Feeding the

Newborn

Dairy Calf

PENNSTATE

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College of Agricultural Sciences
Agricultural Research and
Cooperative Extension

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.

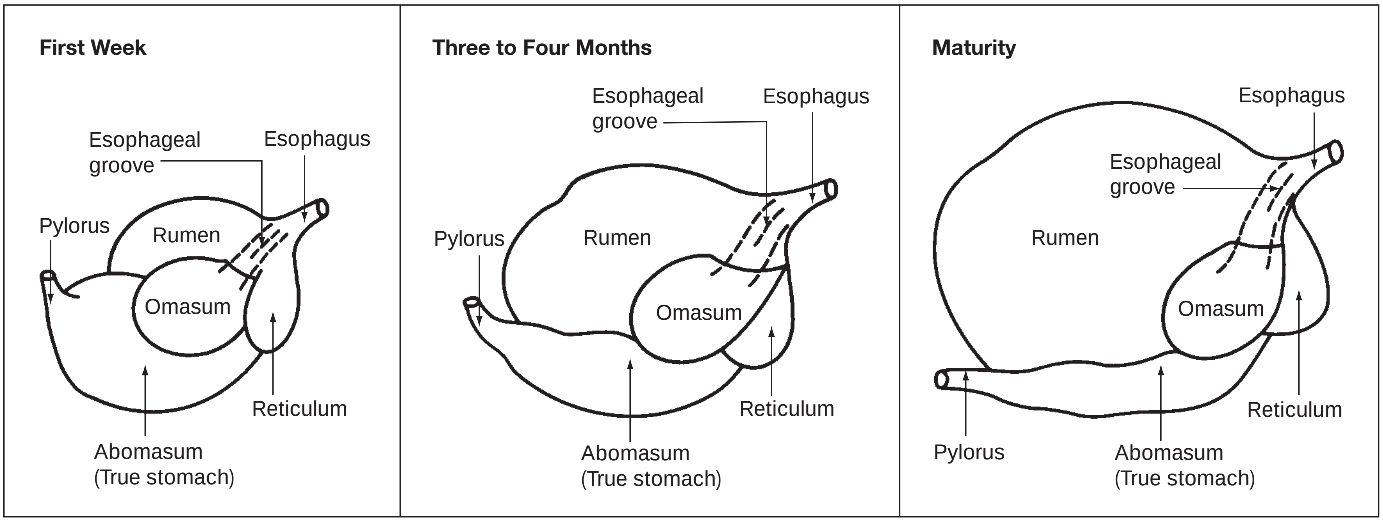
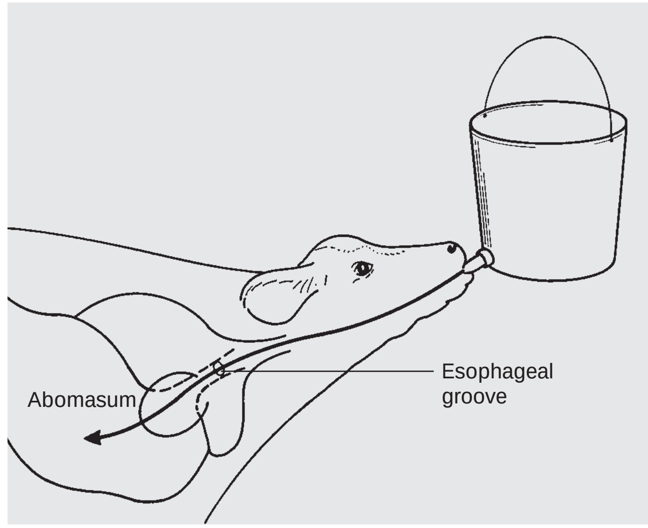
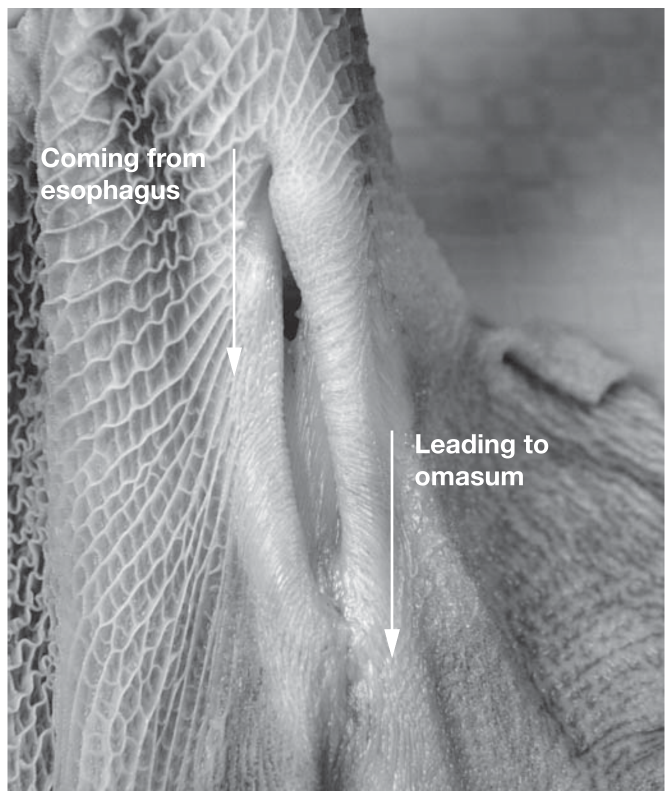


Table 1. Relative size of bovine stomach compartments from birth to maturity.

	% 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

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





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 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.

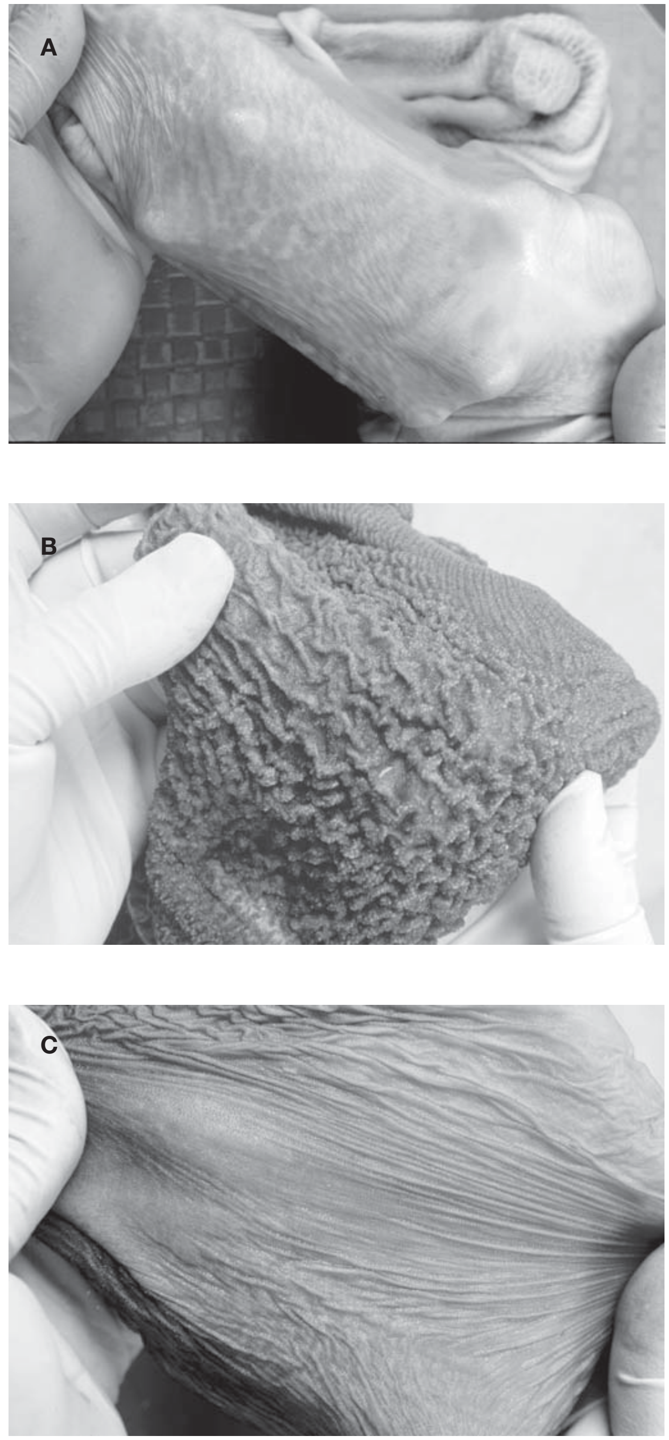
Compare the rumen papillae development of a 6-week-old calf fed only milk replacer with one fed milk and moderate amounts of free-choice grain from 3 days of age. The calf fed grain in addition to milk shows a great deal more papillae development and a much thicker, darker, and more vascularized rumen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

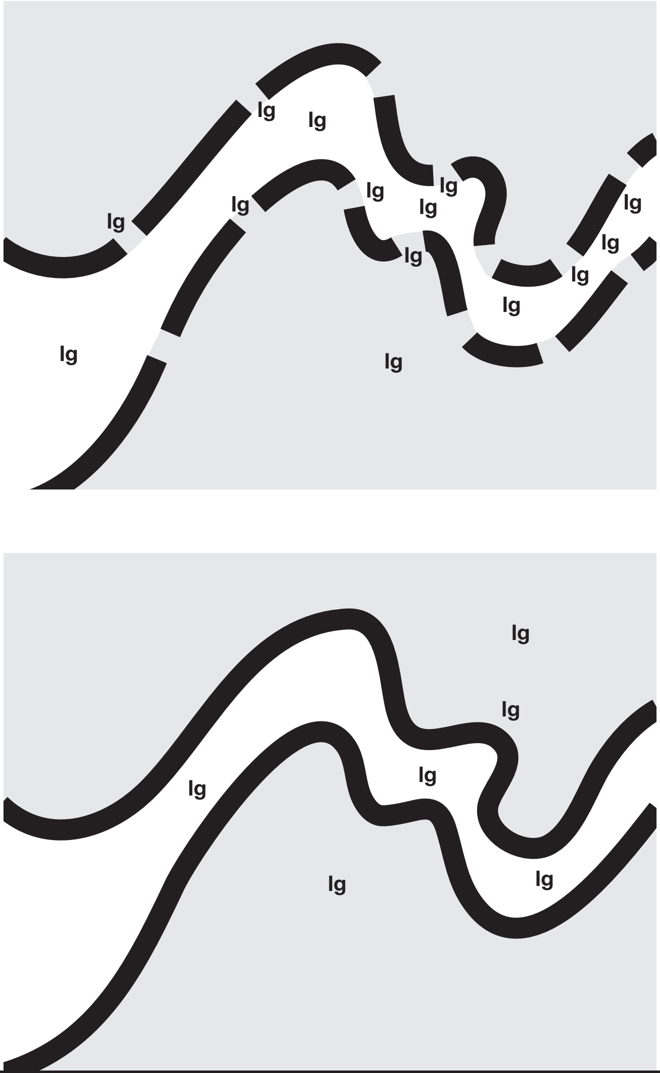
Table 2. Typical composition of colostrum and transitional milk.

	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).



The immunoglobulin content of colostrum ranges from 2 to 23 percent, compared to only about 0.1 percent in whole milk. Immunoglobulin content is directly related to the percentage of solids in the colostrum, which ranges from 17 to 36 percent. The percentage of antibodies in colostrum decreases rapidly with each milking.

Usually, the second milking contains 60 to 70 percent as many immunoglobulins as the first milking (Table 2).

The primary colostrum antibodies are immunoglobulin G (IgG), immunoglobulin A (IgA), and immunoglobulin M (IgM). IgG constitutes 80 to 85 percent of all immunoglobulins in colostrum and provides immunity against a wide variety of systemic infections and disease. IgA comprises 8 to 10 percent of the immunoglobulins, and IgM makes up 5 to 12 percent. Research data shows that the half-life of IgG is 21 days, IgM is 4 days, and IgA is 2 days. IgG is not only the most prevalent type, it also lasts the longest in the calf's bloodstream.

Figure 5. Antibodies from colostrum protect calves until their own immune systems are fully functional.

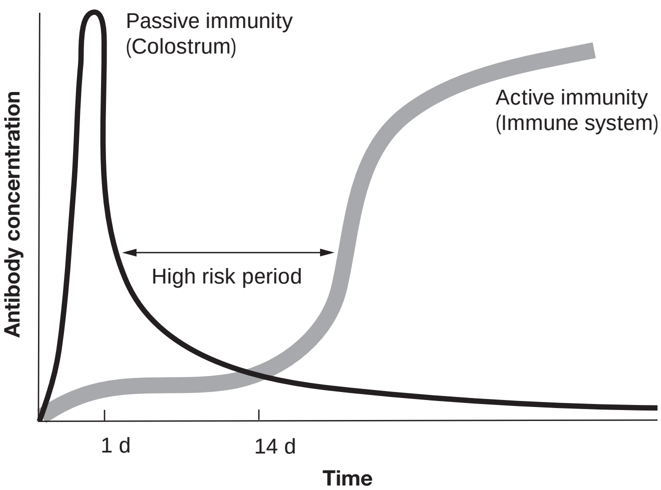


Table 3. Antibody content of milk, according to calving number.

Calving number	Antibody percentage
First	5.9
Second	6.3
Third	8.2
Fourth and later	7.5

Source: *Journal of Dairy Science,* 64:1727-1730.

Quality

Two factors dictate colostrum quality: immunoglobulin concentration (specifically IgG) and the presence or absence of bacteria. In terms of IgG, good quality colostrum contains at least 50 grams of IgG per liter (g/L). Management practices have limited control over IgG concentration, but it can be measured easily, and feeding practices can be managed around it. On the other hand, proper management can ensure low bacterial loads and high quality, clean colostrum.

IgG concentration in colostrum varies tremendously due to a variety of factors, including the disease history and exposure of each cow, the volume of colostrum produced, the season of the year, dry cow nutrition, and breed. Values for IgG in colostrum can easily range from 20 to 100 g/L, which can mean the difference between adequate immunity and failure of passive transfer (inadequate immunity).

Cows tend to produce antibodies in response to pathogens to which they have been exposed. Cows exposed to a greater number of pathogens tend to produce colostrum with more immunoglobulins than cows exposed to fewer pathogens. This explains why older cows often produce colostrum with a greater number and variety of immunoglobulins than younger cows (Table 3). However, if older cows are not exposed to many pathogens, their colostrum may not have high levels of antibodies. Heifers raised on other farms, where they are not exposed to the same pathogens as lactating cows, also produce inferior colostrum. An older cow on your farm produces the best quality colostrum, and a first-calf heifer raised at another location and moved to the farm a few days before freshening produces the poorest.

A good dry cow vaccination program can improve colostrum quality. Vaccines stimulate increased maternal antibody production and aid in passively immunizing the calf. The dam can be vaccinated against rotaviruses, coronaviruses, clostridium, and *E. coli* during the dry period.

Here's a summary of some major factors affecting the IgG concentration in colostrum:

- First milking volume—cows that produce a large quantity of colostrum (greater than 18 pounds, or about 2 gallons) often produce lower concentrations of immunoglobulins, likely due to dilution.

- 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.

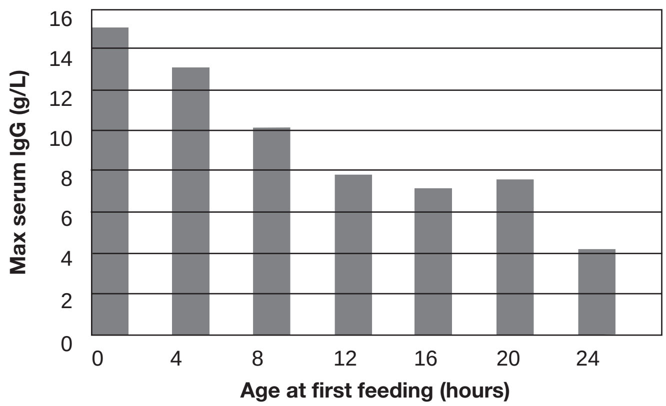
The cells lining the intestine begin to mature shortly after birth. This maturation process makes cells unable to absorb intact macromolecules by about 24 hours of age (Figure 4). In addition, for a limited time after birth, the secretion of digestive enzymes remains low, allowing antibodies to escape 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.



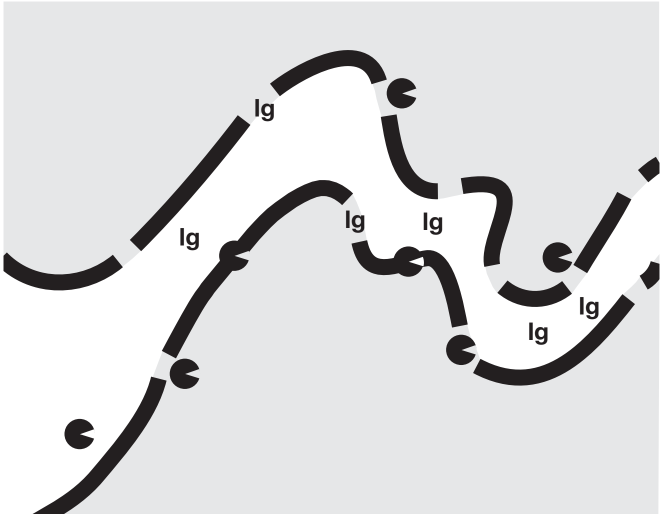
Source: *Journal of Dairy Science,* 62:1766-1773.

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.

Evaluating Colostrum Management

Success in providing adequate immune protection to calves can be monitored by taking blood samples from calves at 24 to 48 hours of age and measuring serum total protein. This measure of total protein in serum is highly correlated to IgG levels. If calves have received enough high quality colostrum, serum total protein will be 5.4 grams per deciliter (g/dl) or greater. When total protein falls between 5.0 and 5.4 g/dl, there is a marginal risk for mortality and morbidity. Total serum protein levels less than 5.0 g/dl put the calf at high risk for health problems.

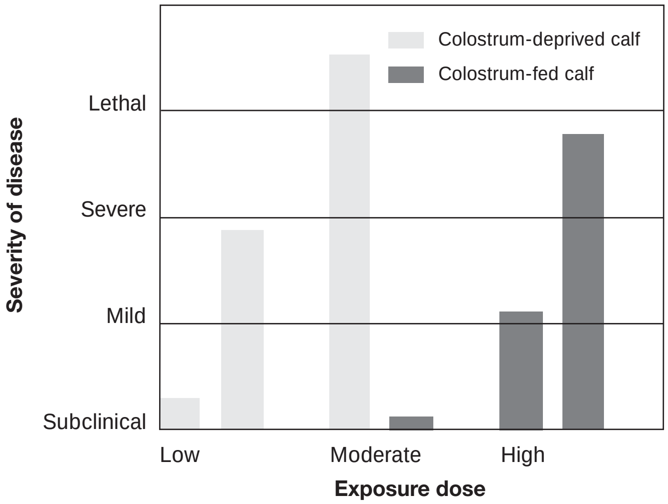
We cannot prevent exposure to intestinal and respiratory pathogens. However, colostrum-derived immunity can significantly diminish the severity of these infections. While the exposure dose of a given pathogen strongly influences disease severity, the calf's immunity can mitigate these effects. In a colostrum-fed calf, a low dose of a given pathogen results in subclinical disease (no visible sickness) and an immune response to the pathogen. The calf's own immune system thus protects it from future infections by that pathogen.

The "clinical threshold dose" (the level of exposure that results in disease) is considerably lower for colostrum-deprived calves than for colostrum-fed calves (Figure 8). The number of organisms needed to cause disease is much lower in calves that have not acquired immunity from colostrum antibodies.

Beyond the clinical threshold dose, the greater the pathogen exposure is, the more severe the illness. Calves with colostrum-acquired immunity can be exposed to larger pathogen doses yet suffer less severe illnesses than colostrum-deprived calves.

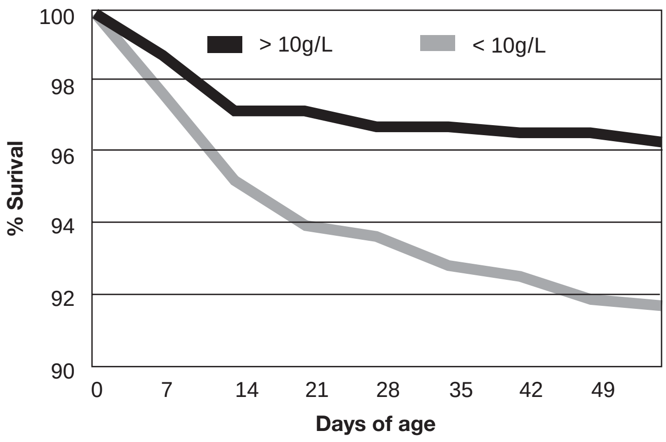
Colostrum affects both morbidity (illness) and mortality (death). Results of a national survey of heifer management practices showed that mortality rates for calves with low antibody levels (less than 10 grams per liter) were more than twice that of calves with higher levels (Figure 9).

Figure 8. Relationship between exposure dose of pathogen and severity of disease.



Source: Adapted from D. Hancock, *Dairy Herd Management*, Feb. 1984.

Figure 9. Calf survival rates by level of serum IgG.



Source: USDA National Animal Health Monitoring System, 1993.

Nutrient Requirements

The newborn calf must be fed highly digestible feedstuffs containing adequate levels of high-quality protein, energy, vitamins, and minerals.

Protein

A newborn calf has few digestive enzymes, and it cannot utilize most vegetable proteins as well as it utilizes milk proteins. Follow the newborn calf's colostrum diet with whole milk or milk replacer containing milk protein or specially processed alternative proteins (see Table 9). By the time a calf is weaned, at 4 to 6 weeks of age, it can utilize most vegetable proteins very efficiently. After 4 months of age, when the calf has a fully developed rumen, larger rumen volume that reduces rate of passage, and an established microbial population, non-protein nitrogen compounds (such as urea) may be fed.

Energy

Young calves lack certain digestive enzymes and are therefore unable to completely digest starch, some sugars (e.g., sucrose or table sugar), and some types of fat. While calves can digest saturated fats, including milk fat, coconut fat, lard, and tallow, they have limited ability to digest unsaturated fats such as corn and soybean oils. The major sources of energy for the newborn should be derived primarily from lactose (milk sugar) and highly digestible fat. It is very important to provide adequate energy, since the calf's metabolic rate, or rate at which energy is used, is greatest during the first two weeks of life. Cold weather and other environmental stresses increase the calf's energy requirements.

The rate of rumen development and microbial growth determines how soon the young calf can digest complex starches and carbohydrates, since microbes convert these energy sources into microbial protein. Within two weeks of age, the calf can digest starch. Shortly thereafter, it can digest complex carbohydrates.

Table 5 shows the daily protein and energy requirements of dairy calves fed milk or milk replacer and calf starter.

Table 5. Daily energy and protein requirements of dairy calves fed milk or milk replacer and starter.

	Calves gaining 1.0 lb/day				Calves gaining 1.5 lb/day			
Body Weight lb	NE_m[1] Mcal	NE_g[2] Mcal	ME[3] Mcal	CP lb	NE_m[1] Mcal	NE_g[2] Mcal	ME[3] Mcal	CP lb
55	0.96	0.70	2.24	0.34	0.96	1.14	2.92	0.48
65	1.09	0.75	2.46	0.34	1.09	1.21	3.18	0.49
75	1.21	0.79	2.67	0.35	1.21	1.28	3.43	0.49
85	1.33	0.82	2.87	0.36	1.33	1.34	3.66	0.50
95	1.45	0.85	3.06	0.36	1.45	1.39	3.88	0.51
105	1.56	0.88	3.25	0.37	1.56	1.44	4.10	0.51
115	1.67	0.91	3.42	0.37	1.67	1.49	4.30	0.52
125	1.78	0.94	3.60	0.38	1.78	1.53	4.50	0.53
150	2.04	1.00	4.01	0.39	2.04	1.63	4.97	0.54
200	2.53	1.11	4.77	0.42	2.53	1.81	5.84	0.57

Source: Adapted from *Nutrient Requirements of Dairy Cattle*, 2001.
[1]NE_m = net energy for maintenance.
[2]NE_g = net energy for gain.
[3]ME = metabolizable energy.

Vitamins

Calves require many of the same vitamins as monogastrics, including vitamin K and the water-soluble B vitamins: thiamine, riboflavin, niacin, choline, biotin, pyridoxine, folic acid, B12, and pantothenic acid. Vitamin K and water-soluble B vitamins are found in colostrum, fermented colostrum, whole milk, and good milk replacers. Rumen microorganisms can produce these vitamins once the calf's rumen begins to function. The young calf also requires the fat-soluble vitamins A, D, and E, which are in short supply at birth, but which are present in colostrum. Whole milk or milk replacers and supplemented grain mixtures normally supply all of these vitamins. Vitamin C is synthesized in the calf's tissue and is not required in the diet.

Minerals

Dairy calves require the same minerals for growth as other animals. Milk and milk replacers generally supply adequate amounts of many minerals needed during the first few weeks of life. The mineral content of colostrum and milk may be low or deficient, especially in mineral-deficient dams. Calf starters usually contain adequate levels of the major and trace minerals required by the young calf.

Liquid Feeds

After a few days of colostrum feeding, there are several liquid feed options available. One or several different liquid feeds may be fed throughout the year. These include milk replacers, waste milk, fresh or fermented colostrum, or whole milk. Any of these is excellent feed when available and if it fits into the calf-raising program. Research indicates that a variety of liquid feeds fed at correct dilution rates can achieve satisfactory results.

Milk Replacers

Calves may be started on a milk replacer when four to six days old, but the switch from whole milk to milk replacer should be gradual. Abrupt changes will increase the likelihood of nutritional scours and stress. Table 6 shows the recommended nutrient composition of milk replacer. Milk replacers designed for calves more than three to four weeks of age should not be used for younger calves. The label directions on the replacer bag should be carefully followed.

More than 70 percent of the dairy calves in the United States are fed milk replacer for most or all of their liquid feeding period. Convenience, economics, and biosecurity are some of the factors that make using milk replacer appealing to dairy producers.

Milk replacers can be manufactured with a variety of ingredients and levels of nutrients to match management requirements of a variety of farms. Additives, including vitamins, antibiotics, coccidiostats, or ionophores, can be supplied in the milk replacer. Typically, these cannot easily be used in whole milk or waste milk feeding systems.

Biosecurity and disease prevention also contribute to the popularity of milk replacers. Diseases such as Johne's, salmonella, *E. coli,* BVD, pasteurella, and mycoplasma can be transmitted through unpasteurized milk.

Table 6. Suggested nutrient content of milk replacer fed to replacement calves.

Nutrient	Amount
Minimum Crude Protein (%)	20 to 28
Minimum Fat (%)	10 to 22
Maximum Crude Fiber (%)	1 to 2
Macro minerals (%)	
Calcium	1.0
Phosphorus	0.7
Magnesium	0.07
Trace minerals (ppm)	
Iron	100
Selenium	0.3
Vitamins (IU/lb)	
A	4,091
D	273
E	22.7

Source: Adapted from *Nutrient Requirements of Dairy Cattle*, 2001.

Economics is the major reason for feeding milk replacer. This is because milk replacers are composed primarily of byproducts of the cheese industry. The casein or milk protein that is taken out for dried skim milk or the casein and fat that are taken out for cheese carry much of the cost of the initial milk product. The whey that remains is much cheaper, and while its demand on the world market is growing, it often commands a much lower price than skim milk.

In a typical milk replacer feeding scenario, one pound of powder containing 20 percent fat replaces 8 to 10 pounds of milk. At a milk price of $12 per hundredweight, the milk replacer is more economical if the price of a 50-pound bag is less than $48 (Table 7).

These 50 pounds provide enough feed until weaning at approximately seven weeks. The trend for increased use of milk replacers will likely continue in the future, as long as this price differential exists.

The composition and quality of a milk replacer influence the growth, health, and overall performance of calves. Ingredient and nutrient levels vary greatly between products. Protein sources are typically the most expensive milk replacer ingredients. The search for less expensive ingredients has produced many options for protein sources (Table 8). These sources vary in amino acid composition, bioavailability or digestibility, and the presence of antinutritional factors. Milk proteins are typically more digestible and contain a more favorable profile of amino acids than nonmilk proteins (Table 9). In a very young calf, milk proteins are highly digestible, at 92 to 98 percent, and plant proteins are somewhat less digestible, at 85 to 94 percent. Plant proteins with antinutritional factors may cause allergic reactions, poor digestion, or diarrhea. Milk replacers in the United States are typically based on whey and whey protein concentrate.

Compared to milk proteins, vegetable proteins often contain more crude protein. However, their protein quality, or amino acid content, is slightly inferior (Table 9). Some soy-based milk replacers contain added lysine and methionine to improve their amino acid profile. Most soy isolates or concentrates used today are highly digestible to the young calf. Animal proteins often contain high levels of protein, and some have very high amino acid concentrations, similar to milk proteins (Table 9).

Recommendations for acceptability of protein sources are presented in Table 8. Sources listed under "recommended" are either milk-based or manufactured and processed specifically for use in calf milk replacers. Their use in calf milk replacers is well researched. Sources listed as "acceptable" are sometimes used in calf milk replacers and may vary in quality. These should be used with caution since some research with these sources shows unsatisfactory results. Sources listed under "not recommended" should not be fed to calves.

Table 7. Example showing potential savings when milk replacer is fed instead of whole milk.

Price you receive for 100 lb whole milk ($/cwt):		$	12
	Times		4
Value of 400 lb of whole milk (50 lb solids*)	Equals	$	48
Cost of 50 lb of milk replacer	Minus	$	40
Therefore, savings equal		**$**	**8**

Source: BAMN, 1998.
*Whole milk is approximately 12.5% solids: 400 lb x 12.5% = 50 lb solids. Therefore, 50 lb of calf milk replacer will replace 400 lb of whole milk. This is the average amount of milk required to feed a calf from birth to weaning.

Table 8. Protein sources used in calf milk replacer, and recommendations concerning their acceptability.

Recommended	Acceptable	Not recommended
Dried whey protein concentrate	Soy flour	Meat solubles
Dried skim milk	Egg protein	Fish protein concentrate
Casein		Wheat flour
Dried whey		
Dried whey product		
Soy protein isolate		
Protein modified soy flour		
Soy protein concentrate		
Modified wheat protein		
Animal plasma		

Source: Adapted from BAMN, 1998.

Table 9. Amino acid content (% of total protein) of common milk replacer ingredients.

Amino acid*	Whey protein conc.	Dried skim milk	Soy protein conc.	Modified wheat protein	Bovine plasma	Porcine plasma
Lysine	9.1	8.2	6.3	1.6	6.5	6.1
Methionine + cystine	4.4	4.2	2.8	4.3	3.2	2.8
Threonine	7.3	4.2	4.1	2.6	4.6	4.0
Isoleucine	6.0	7.0	4.8	4.4	2.2	2.6
Leucine	10.5	10.0	7.9	7.8	7.0	6.7
Arginine	2.5	3.6	6.1	4.0	4.2	4.2
Valine	5.8	6.7	5.2	4.4	5.0	4.7
Tryptophan	2.2	1.4	1.3	1.0	1.4	1.4
Histidine	1.9	2.7	2.6	2.2	2.3	2.4
Phenylalanine + tyrosine	6.2	9.7	8.8	9.9	7.6	7.6

Source: Davis and Drackley, 1998. *The Development, Nutrition, and Management of the Young Calf*.
*Value for each amino acid is grams of the amino acid per 100 grams of crude protein.

The general recommendation for milk replacer crude protein is 20 to 28 percent. The most common levels used by producers are 20 to 22 percent crude protein. Crude fat levels can range from 10 to 22 percent, with 15 to 20 percent being most common. It is important that major minerals (including calcium, phosphorus, and magnesium), trace elements, and vitamins A, D, and E are balanced as well.

Milk replacer nutrient levels vary considerably, and different formulations target different average daily gains and levels of intake. It is important to select the correct milk replacer for your growth rate and weaning age goals.

Feed milk replacer at 10 to 14 percent of birth weight. Faster growth rates can be achieved at higher feeding rates as long as calves start slowly and the amount fed is built up gradually to help avoid scouring.

Most often, energy intake is the first limiting factor to growth. If a calf consumes more energy than is required to meet her maintenance needs, the "extra" energy can be used to convert dietary protein into body tissue. However, if a calf consumes less energy than is required for maintenance, there is no energy available for growth. Diets must be formulated to provide enough energy to support growth and enough protein to be used for that growth. Feeding too little of either nutrient or feeding the wrong ratio of energy to protein will limit growth.

Nutrients are provided by liquid feeds and starter grain, and intake and composition of both these feeds affect growth potential.

Figure 10 demonstrates the difference in energy needs between calves. If calves are fed one pound per day of milk replacer containing 20 percent protein and 20 percent fat (2.15 Mcal ME/lb), each calf receives the same daily amount of ME. One might think all calves will also gain weight at the same rate. This is not the case, because calves with different body weights have different maintenance energy requirements. A constant feeding level will meet the needs of an average calf but exceed the needs of smaller calves and fall short of the needs of larger calves, resulting in different rates of gain. Notice in Figure 10 that all four calves will need more than 1 pound of powder per day to achieve 1 pound of gain per day.

In Figure 10, all four calves have their maintenance energy needs satisfied when fed one pound of 20/20 milk replacer. Energy consumed in excess of maintenance needs can be applied to growth. Therefore, calves with greater excess energy can be expected to grow more. However, there is another factor to consider: increased growth requires increased dietary protein.

In addition to conventional milk replacers, many milk replacer companies now offer high protein, low fat milk replacer (protein greater than 24 percent and fat lower than 20 percent). These replacers provide additional

Figure 10. Energy requirements for maintenance and gain (1 pound per day) in calves fed milk replacer providing 2.15 Mcal/lb ME.

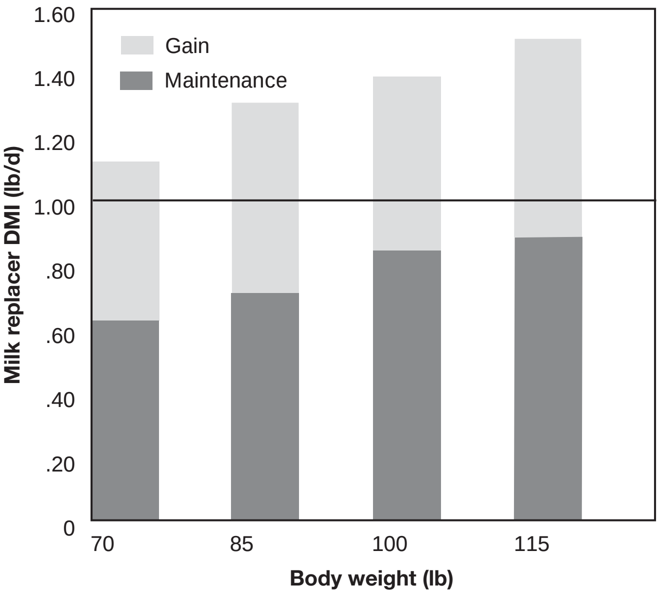
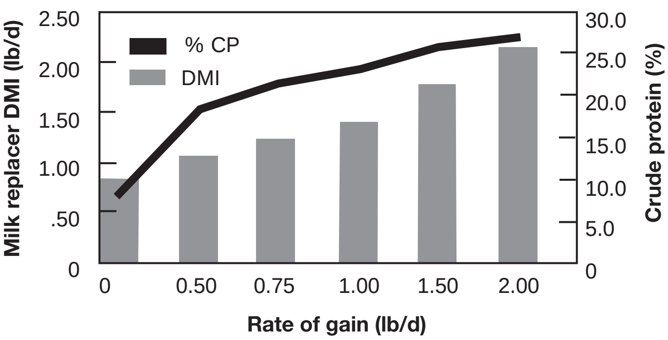


Figure 11. Effect of rate of gain on protein and dry matter intake requirements of a 100-pound calf fed milk replacer containing 2.15 Mcal/lb ME.



protein that can be used for increased growth. Increased gains are typically lean tissue, not fat deposits. Calves must be fed more replacer than conventional programs. Figure 11 shows the increase in protein requirements as rate of gain increases. The graph also shows that calves fed high levels of protein in milk replacer must be fed more dry matter to realize improved rates of gain. If dry matter is not increased, the extra protein is wasted because energy becomes the first limiting factor. In addition, the amount fed to each calf must be adjusted weekly as the calf grows to ensure that both energy and protein needs are met. To make these feeding programs cost effective, the increased cost of high protein milk replacer and the extra cost to feed more dry matter must be offset by long-term improvements in growth or decreased overall heifer production costs, possibly including reduced age at first calving. Calves also must be managed more carefully when feeding for higher rates of gain, as they may be more susceptible to nutritional scours. Grain intake may also be reduced in early life, thereby limiting rumen development.

A standard 20 percent crude protein milk replacer fed at 1.23 pounds per calf per day is sufficient to support daily gains of 0.75 pound in calves weighing 100 pounds. Usually, this rate of gain is sufficient, and it is increased to over 1 pound per day as the calf consumes dry feed.

These examples not only demonstrate the relationship between energy and protein, they also reinforce the importance of knowing each calf's actual body weight. Guessing a calf's birth weight and feeding her less than she requires in the first few weeks of life may stunt her future growth. Weight tapes designed specifically for calves can be used if scales are not available.

It is best to feed calves twice a day at regular times. This avoids digestive upsets and nutritional scours. During periods of stress, including severely cold temperatures, the energy density or overall nutrient density of the diet should be increased. This is easily accomplished by increasing the fat level of replacer or increasing the amount of replacer fed per day by 30 to 50 percent. Providing starter grain also helps calves meet increased energy needs during cold weather.

As mentioned previously, one advantage of milk replacer is the ability to incorporate additives easily. The most common additives include lasalocid and decoquinate, to prevent coccidiosis, and oxytetracycline and neomycin, to aid in preventing bacterial scours. Levels vary by the approved limits of the compound.

Several studies have shown that preruminant dairy calves respond favorably to oral antibiotics. Responses include increased appetite, greater vigor, a smoother hair coat, increased weight gain, and improved feed efficiency. These favorable effects are observed until about 3 to 4 months of age, when the rumen becomes fully functional. Although calves exposed to adverse conditions often show the greatest positive response, oral antibiotics are not a substitute for good management.

Probiotics are an alternative to antibiotics. These are live cultures of microorganisms found naturally in the calf's digestive tract. The most common probiotics are lactic acid-producing bacteria. These products are purported to improve dry matter intake, weight gain, feed efficiency, and disease resistance. However, results of research trials have been variable. Research to date suggests a modest improvement in average daily gain and feed efficiency in young animals. It seems that probiotics would be most beneficial when animals are stressed and normal bacteria populations are disrupted.

Oligosaccharides are another common type of milk replacer additive. Examples include mannanoligosaccharide (MOS), a complex sugar isolated from the cell wall of yeast, and fructooligosaccharide (FOS), a sugar extracted from the chicory plant. These compounds can bind to certain bacteria that cause scours, so they are used primarily to decrease scours and to replace antibiotics.

Whole Milk

Supplementing whole milk with proper amounts of starter is an excellent calf-feeding program. However, overfeeding or suddenly changing the quantity or quality of whole milk can cause digestive upsets and scouring. A calf should be fed approximately 12 percent of its body weight per day. Feeding much below this amount causes poor growth due to lack of necessary nutrients. Feeding high levels of whole milk can result in more rapid growth rates, but it is not recommended due to decreases in grain consumption and prolonged weaning time (and slowed rumen development).

Since feeding whole milk is more expensive compared to other sources of liquid feed, it is usually not considered the best liquid feed for the preweaned calf.

Waste Milk

Under certain circumstances, waste or mastitic milk may be fed to calves. Calves raised for bob or heavy veal should not be fed milk from cows treated with antibiotics. These compounds leave residues in the veal calf. Milk from treated cows should only be fed to calves kept as herd replacements or kept for at least eight weeks after the last feeding of treated milk.

Waste milk contains more microbial life than other liquid feeds. This dictates extra care in storing and handling this milk. Storage at room temperature for even a short period of time will allow rapid growth of bacteria. Mastitic milk should not be fed to group-housed calves that come into direct contact with other calves. Calves that suck each other immediately after drinking mastitic milk may actually inoculate the immature teats and eventually cause heifer mastitis. Mastitis-causing organisms can be passed only through direct contact; they cannot be passed from the gut to the udder.

Waste milk from cows with known infections of Johne's, *E. coli*, leukosis, salmonella, mycoplasma, or pasteurella should not be fed to calves unless it is pasteurized. When waste milk is fed regularly, pasteurization should be considered. Both batch (vat) and continuous flow (high temperature, short time) methods can effectively reduce the bacteria in waste milk. Batch methods should include agitation to ensure even distribution of heat throughout the milk. See Table 10 for recommended pasteurization temperatures. Keep in mind that some bacteria may survive pasteurization; it is not sterilization. In addition, proper cleaning and sanitation of equipment and proper handling of pasteurized milk are still required to prevent excessive bacterial growth. Feed milk soon after pasteurizing, and store any leftover milk at less than 40℉. Milk not fed within 24 hours should be pasteurized again before feeding.

Fresh Colostrum

Excess fresh colostrum is an excellent feed for young calves. It is high in dry matter and protein content and low in lactose and may be stored refrigerated for a few days. Refrigeration prevents microbial growth and preserves nutrients. However, storage and labor requirements for fresh colostrum may be prohibitive.

Because fresh colostrum has such a high dry matter content, surplus colostrum may cause calves' feces to become somewhat loose. This is usually not a problem and can be overcome by diluting 3 to 4 parts colostrum to 1 part water. As with waste milk, pasteurizing excess colostrum can reduce disease transmission.

Table 10. Minimum temperature and time for waste milk pasteurization.

Method	Temperature	Time
Batch (vat)	145℉	30 minutes
High Temperature, Short Time (HTST)	161℉	15 seconds

Fermented Colostrum

Fermenting colostrum uses the surplus milk collected from cows during the first six milkings after calving. Farmers with large numbers of cows whose calvings are spread out over the year may benefit from feeding fermented colostrum. When properly diluted, fermented colostrum is an excellent feed, resulting in weight gains equal to those of calves fed whole milk or milk replacers (Table 11).

Occasionally, calves will not drink fermented colostrum. These animals may be started on whole milk and gradually transferred to the fermented colostrum mixture. The curd particles formed in the stomach when fresh milk is ingested may be the size of a walnut or an egg. Curd formed from soured milk resembles flaky, grain-sized particles and is easier to digest. Feeding rates for fermented colostrum are presented in Table 12.

Table 11. Daily weight gains of calves fed whole milk or fermented colostrum.

Week	Whole milk (lb)	3:1 dilution (lb)	1:1 dilution (lb)
0 – 4	0.62	0.53	0.20
4 – 10	1.56	1.72	1.69
0 – 10*	1.19	1.21	1.12

Source: *Journal of Dairy Science,* 58:1360-1364.
*Weighted average.

Table 12. Suggested feeding rate for fermented colostrum.

	Daily amount[1] (lb or pints)	
Birth weight (lb)	Colostrum	Water
90–100	6.0	3.0
80–90	5.5	2.7
70–80	5.0	2.5
60–70	4.5	2.2

Source: *Journal of Dairy Science,* 61:1033-1060.
[1]Diluted 2:1; one pound = one pint.

Feeding Amount

Provide liquid feeds at 8 to 14 percent of the calf's body weight. Typically, a rate of 12 percent of body weight is recommended. At this rate, a calf weighing 100 pounds would receive 12 pounds of liquid feed per day and a calf weighing 80 pounds would receive 9.6 pounds. If calves are fed the same amount regardless of body weight, some will be underfed and some will be overfed (see discussion on pages 16 and 17).

Typically, liquid feeding programs are designed to limit the amount of liquid feed and encourage early intake of dry feeds. While current programs do not support maximal weight gains, they do promote rumen development and early weaning. Calves can be fed higher rates of liquid feed without increasing rates of nutritional scours. In evaluating different feeding programs, the increased cost of liquid feed must be weighed against increased weight gain using cost per pound of gain. In addition, the long-term impact of higher rates of gain must be evaluated from an economic standpoint.

Weak or Sick Calves

Esophageal Feeder

Newborn calves are sometimes too weak to suckle or nurse from a pail or bottle. The esophageal feeder is an excellent device for force-feeding colostrum to these calves. This inexpensive piece of equipment can save the life of a sick or weak calf.

The esophageal feeder consists of an esophageal probe, tube, clamp, and collapsible fluid container. The probe is a rigid or semiflexible tube made of plastic or stainless steel. It has a tear-shaped end designed to be easily inserted into the esophagus but not into the trachea (windpipe). The esophageal feeder should be thoroughly cleaned to prevent bacterial growth, especially after it has been used for colostrum.

The first step in using an esophageal feeder is to determine the length of tube to be inserted. Measure from the tip of the calf's nose to the point of its elbow, which is the approximate location of the diaphragm. This distance is about 20 inches in most Holstein calves (Figure 12). The spot can be marked on the tube with a piece of tape. In young calves, only about 20 inches of the tube should be passed into the mouth and down the esophagus. If the weather is cold, the tube can be placed in warm water to make it more pliable.

The tube should first be lubricated by dipping it in the colostrum or milk. A calf will likely suck the end of the tube into its mouth, which makes the tube easier to pass.

Open the calf's mouth by applying pressure to the corner of the mouth or by grabbing over the bridge of the nose and applying pressure to the upper palate or gums. Once the mouth is open, pass the tube slowly along the tongue to the back of the mouth. When the tube is over the back of the tongue, the calf starts chewing and swallowing. The tube should then be passed down the esophagus. A correctly passed tube can be felt in the esophagus; the ball on the end of the tube can be felt quite easily.

If possible, the calf should be standing before feeding so fluids are less likely to back up and enter its lungs. Calves that are too weak to stand, however, may be fed lying down. The esophageal feeder is easier to use when calves are properly restrained. Young calves can be backed into a corner for better head control.

After the tube is passed and before any liquids are given, the tube should be checked for proper positioning in the esophagus (Figure 13). If it is properly positioned, the rings of the trachea and the rigid enlarged esophagus can be felt easily. Check the exposed end of the tube for spurts of air, which indicate that the tube is in the trachea.

Next, unclip the tube to allow the liquid to drain out of the bag. Hold the bag above the calf or hang it on a nail; it will take several minutes to drain. Liquids should be at body temperature to prevent temperature shock to an already weak calf.

When feeding is over, slowly remove the tube. Clean and sanitize the feeder, and then allow it to drain and dry.

Figure 12. Hyperextension of a calf's neck and points for estimating length of esophageal tube.

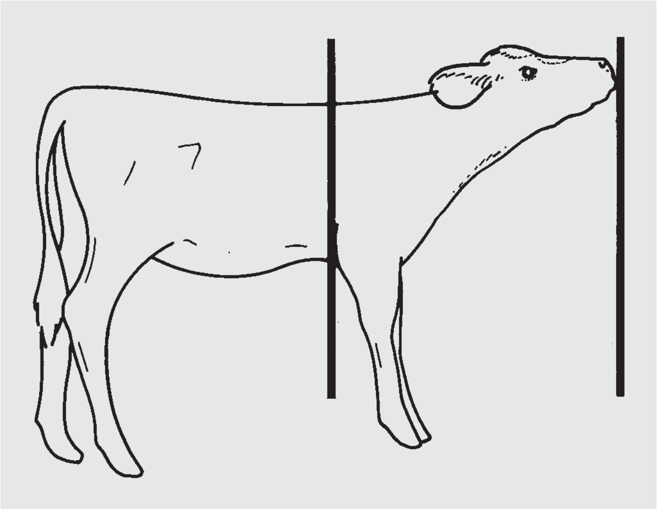
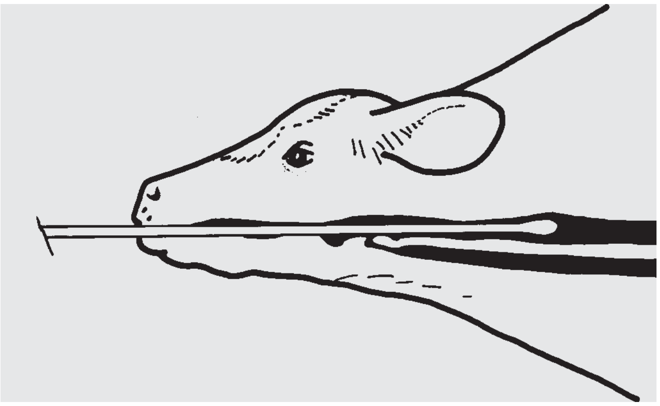
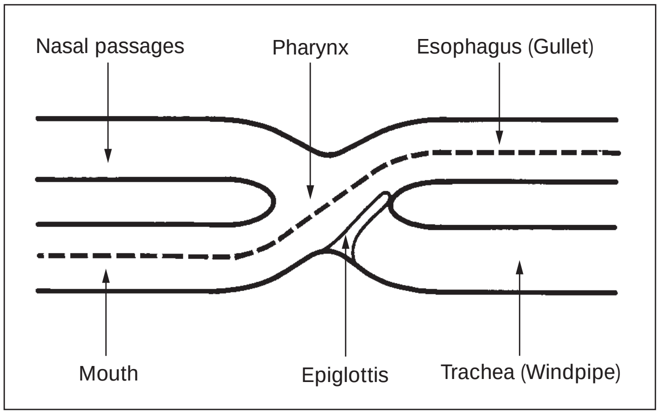


Figure 13. Position of esophageal feeder in relationship to the trachea.





Electrolyte Supplement

Electrolyte supplements are often needed for calves with moderate to severe scours. Treatment should be aimed at replacing lost fluids, restoring acid-base balance, and furnishing nutrients and energy to the calf. An electrolyte formula should be administered according to its label or a veterinarian's recommendation. The esophageal feeder is helpful in feeding these supplements.

A 100-pound calf can lose up to 10 percent of its body weight in one day. This calf needs an extra 3 to 5 quarts of fluid per day to correct dehydration; that is in addition to the 4 quarts the calf would normally consume. Electrolytes do not supply enough energy to be the sole source of nutrients. Therefore, milk should be given in addition to the electrolytes.

A 100-pound calf needs approximately 3,800 kilocalories to gain 1.5 pounds. An electrolyte with 70 grams of dextrose meets only 42 percent of the calf's energy requirements. Calves that do not receive enough energy when scouring will begin to break down muscle protein and will lose weight quickly. Continue to feed the normal amount of milk or milk replacer in addition to the electrolyte product.

An electrolyte supplement should contain sodium, alkalizing agents (bicarbonate, sodium citrate, sodium acetate, or a combination), potassium, chloride, glycine, and dextrose or glucose. Electrolytes containing bicarbonate or citrate should not be fed to calves until 15 to 20 minutes after they have consumed their milk. These two alkalizing agents prevent rennin and casein from clotting in the calf's stomach, causing rapid passage of nutrients through the small intestine. Most milk replacers do not contain casein, so alkalizing agents won't interfere with them. However, electrolyte solutions should not be mixed with milk replacer instead of water. This upsets the balance of electrolytes and ruins the product's ability to rehydrate the calf.

Dry Feed and Weaning

The preweaned calf requires both liquid and dry feeds and should be offered a dry grain mix by three days of age. During the first week of life, calves eat very little grain. By the second week, however, they should be eating noticeable amounts.

Adequate, early intake of dry feed is important because dry grain stimulates rumen development. Dry feed increases the number and variety of rumen bacteria and protozoa. These microorganisms grow rapidly on grain carbohydrates and produce the volatile fatty acids butyrate and propionate. These acids provide nutrients for the calf and stimulate rumen development.

Calves should consume 1.5 to 2.0 pounds of calf starter daily for three days before weaning. This ensures continued adequate energy intake after weaning. The crude protein recommendation for calf starter is 18 to 20 percent (Table 13). Calf starter must be palatable to encourage intake. A textured grain with coarsely processed corn, small grains, and pellets fortified with protein, minerals, and vitamins is recommended (Table 14). Starter commonly contains molasses to improve palatability and reduce separation and waste.

The calf starter should not be dry, dusty, moldy, or have an "off" flavor. Very fine-textured feed tends to cake together when wet, resulting in low intake. High-moisture grains are not recommended for young calves, since they heat quickly and mold in feed buckets or mangers. To use them successfully, grain buckets need to be emptied and refilled one or two times each day, especially during hot weather.

The growth rate of young calves depends heavily on grain intake (Figure 14). Unpalatable or poor-quality starter grains inhibit intake, thereby retarding rumen development and decreasing growth.

Forage is important to promoting growth of the muscular layer of the rumen and to maintaining the health of the rumen epithelium. However, this can be accomplished by incorporating hay into the diet after weaning. Calves can be weaned at 4 to 6 weeks of age and when they are eating 1.5 to 2.0 pounds of calf starter per day. Hay can be offered once grain intake reaches about 5 to 6 pounds daily (probably around 6 to 7 weeks of age). Hay is not

Table 13. Suggested calf starter nutrient content.

Nutrient	Amount (dry matter basis)
Crude protein (%)	18 - 20
Fat (%)	3.0
ADF (%)	11.6
NDF (%)	12.8
ME (Mcal/lb)	1.49
Macrominerals (%)	
Calcium	0.7
Phosphorus	0.45
Magnesium	0.1
Sulfur	0.2
Potassium	0.65
Microminerals (ppm)	
Manganese	40.0
Iron	50.0
Copper	10.0
Zinc	40.0
Cobalt	0.1
Iodine	0.25
Selenium	0.3
Vitamins (IU/lb)	
Vitamin A	1,818.0
Vitamin D	273.0
Vitamin E	11.4

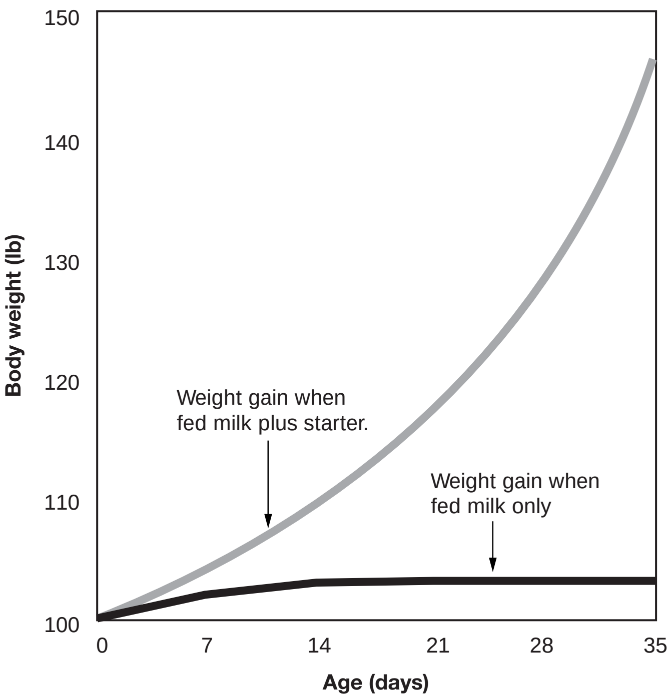
Source: *Nutrient Requirements of Dairy Cattle*, 2001.

Table 14. Example of calf starter composition.

Ingredient	Amount (lb, as-fed)
Dry shelled corn[1]	35.025
Oats, barley[2]	25.000
Soybean meal, 44%	32.000
Molasses[3]	5.000
Trace mineral salt	1.000
Calcium sulfate (22% sulfur, 27% calcium)	0.100
Dicalcium phosphate (23% calcium, 18% phosphorus)	0.500
Limestone (38% calcium)	0.900
Magnesium oxide (54% magnesium)	0.200
Vitamin ADE premix[4]	0.200
Selenium premix (0.02%)[5]	0.075
	100.000

[1]Cracked, flaked, or medium grind.
[2]Crimped, rolled, or medium grind.
[3]Level may be varied from 0 to 10 percent.
[4]Potency (IU/lb): vitamin A, 2,500,000; vitamin D, 500,000; vitamin E, 2,500.
[5]Use in selenium-deficient areas.

Figure 14. Relationship between weight gain and starter intake.



recommended for calves until weaning time and when grain intake is adequate, because it is less energy dense per unit than grain.

Because of their limited body size, calves have a high-energy requirement relative to their ability to consume dry feed. Therefore, if calves consume significant amounts of hay, their intake of starter will be limited. If starter intake is reduced, then growth will be slowed down. Finally, the nutrients in grain are more rapidly and more completely digested than those in forages. The complex, structural carbohydrates in forages reduce digestibility rates in young calves. Most hay, even excellent quality alfalfa, has too little energy per unit of feed for calves. When rumen microbes digest forages, more acetic acid is produced. This will not allow maximum papillae development compared to grains, which are fermented to butyric and propionic acids. In addition, young, small animals, like calves, have limited space in their digestive tracts. Bulky forages quickly fill this space, sending a signal that depresses appetite. Thus, gut-fill quickly becomes a limiting factor to obtaining enough nutrients.

Summary

Proper feeding and care of young calves is the first step in raising healthy, productive replacement animals to enter your milking herd. Feed four quarts of high-quality colostrum within the first eight hours to provide calves with essential nutrients and antibodies. Match milk replacer to growth and weaning age goals to meet calves' needs and to balance feed costs and animal performance. Offer a palatable calf starter by three days of age to stimulate rumen development and allow weaning by four to six weeks of age. Remove uneaten starter daily to maintain freshness. Finally, remember that nutrition is not the only factor affecting calf health and growth. Provide calves with clean, dry, draft-free housing that protects them from harsh sun in the summer and cold winds in the winter. From three days of age, make fresh, clean, free-choice water available. Work with your veterinarian to ensure that calves receive adequate vaccination and to develop treatment protocols for sick calves.

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