Critical Evaluation of Feeding Options for Replacement Calves

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▪ Take Home Messages

- A variety of liquid feeds can be used successfully to produce healthy, well-grown calves.
- Comparisons of performance of calves fed milk replacers or milk must be made on an equal-nutrient intake basis, because milk replacers usually contain only 75-85% as much metabolizable energy as milk.
- Milk replacers have advantages where concern exists about spread of infectious diseases (Johne's, BVD, leukosis) to calves.
- Excess colostrum and transition milk produce the lowest-cost gain, while quota-priced milk produces the most costly gain.
- Milk replacer results in lower-cost gain than quota-priced milk when fed at equal nutrient intakes, but is more costly than over-quota milk.

▪ Introduction

The replacement heifer enterprise typically represents about 20% of the expenses of the dairy farm. This makes it the second largest expense on the dairy farm, trailing only the costs of feed for the milk cow herd. Costs are incurred from the day of birth of the calf, with no economic returns until the heifer calves and enters the milking string. Goals of the replacement heifer enterprise should be to minimize expenses while ensuring healthy, vigorous heifers that grow rapidly and enter the milking herd at 22 to 24 months at proper body size. Getting the heifer off too a fast start during the milk feeding period provides the foundation for healthy, well-grown, economical heifers.

After ensuring adequate intake of high-quality colostrum, the newborn calf should be fed excess colostrum and transition milk (i.e., the 5-7 milkings between first colostrum and saleable milk) during the first 2-3 days of life. After this time, producers must choose a liquid feed on which to raise the calf until it is weaned to solid feed. The choice of the type of liquid feed can impact the growth, health, and profitability of the young calf. This article will summarize information about choice of the type of liquid diet for the young calf. Additional information about nutritional requirements, feeding rates and practices, and other topics related to the management of young calves can be found in Davis and Drackley (1998).

▪ Types of Liquid Feeds for Young Calves

After the initial feedings of colostrum, a variety of liquid feeds can be utilized successfully to raise young calves. These include whole milk, surplus colostrum and transition milk, waste or discard milk, and milk replacer. A recent survey of U.S. dairy producers by the USDA National Animal Health Monitoring System (NAHMS) found that milk replacer was fed on 59% of U.S. dairy farms (NAHMS, 1993; Heinrichs et al., 1994), although milk replacer is less commonly fed in Canada. Milk from cows recently calved, constituting true colostrum and what is commonly called transition milk, was used on 51.9% of farms, whereas "discard milk" (from mastitic cows and antibiotic-treated cows) and whole milk were fed on 34.0 and 32.7% of farms, respectively.

Whole Milk

Whole milk was the primary liquid feed for calves before the mid-1950's (Otterby and Linn, 1981) and still is fed on about one-third of U.S. dairy operations. While milk obviously is a high-quality feed on which calves grow well, its primary disadvantage is that it is the most expensive liquid feed. For maximum profit, producers should use lower-cost options to feed calves, such as milk replacer, surplus colostrum, transition milk, and waste milk. Furthermore, milk has been implicated in transfer of diseases such as Johne's (paratuberculosis), bovine viral diarrhea (BVD), and enzootic bovine leukosis (EBL or bovine leukemia). Producers with eradication or prevention programs in place for those diseases should consider milk replacer as an alternative.

Milk Replacer

High-quality milk replacers are excellent liquid feeds for young calves. Reports of poor calf performance on milk replacer often are attributable to selection of an inappropriate or poor-quality milk replacer, or to underfeeding the calf. Milk replacer almost always will be a cheaper feed for young calves than saleable whole milk. Although more expensive than over-quota milk, surplus colostrum, transition milk, or waste milk, milk replacers have advantages in consistency of product from day to day, ease and flexibility of storage, and disease control.

Comparisons of calf performance between milk and milk replacer must be based on equal nutrient intakes by calves. Milk nearly always contains substantially more fat and protein than milk replacer. For example, a 45-kg calf fed whole milk at 10% of body weight consumes 4.5 kg of milk, or 562 g of dry matter (DM) assuming milk contains 12.5% solids. The metabolizable energy (ME) content of milk is 5.29 Mcal/kg of DM (National Research Council, 1989), so the calf consumes 2.97 Mcal of ME daily. In contrast, if the calf instead consumes 562 g/d of milk replacer containing 4.40 Mcal ME/kg of DM, then intake of ME is only 2.47 Mcal daily. According to recently developed equations for ME requirements of young calves (Davis and Drackley, 1998), the calf would be expected to gain 446 g/d and 289 g/d when consuming milk and milk replacer, respectively, assuming that protein was not limiting in either case. This growth advantage of 157 g/d for milk is explainable entirely on the basis of energy intake and should not be construed as due to milk replacer being of inferior quality.

Surprisingly few direct comparisons of milk and milk replacers are available in the scientific literature, especially during the last decade when milk replacer formulation has changed dramatically. Furthermore, comparisons that have been made often have not taken into account the lower energy content of milk replacer (e.g., Lynch et al., 1978). Nevertheless, available data indicate that milk replacer supports gains equivalent to those of calves fed milk. For example, Jaster et al. (1990) at the University of Illinois fed calves either whole milk (3.4% fat and 3.1% protein) or an all-milk protein milk replacer (20.0% fat and 21.0% protein, DM basis), reconstituted to 12.5% solids. Both diets were fed at a rate of 9% of body weight, and amounts fed were adjusted weekly as calves grew. The average daily gain of calves during d 3 to 28 of age were 99 and 120 g/d for calves fed milk or milk replacer, respectively, and did not differ significantly between diets.

Excess Colostrum and Transition Milk

Cows usually produce much more colostrum and transition milk (i.e., the first six milkings) than needed to feed the newborn calf for the first 2-4 d of life. Producers who test and freeze only high-quality colostrum also may have abundant supplies of colostrum with lower immunoglobulin concentrations available. Therefore, until milk is saleable after cows calve, there may be considerable quantities of colostrum and transition milk available to feed to calves, which otherwise would be wasted if not fed to calves. On most farms there may be enough to feed all heifer calves from birth until weaning at 28-35 days of age (Foley and Otterby, 1978).

The feeding value of surplus colostrum/transition milk was known before the mid-1950's (Appleman and Owen, 1975). However, availability, storage, and preservation were major drawbacks to its use, and little was used on farms at that time. A series of experiments in the 1960's and early 1970's helped to develop practical feeding programs for excess colostrum and transition milk. Freezing was shown to be acceptable method of preservation, and the increased availability of home freezers made this an option on more farms (Appleman and Owen, 1975). Producers can feed calves quite cheaply by purchasing used chest-type freezers and freezing excess colostrum/transition milk. It is most convenient to freeze single-feeding quantities in plastic milk jugs or other containers (Foley and Otterby, 1978), which can be removed from the freezer before each feeding and thawed in warm water or a microwave oven on low power. Labor requirements are increased, however, because of the extra steps involved with freezing and thawing colostrum. Having sufficient freezer space for feeding large numbers of calves also becomes problematic.

The use of non-refrigerated colostrum and transition milk that had been allowed to ferment naturally was first reported by Swannack (1971). This report stimulated an abundance of research during the remainder of the 1970's in attempts to take advantage of this plentiful "free" feed. Research showed that allowing colostrum and transition milk to ferment produced a high-quality feed that was acceptable to calves, and which supported weight gains comparable to those of calves fed whole milk without any increase in scouring. In cold or cool ambient temperatures (less than about 25EC) the fermentation produces primarily lactic acid, and results in final pH of about 4.5 (range of 4.1-4.8; Foley and Otterby, 1978).

In warm or hot weather, however, less desirable fermentations occur. In particular, putrefactive fermentations often occur, which results in a product that is unacceptable to calves. For use in warm weather, therefore, it is recommended that some preservative agent be used. A number of preservatives have been tested, with acetic, propionic, and formic acids and formaldehyde being most effective (Foley and Otterby, 1978). The need to mix and handle caustic and toxic chemicals into colostrum to prevent losses has resulted in loss of popularity of this practice in warm climates.

Guidelines for use of fermented colostrum/transition milk have been described by Foley and Otterby (1978). Colostrum and transition milk can be collected in large garbage cans with plastic liners. Daily stirring helps to minimize the separation that otherwise occurs, and colostrum should be stirred before use to help make the product more uniform. If chemical additives will be used, they should be incorporated into the fresh material before adding it to the storage container, to prevent the initiation of undesirable fermentation processes. Fermented colostrum/transition milk should be fed within a few weeks of collection.

The solids content of mixed colostrum and transition milk generally will be from 16-18% (Foley and Otterby, 1978). Gains of calves have been equivalent to those of calves fed whole milk when results are compared on the basis of equal DM intakes. Common recommendations, therefore, are that this material be diluted with one part water to two or three parts colostrum/transition milk. Use of warm or hot water for dilution may help increase acceptability by calves but does not affect calf growth (Appleman and Owen, 1975).

Although use of surplus colostrum and transition milk grew in popularity in the U.S. during the late 1970's and early 1980's, it since has fallen out of favor with producers (NAHMS, 1993). With increases in average herd size, the extra handling, care, and labor necessary to keep high quality feed available, as well as the storage space required, may be partially responsible for decreased use. Furthermore, concerns about pathogenic organisms or toxins produced in less desirable fermentations (Appleman and Owen, 1975; Foley and Otterby, 1978) and concerns about spread of diseases such as Johne's disease, BVD, and leukosis from infected cows to unaffected calves also make this practice less attractive. Larger herds may combine colostrum and transition milk with non-saleable or discard milk and feed it fresh to calves (see next section), thereby eliminating the need for fermentation or freezing.

Non-Saleable (Waste or Discard) Milk

Milk from cows after antibiotic treatment for mastitis or other bacterial diseases cannot be sold and must be discarded. Waste milk represents an enormous economic loss to dairy producers, and its disposal also poses environmental problems. Such milk often is fed to dairy calves as a method to capture some economic value from an otherwise wasted resource and to more effectively recycle nutrients. As pointed out by Quigley (1998), the true opportunity cost of waste milk is the market value of the whole milk that otherwise could be sold. Thus, it is important that producers strive for excellent mastitis control and health programs that minimize the amount of waste milk produced.

Resistance by producers to feeding waste milk arose from early studies that showed increased numbers of heifers calving with mastitis or blind quarters after being fed milk from mastitic cows (Kesler, 1981). However, calves in those early studies were usually housed in groups where suckling of developing mammary glands among heifers was common. Additional concern developed over use of milk from antibiotic-treated cows by producers using fermented colostrum or waste milk, because of concerns that the presence of antibiotics would retard or prevent the fermentation process (Keys et al., 1976).

Subsequent research in the late 1970's and early 1980's demonstrated that waste milk can be used effectively to feed young calves. Growth rates and incidence of scouring by calves fed milk from mastitic cows before or during antibiotic treatment were similar to those of milk-fed controls (Chardavoyne et al., 1979; Keys et al., 1980; Kesler, 1981; Keith et al., 1983). Furthermore, no long-term effects on production or health were noted in first-lactation heifers previously fed waste milk as calves (Keys et al., 1980; Kesler, 1981). Calves fed milk inoculated with *Staphylococcus aureus* had no greater incidence of mammary infection at calving than controls (Barto et al., 1982).

Although use of waste milk in general has been shown to be an effective feed for calves, there are increasing concerns about the impact of microbial loads and antibiotic residues present. Mastitic colostrum should not be fed to newborn calves during the first day of life (see Kesler, 1981) because of permeability of the intestine to bacteria and the subsequent risk of infection. Milk from mastitic cows also should be fed only to calves that are housed individually, to prevent transmission of infectious organisms through calves suckling one another (Kesler, 1981). Milk that is extremely bloody or contains clots or other abnormal appearing material should not be fed to calves because of the likelihood of high amounts of microbial pathogens. Milk from the first two antibiotic treatments should not be fed to calves and thereafter milk from antibiotic-treated cows should be fed with caution to calves destined for meat production because of the possibility of carryover of antibiotic residues in meat (Kesler, 1981).

Effects of discard milk with high concentrations of pathogenic bacteria, viruses, endotoxins, or mycoplasma organisms also are of concern. Milk from cows with known *Escherichia coli (E. coli)* or *Pasteurella* infections should not be fed to calves because of the possibility of causing infection and digestive disease in calves. California researchers studied the microbial load in waste milk fed to calves (Selim and Cullor, 1997). The most common bacteria found were *Streptococcus* species (84 out of 165 samples), *Enterobacter* species (83 out of 165), *Staphylococcus* species (68/165), and *E. coli* (53/165). Waste milk contained significantly more viable bacteria than fresh milk, colostrum, or milk replacer. Waste milk from infected cows will be a significant source of other disease-causing organisms, such as *Salmonella, Listeria,* and BVD. Waste milk was associated with increased disease in calves in a Michigan study (Walz et al., 1997).

The microbial content of waste milk increases with storage time, especially if left standing for long periods (e.g., from the morning milking to the afternoon calf feeding) in a warm milk house or during the summer. Contamination from unsanitary containers, feeding equipment, flies, or manure increases the microbial load in the milk.

Some of the concerns about viable pathogens in waste milk and proliferation of organisms causing spoilage of milk could be overcome by pasteurization of the milk. Until recently, such a practice was thought to be prohibitively expensive. However, as larger and larger dairy operations are established, sufficient calves may be available to make pasteurization profitable.

Jamaluddin et al. (1996b) studied the effects of pasteurizing colostrum and waste milk for calves born on a 5000-cow California dairy. Pasteurization resulted in decreased morbidity and increased growth rates in calves, both pre- and postweaning. During the preweaning phase, calves fed pasteurized milk had less diarrhea than calves fed non-pasteurized milk. This early benefit had significant carry-over effects on later growth. At 180 d of age, calves previously fed pasteurized colostrum and waste milk remained 3.7 kg heavier than calves fed the same feed not pasteurized.

In an economic analysis of all costs and benefits of pasteurization, Jamaluddin et al. (1996a) estimated that calves fed pasteurized colostrum and waste milk were worth $8.13 more than calves fed non-pasteurized colostrum and waste milk. Under their experimental conditions and assumptions, Jamaluddin et al.

(1996a) calculated that at least 315 calves needed to be fed daily to make pasteurization economically feasible. Under normal conditions, this would translate into a 1260-cow dairy farm. While this practice currently would not be profitable for smaller dairies, it might be possible for several producers to cooperate and install a pasteurization system at a convenient central location to supply pasteurized milk to all cooperating farms (Jamluddin et al., 1996a).

Concern continues to grow over antibiotic use in livestock. Short-term studies have shown no obvious increase in antibiotic resistance of intestinal bacteria in calves fed waste milk (Wray et al., 1990). However, antibiotic milk was unpalatable to calves and rejection rates were high. In a California study, 63% of waste milk samples tested positive for beta-lactam (penicillin) or tetracycline residues (Selim and Cullor, 1997). Feeding milk containing low levels of antibiotics to calves likely will come under increasing regulatory scrutiny for its potential to foster generation of resistant bacterial species.

Fermentation of antibiotic-treated waste milk, similar to that discussed for colostrum and transition milk, was shown to be effective in preservation of the milk and in destruction of many antibiotics (Keys et al., 1976, 1979). With the exception of the first two milkings after administration of antibiotics, fermentation of waste milk was not retarded by antibiotic residues and proceeded normally (Keys et al., 1976). Fermentation may not proceed rapidly enough if waste milk cannot be maintained at warm temperatures (20-30EC; Keys et al., 1979; Wray et al., 1990).

Producers with large dairy operations might find it economical to install or convert a used milk cooling tank for daily storage of waste milk. In this way, all non-saleable milk, including surplus or poor-quality colostrum, transition milk, and waste milk, can be pooled and used to feed calves. This practice removes concerns about excessively high antibiotic concentrations in any one feeding and negates the need to dilute colostrum before feeding. It is important, however, that the tank be completely emptied and cleaned on a regular basis, preferably every second day or less.

Dairy producers who are concerned with eliminating or preventing diseases such as Johne's, BVD, or leukosis are advised not to feed whole milk of any kind to calves unless the cows are known to be completely infection-free.

▪ Economics of Liquid Feeding Options for Replacement Heifer Calves

What is the most economical liquid feeding program for young calves in Western Canada? The answer to this question, of course, depends a great deal on the individual situation of each dairy farm, but some general guidelines can be established.

Overall, the scientific literature indicates that feeding whole milk or waste milk at 8-10% of body weight with calf starter and water available at all times is sufficient to produce healthy calves with good appetites for solid feed. Gains for calves fed milk replacer (reconstituted to 12.5% solids) at 10% of body weight will be less than similar amounts of liquid as whole milk, yet still should produce satisfactory results. In the author’s opinion, feeding milk replacer at a rate off 10-12% of body weight is a more favorable thumbrule for growth and health of young calves than the alternate thumbrule of 454 g/d (1 lb/d) of powder per calf, as specified on many milk replacer tags. In all cases, availability of fresh, high-quality starter feed from an early age is important to rumen development and preparation for weaning.

During cold weather, the amount of milk or milk replacer fed daily should be increased by 20-25% to compensate for the increased energy demand just to maintain body temperature. Research has demonstrated that maintenance energy requirements increase by 30 to 50% during cold exposure (Gebremedhin et al., 1981; Scibilia et al., 1987). Put another way, if the same amount of liquid diet is fed during winter weather as is fed during moderate weather, growth rates of calves will decrease, perhaps to the point where calves will actually lose weight and become health-compromised. Simply feeding a greater amount of milk or milk replacer at each feeding (Schingoethe et al., 1986), or introducing an additional feeding daily, is probably a more practical and economical approach in cold weather than addition of supplemental fat packs or additional solids to the milk (Jaster et al., 1990).

At the time of this writing, the quota price for whole milk in Alberta was approximately $52 (Canadian) per hundred liters, less approximately $3.00 per liter for hauling and other deductions. Based on that information, a net price of $0.475 per kilogram of whole milk was used in the following calculations. For over-quota milk, at a price of $22/hL, a net price of $0.184 per kilogram was used. An all-milk-protein milk replacer containing 20% protein and 20% fat could be purchased for $53 per 20-kg bag, or $2.65 per kilogram of powder.

Example calculations are shown in Table 1. At a feeding rate of 10% of body weight, feed costs per day for whole milk are $2.14 for quota milk and $0.83 per day for over-quota milk. If milk replacer is fed at an equal energy intake, the feeding rate (5.47 liters with milk replacer reconstituted to 12.5% solids) is 12.2% of body weight and the feed costs are $1.81 per day. Calves fed this amount of milk replacer or whole milk would be expected to gain about 458 g/d. Feeding an equal amount of milk replacer (10% of body weight) would cost only $1.49 per day but the calf would only be expected to grow 291 g/d.

Table 1. Comparison of costs of feeding a 45-kg calf whole milk at quota or over-quota prices with milk replacer fed at equal volume or for equal body weight gain[1].

Liquid feed	Liquid fed, kg/d	Body weight gain, g/d	Feed cost per day	Feed cost per kg gain
Milk (quota)	4.5	458	$ 2.14	$ 4.67
Milk (over-quota)	4.5	458	$ 0.83	$ 1.81
Milk replacer	5.47	458	$ 1.81	$ 3.95
Milk replacer	4.5	291	$ 1.49	$ 5.12

[1]Assumptions used: Milk fed at 10% of body weight; milk replacer containing 4.4 Mcal ME/kg DM fed at 12.5% solids; expected growth performance of calves calculated as described in Davis and Drackley (1998); quota cost of milk is $52/hL (Canadian); over-quota price is $22/hL; hauling and miscellaneous deductions is $3/hL; all-milk milk replacer costs $53/20 kg.

Looking at cost per unit of body weight gain, feeding the low rate of milk replacer was the most costly ($5.12/kg gain), while feeding over-quota milk would provide the lowest-cost gain ($1.81/kg gain) on an “out-of-pocket” cost basis. Feeding an equivalent amount of energy from milk replacer produces lower-cost gain ($3.95/kg) than quota-priced milk ($4.67/kg).

While these are actual out-of-pocket costs, the true costs of feeding over-quota milk are more accurately reflected as “opportunity costs”, or the amount of potential income that is given up. That is, if more quota were available, or production was in line with quota capacity, the quota price would be received for all milk. Thus, the real cost of feeding over-quota milk is the value of quota-priced milk.

Waste milk or excess colostrum/transition milk is often thought of as “free feed”. The situation for waste milk is similar to that described for the quota-price situation described above. If waste milk were not being produced, then the “free milk” would be receiving the milk sale price. Thus, there is significant “opportunity cost” associated with excessive dumping of milk. Nevertheless, nearly all farms will have some waste milk available at times.

On the other hand, excess colostrum and transition milk has no other use – it is truly a “free feed” except for additional labor costs and costs associated with storage. However, producers must keep in mind the disease control considerations of feeding any waste milk or colostrum/transition milk, which could significantly increase the “true” costs of using these feeds.

Many producers will use whatever non-saleable milk is available each day to feed calves, whether excess colostrum, transition milk, or discard milk. This practice results in the calf receiving a diet that varies considerably in composition from day to day. Such variability reportedly does not affect the incidence or severity of scouring or overall rates of gain (Foley and Otterby, 1978). Even frequent changes between sources of colostrum or waste milk and milk replacer did not affect calves adversely in several earlier studies (Appleman and Owen, 1975). However, maintaining as much consistency as possible in the diet for young calves minimizes chances for digestive upsets. This may be particularly important when calves are raised under conditions of increased stress, such as cold or wet weather or during outbreaks of disease.

▪ Conclusions

With proper management, whole milk, excess colostrum, discard milk, and milk replacer all can produce healthy, well-grown calves. Producers with concerns about spread of infectious diseases such as Johne's, BVD, or leukosis probably should feed no whole milk, waste milk, or colostrum to calves unless the cow is known (tested) to be disease-free. Under current economic assumptions, excess colostrum and transition milk produce the lowest-cost gains, while milk that could be sold at quota price is the most expensive. Discard milk also has little out-of-pocket cost, but the opportunity cost of having to dispose of potentially saleable milk means producers must work to minimize milk dumping. Milk replacer is the best choice where disease control is a consideration. When fed at equal nutrient intakes, milk replacer also produces cheaper gains than milk sold at quota prices, but not for over-quota milk.

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