Feeding the Newborn Dairy Calf

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Contents

Calf health, growth, and productivity rely heavily on nutrition and management practices. Every heifer calf born on a dairy farm represents an opportunity to maintain or increase herd size, to improve the herd genetically, or to improve economic returns to the farm. The objectives of raising the newborn calf to weaning age are optimizing growth and minimizing health problems. To accomplish these goals, it is necessary to understand the calf's digestive system, immune system, and nutrient needs, as well as the feed options available to meet those needs.

The Digestive System

Introduction

At birth, the dairy calf's digestive system is underdeveloped. From birth to about 2 weeks of age, the calf is a monogastric, or simple-stomached, animal. The abomasum is the only stomach compartment actively involved in digestion, and milk or milk replacer provides nutrients. As the calf begins to eat dry feeds, particularly grains containing readily fermentable carbohydrates, the rumen takes on a more important role. The stomach compartments grow and change as the calf develops into a ruminant animal. The fascinating differences between calves and mature ruminants create unique nutritional needs for preweaned calves.

Anatomy

At birth, the calf's stomach contains the same four compartments found in adult ruminants. However, the calf's reticulum, rumen, and omasum are inactive and undeveloped. The newborn's functional stomach, the abomasum, is similar to a human's stomach. As the calf grows and begins to consume a variety of feeds, its stomach compartments grow and change accordingly (Figure 1 and Table 1).

Figure 1. Development of bovine stomach compartments from birth to maturity.

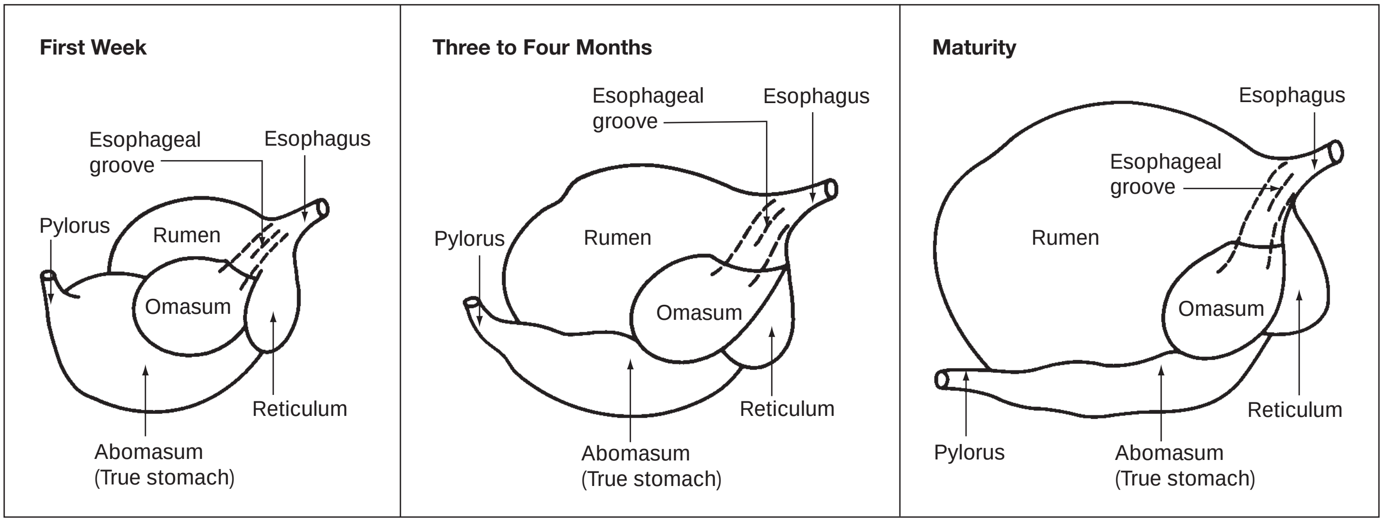


Table 1. Relative size of bovine stomach compartments from birth to maturity.

	% of Total stomach capacity			
Age	**Rumen**	**Reticulum**	**Omasum**	**Abomasum**
Newborn	25	5	10	60
3 to 4 mo.	65	5	10	20
Mature	80	5	7 to 8	7 to 8

The abomasum constitutes 60 percent of the young calf's stomach capacity. In contrast, it makes up only 8 percent of the stomach capacity in a mature cow. At birth, the reticulum and rumen make up 30 percent of the stomach capacity, and the omasum makes up approximately 10 percent. By 4 weeks of age, the reticulum and rumen comprise roughly 58 percent of the stomach, the omasum remains the same at 12 percent, and the abomasum falls to about 30 percent.

The stomach compartments grow in proportion to the calf's body size. By 12 weeks of age, the reticulum and rumen will make up more than two-thirds of the total stomach capacity. The omasum still makes up about the same proportion at 10 percent. In contrast, the abomasum comprises only 20 percent.

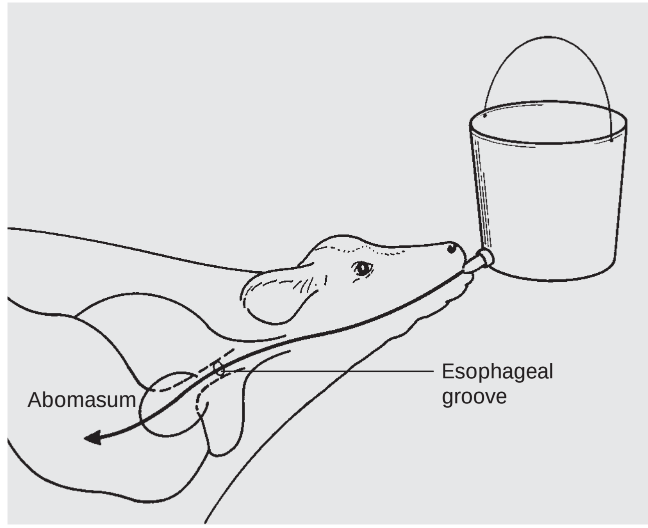
The abomasum continues to function as it did at birth, and it actually grows in size. However, the reticulum and rumen grow in size and in function; they become the most important parts of the stomach system. As the stomach develops more fully, the calf begins functioning as a mature ruminant. The objective of calf nutrition is to promote rumen development early in life.

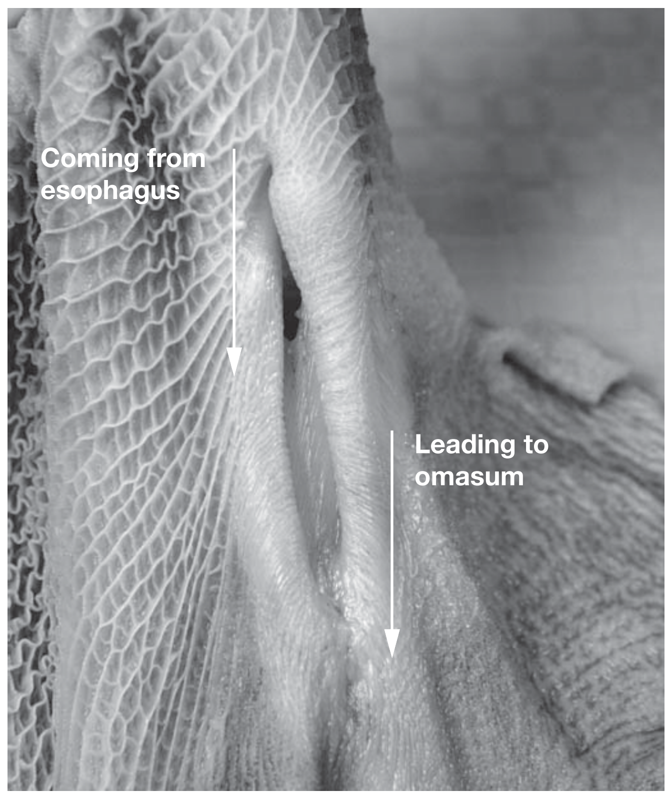
Preruminant Digestion

At birth, the rumen is nonfunctional; it has little tissue development and lacks a population of microorganisms. In the absence of a functional reticulorumen, the calf depends on its digestive enzymes. These are released primarily from the abomasum and small intestine and break down fats, carbohydrates, and protein.

In the young calf, some liquids can bypass the rumen and flow directly to the abomasum through the esophageal groove (Figure 2). The esophageal groove is formed when muscular folds from the reticulorumen are stimulated to come together. The process is controlled by neural-stimulation; suckling and milk proteins stimulate the

Figure 2. Muscular folds of the reticulorumen form the esophageal groove and direct milk to the abomasum.





formation of the esophageal groove. Therefore, milk, colostrum, and milk replacers bypass the rumen. Water, however, enters the rumen instead of the abomasum (unless consumed immediately after milk). The esophageal groove forms whether calves are fed from a nipple bottle or from an open pail.

Within 10 minutes after milk or colostrum feeding, the liquid forms a clot in the abomasum due to enzymes (chymosin and pepsin) and hydrochloric acid acting on casein (milk protein) and fat in the milk. Chymosin, also known as rennin, binds specifically with casein. Clotting binds much of the casein and fat into a clump, or curd, to be digested slowly by stomach enzymes over a period of 12 to 18 hours. Many of the enzymes required for normal, rapid digestion of feeds are produced in limited amounts in the first 48 hours of life. Low enzyme activity and curd formation following first colostrum feeding allow the calf to digest and assimilate nutrients slowly, yet efficiently, preventing scours caused by undigested nutrients reaching the large intestine. When a second feeding of colostrum or transition milk occurs, it simply adds to the already formed curd in the calf's stomach. This system allows the calf to receive a steady supply of nutrients over the first 24 to 48 hours of life, as long as it is fed casein-containing liquids.

The fraction of milk that does not form a curd is called whey. Whey is composed of water, minerals, lactose, and other proteins (including immunoglobulins). Whey passes directly into the small intestine for absorption and/or digestion within 10 minutes after feeding. From the small intestine, immunoglobulins can be absorbed into the calf's blood stream. Again, the newborn's limited digestive capacity aids the calf by enabling rapid absorption of the immunoglobulins that it needs.

Digestion of carbohydrates by the newborn calf is relatively poor; the exception is lactose or milk sugar. Digestion of starch varies according to its origin and processing methods. By three weeks of age, there is a marked improvement in the calf's ability to digest starches. After this period, as enzymes become more active, there is also an increased ability to digest vegetable proteins in feeds.

Rumen Development

The functional rumen acts as a fermentation vat, where microorganisms digest complex carbohydrates and high-fiber feedstuffs. The lining of the rumen wall in an adult cow has a very pronounced covering of papillae. These papillae are finger-like projections that greatly increase rumen surface area, the area through which nutrients can be absorbed. Papillae development is stimulated by the end products of microbial fermentation, specifically butyric acid and, to a lesser extent, propionic acid.

Developing the rumen of newborn calves is one of the most important and interesting areas of calf nutrition. From the standpoint of efficiently and economically feeding dairy replacements, developing the rumen so that it can serve as a fermentation chamber for forages and grains is fundamental.

Within a few days of birth, the calf's rumen begins to develop a population of microbes. The number and types of bacteria are a function of the types of feeds the calf eats. The esophageal groove does not function when the calf eats dry feeds; they enter the rumen, where they must be digested by microbes or chewed further by rumination. In addition to feeds, the environment, bedding, and hair provide microorganisms that inoculate the calf's rumen. The types of rumen microbes that proliferate are those that best digest and utilize the feeds eaten by the calf. In addition to feed particles, rumen microbes require water to grow properly and ferment feedstuffs. If water is not provided to the calf early in life, rumen microbial growth is limited. Water consumed as plain water enters the rumen and becomes available for the microbes' use. However, water consumed in other feeds, including milk or milk replacer, is not readily available to rumen microbes because it enters the abomasum.

There are two separate components to rumen development. The first is the physical size of the organ. At birth, the rumen is small and undeveloped. The diet has long been known to affect this aspect of rumen development. By 4 weeks of age, if the calf is fed only milk or milk replacer, the rumen will be quite small. As milk or milk replacer is fed in increasing amounts, the abomasum grows in size, but the rumen remains proportionately small and grows only moderately. This difference is great, especially when calves of the same age that are fed different diets are compared.

The rumen will be small relative to the abomasum if the calf receives a diet of only milk or milk replacer for 6 or more weeks. The longer a calf is fed large amounts of liquid feed, the greater the restriction on rumen growth relative to the size of the calf. Interestingly, while the calf appears normal or grows at rapid rates, her rumen is underdeveloped. Lack of rumen development causes a slump in growth rates after weaning.

The second aspect of rumen development is the elongation of rumen papillae and thickening of rumen walls. Feeding management can drastically affect their development.

Compare the rumen papillae development of a 6-week-old calf fed only milk replacer with one fed milk and moderate amounts of free-choice grain from 3 days of age. The calf fed grain in addition to milk shows a great deal more papillae development and a much thicker, darker, and more vascularized rumen wall (Figure 3, A and B).

Now compare a third calf fed milk and good quality hay from 3 days of age (Figure 3, C). Despite eating moderate amounts of hay, the papillae are not developed at all, and the rumen wall is quite thin. This is because the digestion end products of hay include more acetic acid, which rumen walls do not use for papillae growth and development. Calves with access to large amounts of roughage will have a considerable increase in rumen size. However, this is due largely to stretching, not real growth, of the rumen tissue.

In calves fed milk and grain papillae grow larger and the rumen walls thicken as calves get older. In comparison, calves fed milk and hay until 8 or 12 weeks have very limited papillae development, and the rumen walls remain thin, despite the consumption of appreciable amounts of hay. In fact, the rumen development of a 4-week-old calf on milk and grain is greater than that of a 12-week-old calf fed milk and hay. Rumen development of calves fed milk, grain, and hay will vary from calf to calf depending on individual preferences for dry feedstuffs.

The bottom line is that a small amount of grain, along with water, will create fermentation and, therefore, butyric acid production in the rumen. This, in turn, enhances the development of a more functional rumen that can better digest grains and, later in life, forages.

Figure 3. Comparison of rumen papillae development at 6 weeks in calves fed milk only (A), milk and grain (B), or milk and hay (C). Note the marked differences in papillae length and color.

The process of rumen papillae growth is self-generating and allows grain-fed calves to have a tremendous amount of rumen development at an early age—3 to 4 weeks. Early rumen development and therefore earlier weaning are the reasons to feed grain early. Calves started on grain late or those that consume too little grain at a young age are at a definite disadvantage.

Colostrum

Introduction

Colostrum is the first milk produced after a normal dry period and mammary involution, or the first milk secreted by a heifer, and it is an essential part of a newborn calf's survival. As the newborn's first food source, colostrum provides essential nutrients to increase metabolism and stimulate digestive activity. Colostrum is also the source of passive immune protection that is essential for keeping the calf healthy. The quality, quantity, and timing of colostrum feeding are major factors affecting calf morbidity and mortality.

True colostrum contains twice as much dry matter, three times as many minerals, and five times as much protein as whole milk (Table 2). It is also higher in energy and vitamins. The high content of fat and vitamins A, D, and E in colostrum are especially important because the newborn calf has low reserves of these nutrients. In addition, the relatively low lactose content of true colostrum reduces the incidence of diarrhea.

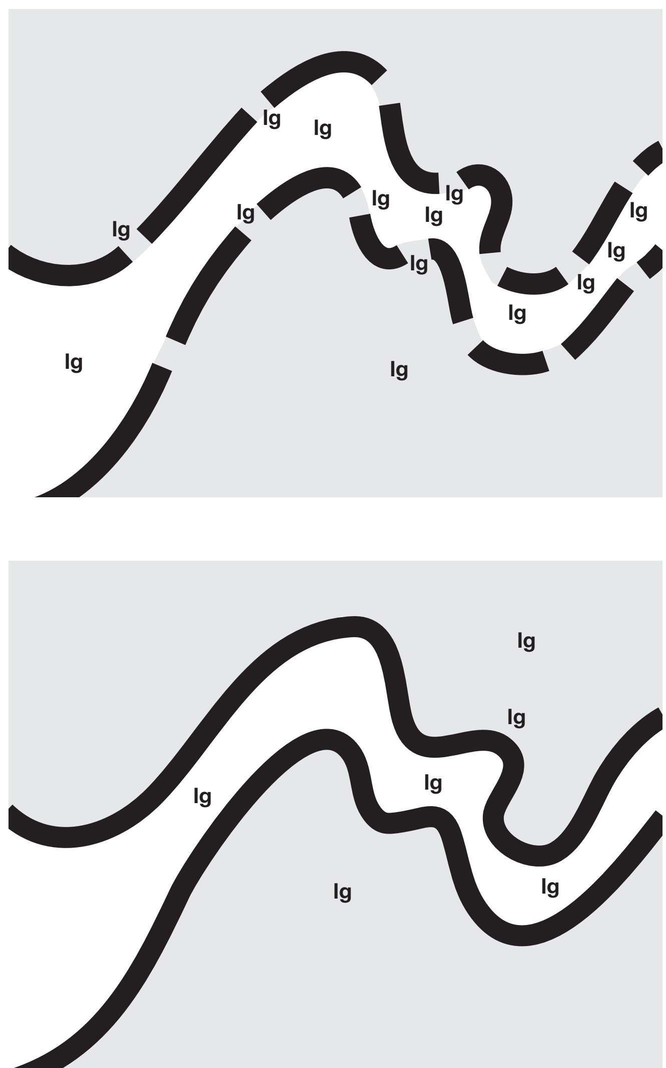
Table 2. Typical composition of colostrum and transitional milk.

	Milking number			
Item	**1**	**2**	**3**	**Milk**
Solids (%)	23.9	17.9	14.1	12.9
Protein (%)	14.0	8.4	5.1	3.1
IgG (mg/ml)	32.0	25.0	15.0	0.6
Fat (%)	6.7	5.4	3.9	4.0
Lactose (%)	2.7	3.9	4.4	5.0
Minerals (%)	1.1	1.0	0.8	0.7
Vitamin A (ug/dl)	295.0	190.0	113.0	34.0

Source: *Journal of Dairy Science,* 61:1033-1060.

Colostrum also contains immunoglobulins (antibodies), which are critical in providing the calf with immunity from infectious diseases. In the bovine, antibodies cannot cross the placental wall and pass directly from the dam to the fetus. Instead, the calf receives immunity by consuming adequate amounts of colostrum within the first few hours after birth. During the first 24 hours after birth, the calf can absorb antibodies directly from the gut into the bloodstream without digesting them (Figure 4). This type of protection, from the dam to the calf via colostrum, is called "passive immunity." Passive immunity helps to protect the calf until its own immune system becomes fully functional. The gap between passive immunity provided by colostrum and the calf's own immunity creates a period where the calf is at greater risk of illness (Figure 5).

Figure 4. Illustration of antibodies (Ig) being absorbed from colostrum and crossing into the calf's bloodstream (top). By about 24 hours of age, the calf can no longer absorb antibodies (bottom).



- Immune status of the dam—as it relates to her pathogen exposure and vaccination level.
- Length of the dry period—a 3- to 4-week dry period is needed to allow antibodies from the blood to be concentrated in colostrum.
- Dry cow nutrition—cows fed too little protein or energy tend to produce lower quality colostrum than cows fed adequately.
- Age of the cow, especially as it relates to increased exposure to pathogens—2-year-old cows often have the poorest colostrum quality.
- Leaking milk prepartum or milking before calving—both reduce antibody levels by colostrum removal or by dilution.
- Breed—Jerseys tend to have the highest levels of antibodies, Holsteins have the lowest, and other breeds fall in the middle.
- Season of the year—may be related to added stress and forage quality. Temperature extremes are problematic. In the north, late winter is often associated with poor quality. In the south, summer's heat has been associated with lower quality colostrum.

The large amount of variation in colostrum quality can make feeding and managing this critical feed challenging. Colostral IgG can be measured in a lab with great accuracy, but the tests are expensive and time-consuming. While high quality colostrum containing a large percentage of immunoglobulins is typically very thick and creamy, appearance alone is not a good indicator of quality. Instead, a simple device called a colostrometer can be used to quickly estimate colostrum IgG content. This instrument measures the specific gravity of colostrum, which is correlated with antibody concentration.

The colostrometer is really a hydrometer with a scale calibrated in milligrams per milliliter (mg/ml) of immunoglobulins. When it is placed in a container of colostrum, colored areas on the scale indicate whether the colostrum is superior, acceptable, or unacceptable for feeding newborn calves. Superior readings range from 50 to 140 mg/ml or more, moderate readings (acceptable) range from 20 to 50 mg/ml, and inferior or unacceptable values fall below 20 mg/ml of immunoglobulins. Note that the units mg/ml and g/L are equivalent.

For greatest accuracy, measure colostrum IgG concentration using colostrum cooled to room temperature (72°F). At lower temperatures, the colostrometer overestimates the IgG concentration, and temperatures above 72°F will underestimate immunoglobulin concentrations.

Colostrum quality is typically expressed in terms of IgG, but contaminants also influence quality. Obviously, fewer contaminants mean higher quality. Common contaminants include blood, remnants of mastitis, and bacteria. Even good colostrum can be damaged if a cow's udder and teats are not well-cleaned, sanitized, and dried before the initial milking or nursing. Do not feed excessively bloody or mastitic colostrum. Regularly maintain and clean milking equipment, especially waste milk cans and their lids. These containers should be cleaned and sanitized just like other milking equipment to minimize bacterial contamination of colostrum.

Quantity

Calves should receive 2 to 3 quarts of undiluted colostrum as soon as possible after birth, and another 2 to 3 quarts within eight hours. An alternative to this colostrum feeding schedule can be used when a second feeding of colostrum is not possible. In this case, feed 4 quarts of colostrum in a single feeding. Since many calves will not or cannot drink this large amount at one time, an esophageal feeder may be used to feed all or part of the colostrum. However, note that this method increases the risk of calf death due to improper placement of the esophageal feeder and decreased efficiency of antibody absorption. This method is only recommended when it is the only alternative. Procedures for using an esophageal feeder are described on pages 19 and 20. If colostrum is available, continue to feed it at a rate of 10 percent of birth weight for several days.

The level of IgG necessary to provide adequate protection to the calf will vary depending on the pathogen load in colostrum and the environment, stress, housing, and feeding practices. Other factors include the calf's size and the efficiency of IgG absorption.

It is important to understand that feeding a large volume of colostrum cannot overcome low antibody concentration or high bacterial contamination. Volume is not the only factor determining the successful transfer of immunity from cow to calf.

Timing

Timing of colostrum feeding is critically important for two reasons: the short-lived ability to absorb large molecules and the potential for pathogenic bacterial colonization of the intestine.

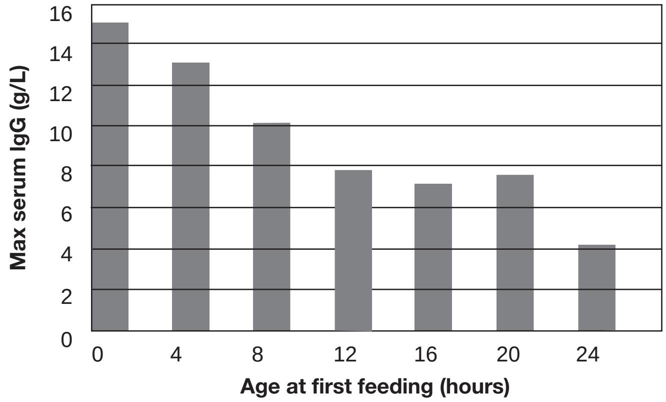
The cells lining the intestine begin to mature shortly after birth. This maturation process makes cells unable to absorb intact macromolecules by about 24 hours of age (Figure 4). In addition, for a limited time after birth, the secretion of digestive enzymes remains low, allowing antibodies to escape digestion and enabling maximum absorption. By about 12 hours after birth, enzyme secretion increases, thereby reducing the antibodies' ability to reach the blood. Stressed calves typically have even less time to absorb antibodies than normal calves.

At best, only 25 to 30 percent of the antibodies a calf consumes ever reach the bloodstream. Within six hours, the average ability of the gut walls to absorb immunoglobulins decreases by one-third. By 24 hours, the walls absorb less than 10 percent of what could originally be absorbed (Figure 6).

However, antibodies in colostrum may help fight infectious organisms in the calf's digestive tract beyond 24 hours. The unabsorbed antibodies line the calf's intestinal tract, providing a protective coating that prevents microorganisms from attaching to the wall. This defense mechanism is inhibited if bacteria such as *E. coli* (found in manure) enter the digestive tract first. *E. coli* organisms can attach to the gut walls and inhibit the attachment and absorption of colostrum antibodies (Table 4).

Early bacterial inoculation of the gut creates another problem: immature intestinal cells can absorb infectious organisms as well as antibodies (Figure 7). If bacteria enter the bloodstream before antibodies, the calf has an extremely high risk of death. Therefore, the colostrum and the calf must be kept as clean as possible. Colostrum does contain a relatively large amount of lactoferrin, an iron-binding protein that limits the growth of iron-requiring, disease-causing microorganisms, but it cannot overcome high levels of bacteria.

Figure 6. The calf's ability to absorb antibodies declines rapidly over the first 24 hours.



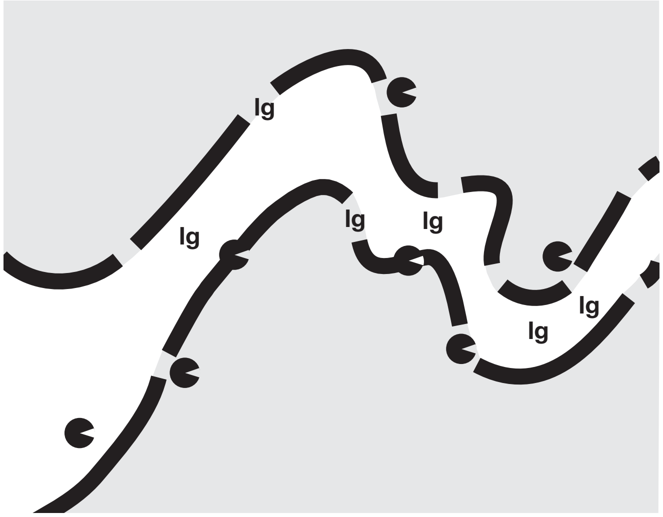
Source: *Journal of Dairy Science,* 62:1766-1773.

Table 4. Effects of early colostrum feeding on intestinal *E. coli* attachment in colostrum-deprived calves.

Feeding	Results
E. coli fed alone	Bacterial attachment to intestine and level of *E. coli* in circulation high.
Colostrum and *E. coli* fed together	No bacterial attachment to intestine.
Colostrum fed alone, *E. coli* fed one hour later	No bacteria attached to intestine and no *E. coli* in circulation. High level of circulating antibodies.

Source: *Journal of Dairy Science,* 60:1416-1421.

Figure 7. If bacteria reach the intestine before colostrum does, they often enter the blood and may be fatal. The bacteria also can prevent antibodies from reaching the calf's blood.



Storage and Handling

Storage and handling influence colostrum quality. Colostrum must be fed as soon as possible (within one hour) after collection or cooled to lower than 40°F to prevent bacterial growth during storage. Do not let colostrum sit at room temperature; even half an hour at room temperature during the summer may allow bacterial populations to double. The same problem with bacterial growth can occur after frozen colostrum is thawed. Pouring off the liquid portion periodically as colostrum thaws (and putting it in the refrigerator) will limit bacterial growth.

Storing high quality colostrum is a good management practice. Surplus colostrum can then be used when good quality, fresh colostrum is not available for a newborn calf. Refrigeration (at 33 to 35°F) can preserve colostrum quality for only about 24 hours before bacterial growth reaches unacceptable levels. For long-term colostrum storage, freezing is the best alternative. Colostrum may be frozen (at -5°F) for up to a year without significant decomposition of antibodies. One report indicated that colostrum was stored for up to 15 years without serious deterioration. Frost-free freezers are not optimal for long-term colostrum storage, as they go through freeze-thaw cycles that can allow the colostrum to thaw. Repeated freeze-thaw cycles markedly shorten colostrum storage life.

Freezing colostrum in 1- or 2-quart bottles or 1-gallon plastic bags (with zipper-closure) is an excellent method of storage. When needed, these containers can be placed in warm (not hot: less than 120°F) water and allowed to thaw. Alternately, colostrum can be thawed in a microwave oven with little damage to the antibodies. It is important to microwave colostrum for short periods on low power and pour off liquid periodically to minimize heating. Also avoid "hot spots" inside frozen colostrum. Use of a turntable can help to minimize antibody damage.

Recent research has indicated that white blood cells (leukocytes) present in colostrum also contribute to the health of calves. Leukocytes in colostrum reduce the effects of bacterial disease in young calves. Leukocytes are killed by frozen storage and are found only in fresh colostrum. Although additional research is needed, it appears that using fresh colostrum from the dam may be the best way to get these disease-fighting cells into calves.

It is ideal to keep enough frozen colostrum on hand to feed several calves. A package of frozen colostrum should be used when colostrum is of questionable quality or when it is not available.

Colostrum supplements are another option when high quality colostrum is not available. These products can be added to marginal colostrum when no other source of colostrum is available. Supplements cannot replace high quality colostrum. They do not contain sufficient quantities of antibodies to raise the blood level in calves beyond what average quality colostrum will do.

A new product designed to replace colostrum is now available. The colostrum replacer has more immunoglobulin than supplement products and provides more antibodies than poor or moderate quality colostrum. In reasearch trials, calves fed colostrum replacer have performed as well as calves fed maternal colostrum with no differences in IgG levels, incidence of scours, or growth rates. High-quality maternal colostrum is still the "gold standard" for feeding newborn calves. However, colostrum replacer can be fed to reduce the spread of diseases, including Johne's, BVD, leucosis, and mycoplasma infections. When colostrum supplies are limited, colostrum replacer provides an effective, convenient method of providing passive immunity to calves.

Feeding Method

Newborn calves should receive fresh, clean colostrum within one hour of birth. Colostrum should be fed by hand, as 40 percent of calves allowed to nurse on their own do not drink enough colostrum. Only 25 percent will get adequate colostrum within the first hour after birth. Quality, quantity, and timing all may be compromised by nursing.

Colostrum may be fed from a bottle or pail or by using an esophageal feeder. It is important to recognize that using an esophageal feeder as the first-choice method of feeding colostrum results in lower antibody levels in calves. However, using an esophageal feeder is preferable to insufficient colostrum intake.

Research conducted in North Carolina and Tennessee showed that, compared to a split feeding, providing colostrum in a single feeding did not affect dry matter intake, weight gain, or the serum immunoglobulin G concentration at 48 hours of life. High quality colostrum can be fed in either one or two feedings without affecting IgG absorption.