Disease Protection for Baby Calves

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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, were the second leading cause of baby calf deaths. Difficulty at birth was the single largest source of death loss.

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 passing of antibodies from dam to calf via the colostrum (first milk after calving). This transfer only occurs during the first few hours following birth.

Colostrum and Passive Immunity in Baby Calves

Lack of colostral 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. However, there is more knowledge available than what is currently being put to practical use.

Baby calves are born with incompletely developed host-disease defense mechanisms, and colostral protection plays an important role in early life. Feeding colostrum provides the newborn calf with a source of pre-formed immunoglobulin, some of which is actively absorbed across the small intestine and provides passive 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 percent solids compared with the 12 percent solids of normal whole milk. Much of this extra solid is immunoglobulin, but colostrum is also a rich source of milk protein (casein), energy in the form of fat and sugars, and vitamins, especially Vitamin A and E. The easily digested energy can be of great importance to the baby calf in inclement weather. Energy is required for all metabolic functions including maintenance of body temperature. 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_1" is the principal colostral immunoglobulin. In cows, immunoglobulin is concentrated in colostrum from about 5 weeks prepartum, probably in response to rising estrogen concentration in the dam. Special receptors on the mammary epithelium selectively bind serum IgG_1, and this is taken into the cells by transcapillary exchange and transported to the lumen of the mammary gland where it is released into colostrum. Serum IgG_1 concentrations fall to 50 percent, as colostral concentrations rise to 3 -12 times that of serum. Other colostral 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 more colostrum than beef cows. Cows produce more than heifers. Feeding energy deficient diets markedly reduce colostral volume (Table 1 and Table 5). 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.

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

There are marked breed differences in colostral immunoglobulin concentration. Low colostral IgM and IgA concentrations in Guernsey's have led to the speculation that this may result in high calf mortality in this breed. 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, colostral 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 both adversely influence colostrum quality.

Administration of long-acting corticosteroids, which takes 9 to 19 days to induce parturition, will depress colostral immunoglobulin concentration. Limited evidence suggests that the short-acting corticosteroids commonly used in North America, which take about 2 days to induce calving, do not adversely affect the immunoglobulin concentrations attained by calves if the cow was over 270 days into gestation at induction.

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

Timing of colostrum feeding is important because the efficiency of absorption of immunoglobulin from colostrum decreases linearly from birth (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 colostral 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 baby calf previously obtained colostrum.

Table 2. Effect of time of colostrum feeding (hours after birth) on total immunoglobulin absorption in baby 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

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 then 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 so 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 of the calf dry 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 nurse its dam in the first 8 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. This is probably because beef cows are more aggressive mothers even though they do not produce as much colostrum.

Mothering has a tremendous beneficial effect on the efficiency of absorption of immunoglobulin. Mothered calves absorb 70 percent 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 feeds. Field surveys implicate separating the calf from its dam as one cause of hypoimmunoglobulinemia in calves. Dairy calves that have easy access to the teats and are kept with their dams attain higher serum immunoglobulin concentrations than hand fed calves even though the mothered calves may suckle slightly less colostrum than hand fed calves. However, many dairy calves have tremendous difficulty nursing the teats of a cow with a very low bulging udder. In those instances, the calf will receive more passive immunity if hand fed.

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. In either case, the calf should be protected from temperature extremes, if at all possible.

Calving Difficulty Affects Immune Response in the Baby

The effect of calving difficulty is shown in Tables 3 and 4. Calving difficulty had a significant influence on IgG_1 and IgM concentrations in blood of one-day old baby calves, even though heifers that were assisted were milked immediately after calving and their calves fed the

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
IgG_1 (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 IgG_1.*
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

colostrum. The amount of colostrum produced by these heifers averaged 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. 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 even if artificially fed colostrum, therefore effort should be made to provide weak newborn calves with the best source of colostrum available via bottle suckling or tube feeding.

These data suggest 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 eager to obtain colostrum naturally. These calves will also be able to absorb more immunoglobulins than calves that undergo lengthy, difficult deliveries.

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. Many researchers and ranchers determine the nutritional well-being of the beef cow by the body condition score (BCS). Colorado researchers examined the amount of disease protection baby 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.

Table 5. Effect of cow body condition score at calving on interval from calving to standing, colostrum production and immunoglobulin concentration in the baby 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
IgG_1 (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.

Calves born to heifers of condition score 5 and 6 stood sooner after birth than those of condition score 3 and 4. Calves born to heifers of better body condition also tended to have higher IgG_1 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 1970s) found a 10% higher incidence of death at calving time and another 19% death loss from scours in calves from dams on low feed levels in the last 100-days prepartum. In addition, **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 7 to 8 months later.**

How Much Colostrum Does a Baby 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 5 to 6% of the calf's body weight within the first 6 hours. Then feed the same amount again when the calf is about 12 hours old. For an 80-pound baby calf, this will equate to approximately 2 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 colostral 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 (100 grams) of immunoglobulins into the baby 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 IgG_1 concentrations that are associated with the best passive protection. Dried colostrums will be discussed in greater detail later.

Previously obtained colostrum must be kept frozen in order to protect the integrity of the large protein molecules that make up the various immunglobulins. 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.

Thawing Frozen Colostrum

Frozen colostrums should be stored in 1- or 2-quart containers so that only the amount 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 Watts) micro waving; 17 minutes of half power (325 Watts) 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 concentration of "Immunoglobulin G" or "Immunoglobulin M" were affected by the microwaving 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.**

An additional note of caution should be observed. Most modern microwave ovens are more powerful than those used in this study. Typical household microwave ovens range in wattage power from 400 watts to 1200 watts with many ovens exceeding 700 watts. Therefore, the amount of time or the amount of power used should be adjusted accordingly in order to avoid denaturation of the protein

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 (H_20).

Immunoglobulin	*FM*	*HM*	*H_20*
		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

in the colostrum. Thawing the frozen colostrum slowly in warm water will always be safest, when time allows.

Effectiveness of Dried Colostrum Supplements

The relative effectiveness of dried colostrums have been debated in recent years. Several research trials have been conducted to examine dried colostrum in comparison to fresh or frozen colostrum. An example of this research was recently published in the Journal of Dairy Science. In that study, Holstein calves fed 85 grams of dried colostrum powder dissolved in 3 kg. of whole milk had significantly lower blood concentrations of IgG by 24 hours after birth than calves fed pooled fresh colostrum. Morbidity and mortality rates, and growth rate by 30 days were not significantly different.

Colorado State University researchers compared frozen dairy cow (pooled from several cows) colostrum to two commercially available dried colostrums and to the passive immunity received by calves nursing their two-year old mothers with no additional colostrum supplied. These researchers concluded, "The results of this study indicate that dairy pooled colostrum was the most effective method to provide additional passive immunity transfer and disease protection in calves born to two-year old heifers. Also, calves fed with either commercial colostral substitute had a tendency to have lower IgG_1 and IgM serum concentrations and lower average daily gain to weaning."

Disease in Immunoglobulin-deprived Newborn Calves

Colostrum-fed calves attain peak immunoglobulin levels 24 hours after birth. Serum immunoglobulin concentrations decline with a half-life of 20 days for IgG, 4 days for IgM, and 2 days for IgA. Colostrum-deprived calves synthesize immunoglobulin from birth, but it takes 3 months before they reach similar immunoglobulin levels to those found in colostrum-fed calves. The immunoglobulin profile becomes comparable to the adult between 3 and 6 months of age.

In general, receiving colostrum on the first day of life helps protect the calf for the first 3 to 5 weeks of life. Severely deprived calves tend to die of scours in less than 4 days or suffer from chronic joint illness. 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 colostral antibody levels, is mainly due to local effects.

There is evidence that colostral immunoglobulin can give partial protection up to 5 months of age. In one survey, death from pneumonia was reduced in calves that had high serum levels of colostral immunoglobulin. Experimental challenge studies with parainfluenza type 3 virus produced less severe clinical signs in colostrum-fed calves. Antibody to infectious bovine rhinotracheitis (IBR) virus appears in nasal secretions within 1 day of colostrum ingestion and persists for 15 to 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 5 to 6 months of gestation with a Moraxella bovis vaccine produced colostrum that partially protected calves against signs of pinkeye when experimentally challenged at 2 months of age.

Summary

Baby 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 colostral 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. See OSU Extension circular E-869, "Management of Beef Cows for Efficient Reproduction," for more details on body condition.
2. Breed heifers to bulls that sire low birth weight calves and cows to bulls that sire moderate birth weight calves to reduce the incidence of dystocia.
3. Offer early obstetrical assistance to heifers or cows observed in labor so that the baby calf is not allowed to become extremely acidotic, weakened, and therefore unable to nurse the colostrum or have inhibited immunoglobulin absorption.

4. Provide baby calves that are born to first calf heifers at least 2 quarts of fresh or thawed frozen colostrum within the first 6 hours of life and another 2 quarts within another 12 hours. This is especially important for those calves born to heifers that have very little first milk or baby calves too weak to nurse naturally.
5. Thaw frozen colostrum **slowly** in a microwave oven or warm water so as to not allow it to over heat. Therefore, denaturation of the protein does not occur.

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