will provide benefit to calves whose alternative is no colostrum at all, a far better alternative is frozen stored colostrum from another cow.

In a separate study done at CSU, calves from two-year-old beef heifers were used to evaluate the effectiveness of colostrum products in providing passive immunity and disease protection in newborn calves. Calves born to these heifers were assigned to one of four treatment groups: 1) calves were fed one liter of dairy cow colostrum; 2) calves were fed product A; 3) calves were fed product B; and 4) control - calves were fed a supplement. All treatment calves received their supplement between four and twelve hours of age. Calves receiving dairy cow colostrum had higher IgG and IgM levels than calves receiving product A. Few calves in any treatment became sick. Treatment did influence average daily gain to 250 days of age. The group receiving dairy cow colostrum gained faster than those that received product A.

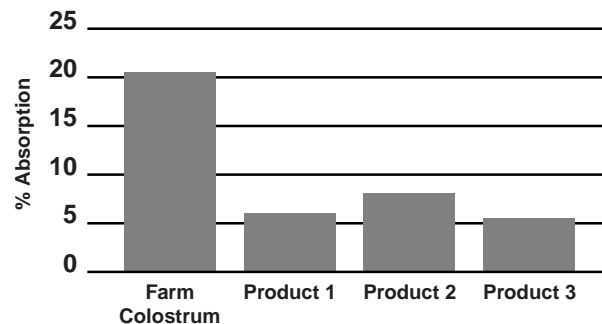


Figure 1. Apparent Percentage Absorption of IgG Consumed by Calves Fed Pooled Colostrum or 1 of 3 Colostral Supplements Within 12 Hours of Birth. (Garry, et al. 1996)

#### Thawing Frozen Colostrum

Frozen colostrums should be stored in one or two quart containers so that only what colostrum is needed at any given time will be thawed. Thawing procedures for frozen colostrum have been debated for years. Ohio research sheds some light on the controversy of the use of microwave ovens for the thawing of colostrum. They compared the results of thawing colostrum in 10 minutes with full power (650 W) micro-waving; 17 minutes of half power (325 W) micro-waving; and 25 minutes of thawing while submersed in 113° F water. Both concentration of and total content of "Immunoglobulin A" were higher in the water thawed colostrum than in the microwaved treatments. Neither the amount or con-

Table 6. The Effect of Feeding Dairy Colostrum, Colostral-supplements, or No Supplements to Calves Suckling Two-year-old Beef Heifers on Serum Immunoglobulin Levels and Average Daily Gain (ADG; lb.) to 60 Days or 250 Days of Age

Item	Treatment			
	Dairy Colostrum	Product A	Product B	Control
IgG (mg/dl)	2357.6 <sup>a</sup>	1184.8 <sup>b</sup>	1629.6 <sup>ab</sup>	1831.1 <sup>ab</sup>
IgM (mg/dl)	247.2 <sup>a</sup>	178.9 <sup>b</sup>	157.4 <sup>b</sup>	187.4 <sup>b</sup>
ADG (lb.; birth to 60 d of age)	1.49	1.34	1.36	1.43
ADG (lb.; birth to 250 d of age)	2.05 <sup>a</sup>	1.87 <sup>b</sup>	1.96 <sup>ab</sup>	2.00 <sup>ab</sup>

<sup>abp</sup><.05

Mihura, et al. 1995

centration of "Immunoglobulin G" or "Immunoglobulin M" were affected by the micro-waving treatments. These researchers concluded that frozen colostrum thawed in a microwave oven should provide a reasonable source of colostrum when fresh high quality colostrum is not available.



**Table 6. Immunoglobulin Concentration and Total Immunoglobulin Content for One Liter of Frozen Colostrum Thawed Using Full Power Microwave (FM), Half Power Microwave (HM), and Warm Water Thaw (H2O).**

Immunoglobulin	FM	HM	H2O
	concentration (mg/100 ml)		
IgG	3230	3199	3023
IgM	340	380	374
IgA	156	182	196
	total quantity (mg)		
IgG	25,590	26,026	26,088
IgM	2706	3136	3328
IgA	1235	1496	1687

#### Disease in immunoglobulin-deprived newborn calves

Colostrum-fed calves attain peak immunoglobulin levels 24 hour after birth. Serum immunoglobulin concentrations decline with a half-life of 20 days for IgG, four days for IgM, and two days for IgA. Colostrum-deprived calves synthesize immunoglobulin from birth, but it takes three months before they reach similar immunoglobulin levels to those found in colostrum-fed calves. The immunoglobulin profile becomes comparable to the adult between three and six months of age.

In general, receiving colostrum on the first day of life helps protect the calf for the first three to five weeks of life. Severely deprived calves tend to die of colisepticemia in less than four days or suffer from chronic polyarthritis. Moderately hypoimmunoglobulinemic (low blood concentrations of immunoglobulins) calves are susceptible to diarrhea and other diseases. In addition, saving colostrum and continuing to feed it after the gut has closed gives additional local protection. For example, feeding immunity-producing colostrum can protect against rotaviral diarrhea. Presumably, protection against enterotoxigenic *E. coli* diarrhea, obtained by vaccinating the dams in late pregnancy to boost colostrum antibody levels, is mainly due to local effects.

There is evidence that colostrum immunoglobulin can give partial protection up to five months of age. In one survey, death from pneumonia was reduced in calves that had high serum levels of colostrum immunoglobulin. Experimental challenge studies with parainfluenza type three virus produced less severe clinical signs in colostrum-fed calves. Antibody to infectious bovine rhinotracheitis (IBR) virus appears in nasal secretions within one day of colostrum ingestion and persists for 15 - 20 days. Serum antibody persists longer. Colostrum-fed calves with intra-nasal IBR antibodies were resistant to experimental IBR infections. Colostrum-derived immunoglobulin also helps protect against infectious bovine keratoconjunctivitis. Cows vaccinated at five to six months of gestation with a *Moraxella bovis* vaccine produced colostrum that partially protected calves against signs of pinkeye when experimentally challenged at two months of age.

#### Summary

Calves are born without the benefit of circulating immunoglobulins or antibodies that protect the calf from pathogenic microorganisms such as those that cause scours or pneumonia. Virtually all of the early life disease protection that newborn calves obtain comes from the passive immunity of colostrum immunoglobulins.

Management factors that enhance the development of the passive immunity include:

- 1) Provide proper replacement heifer development programs and adequate prepartum nutrition for the cow herd to ensure heifers are in a body condition score of 6 and cows are at least in a 5 body condition score at calving.
- 2) Heifers are bred to bulls that sire low birth weight calves and cows are bred to bulls that sire moderate birth weight calves to reduce the incidence of dystocia.
- 3) Heifers or cows observed in labor are offered early obstetrical assistance so that the calf is not allowed to become extremely acidotic, weakened, and therefore unable to nurse the colostrum or have inhibited immunoglobulin absorption.
- 4) Calves born to first calf heifers that have very little first milk or calves too weak to nurse naturally are given at least two quarts of fresh or thawed frozen colostrum within the first six hours of life and another two quarts within another 12 hours.
- 5) Frozen colostrum can be thawed with a microwave oven if done slowly so overheating is not allowed to denature the protein.

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