Milk Replacers: Evaluation and Use

Robert W. Phillips, *D.V.M., Ph.D.*
Lon D. Lewis, *D.V.M., Ph.D.*
Department of Physiology and Biophysics
Colorado State University
Fort Collins, Colorado

Today commercial milk replacers are an essential component for the successful rearing of dairy calves. There will also be an increased need for milk replacers in the beef industry as reproductive biologists transform the role of the beef cow to a factory assembly line for calves thus increasing the number of "orphan" calves. As the number of herd health type practices and demand for professional consultation concerning total health needs grow, there is an increasing need for the bovine practitioner to be knowledgeable in this area. In the following discussion we will outline the major components which should be found in milk replacers and how to feed them.

Carbohydrate Content and Utilization:

A milk replacer must contain the necessary carbohydrates, protein, lipids, vitamins and minerals to allow normal growth in the calf. Currently, most of these replacers utilize large amounts of milk by-products but innovations using other sources of animal and plant products are occurring. Most milk replacers are low in fat and protein when compared to milk (Table I). They are also low in fiber which is relatively nondigestible by the young calf. Decreasing protein and fat necessitates that the milk replacer have an increased percentage of carbohydrate which is used both as an energy source and as a filler.

TABLE I

Composition: Whole Milk vs. the Average Commercial Milk Replacer

		Milk Replacer	
	Milk	Powder	Liquid*
Water (%)	87.3	10.0	87.2
Protein (%)	3.5	20.0	2.9
Carbchydrate (%)	5.0	50.0	7.1
Fat (%)	3.5-5.5	10.0	1.4
Ash (%)	0.7	10.0	1.4

*1 part milk replacer + 6 parts water

Young calves have a limited ability to use carbohydrates. They are unable to effectively digest and absorb starch, cellulose or either of the common dissacharides, maltose and sucrose (cane sugar). The enzymes maltase and sucrase, which are essential for digestion of these sugars, are not present in the intestinal epithelial cells. Only two sugars—lactose (milk sugar) and glucose—are capable of interacting with the digestive absorptive surface of the small intestine and being absorbed (1,2). For these reasons, calf replacers which contain appreciable quantities of sucrose or starch which is degraded to maltose should not be used. Their greatest detriment is not because their potential energy is unavailable to the calf, but because the sugars that fail to be absorbed are metabolized by bacteria and may cause a "dietary diarrhea." However, even the very young calf can tolerate some starch. Up to 10% of the total carbohydrate can be fed as starch until the calf is three weeks old, then up to 25% starch can be included (5). Sucrose should not be included at all in milk replacers.

Since starch is a very inexpensive and readily available carbohydrate source, considerable effort is being expended to increase its digestibility. Two of the more promising techniques appear to be the inclusion of the enzyme maltase with the starch to facilitate its breakdown to glucose and the physical disruption of the starch molecules by precooking and expanding (2).

Protein Content and Utilization:

An adequate supply of high quality protein is an absolute necessity for the young calf. The quantity needed, as a percent of the diet decreases as the calf grows. Figure 1 is a plot of the recommended level of protein versus body weight for young calves (3). The most widely used protein source for milk replacers is casein, usually in the form of dried skim milk, and to a lesser extent dried whey which is a by-product of the cheese industry. Although whey has less protein and more of the carbohydrate lactose than skim milk, it is still a valuable component in milk replacers. Its composition compared with skim milk is shown in Table II.

In the process of cheese manufacture either acid or sweet whey may be produced. Sweet whey is a much better nutrient source and causes less diarrhea (5).

Dried skim milk, currently the major protein

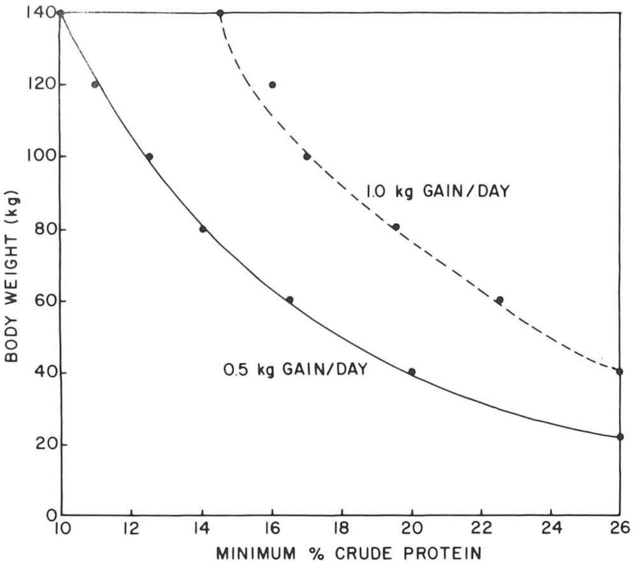


Figure 1: Minimum % crude protein (96% dry matter) required in milk replacers for a daily gain of 0.5 kg (– – – –) and 1.0 kg (———) for calves of different body weight (6).

TABLE II

Nutrients in Dried Whey and Skim Milk

	Protein	Lactose
Skim Milk	36	52
Whey	13	74

component of most calf replacers, is an excellent protein source for the calf. However, a potential problem associated with the use of dried skim milk is the treatment used in its preparation. Too much heat or too long a period of heat exposure will denature the protein which when fed to the calf may result in diarrhea due to decreased abomasal digestion (5). What actually occurs is that the abomasal enzyme, rennin, cannot coagulate the heat denatured casein, therefore no clot is formed and the rate of passage is increased to the point that digestion is reduced. As with nondigested carbohydrate this can lead to increased intestinal bacterial colonization and diarrhea.

A third milk protein source is buttermilk powder, a milk by-product, which is a high protein product still containing sufficient fat to permit normal calf growth.

Unfortunately for the calf, the supply of milk protein will probably be greatly reduced in the next few years as it becomes increasingly important for human consumption. As this occurs, new combinations of non-milk proteins will be developed for use in milk replacers.

Today only two non-milk proteins are used in milk replacers to an appreciable extent, soybean meal and fish protein concentrate. Soybean meal is an excellent source of protein although it may be deficient in the essential amino acid methionine. Its utilization by the calf is enhanced by either acid or alkali treatment which increases digestibility, and growth rate and appears to decrease the incidence of diarrhea (6). The second major non-milk protein source, fish protein concentrate (FPC), has been used for up to 50% of the total protein without adverse effects (5). When included to a greater extent an increased incidence of digestive upset has been noted. FPC increases the requirement for vitamin E supplementation (6), which can be easily accomplished. In general, the younger the calf the less is his ability to digest non-milk protein. This is perhaps most critical in the first two weeks of life.

There is an increasing interest in the development of combinations of whey protein with non-milk protein as the major protein source for milk replacers. Whey is currently a cheap source of non-casein milk protein. The goal is to provide the young calf with an inexpensive, high quality, readily digestible protein source. Such combinations would be of considerable value not only to the orphan calf industry but could have broad application in human nutrition in the underdeveloped countries.

Fat Content and Utilization:

With the exception of powdered buttermilk, milk fat is almost completely removed from processed milk so that other lipid sources must be added to replacers. Lard, which is the most digestible source of animal fat, and tallow are both used. In addition, various plant oils that are polyunsaturated are also commonly included. Since many of these compounds are unstable, vitamin E is required to prevent oxidation (7). Fat utilization may be enhanced by adding emulsifiers such as lecithin and by homogenization during preparation of the replacer on the farm (2).

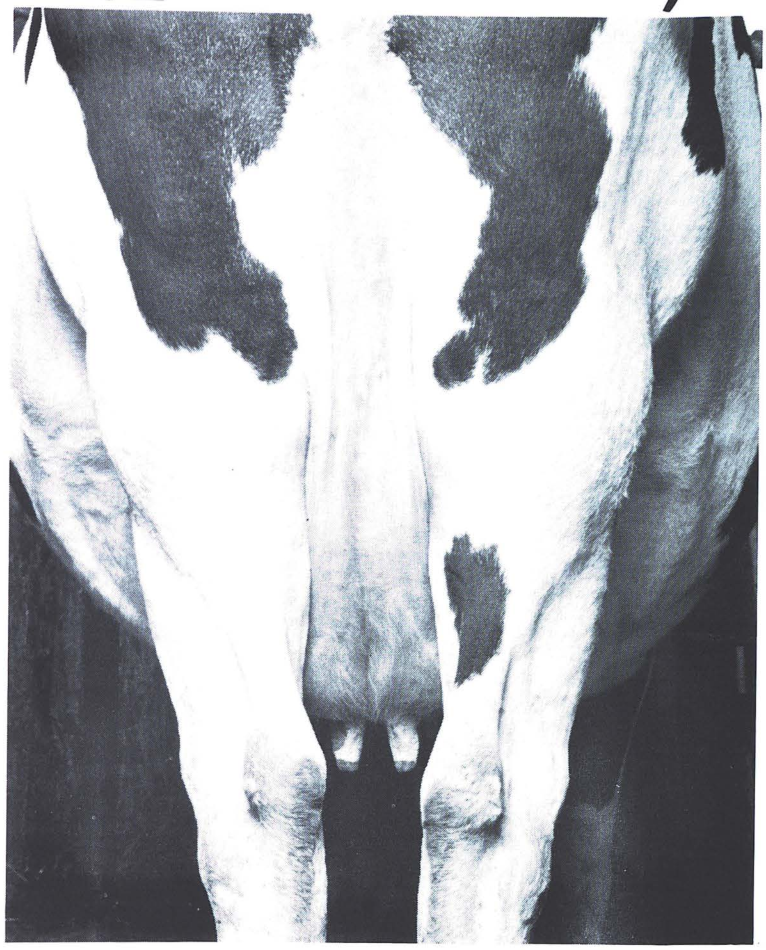
Energy Content and Requirements:

Although the calf's energy requirements are fairly well known, most people have difficulty in translating available energy information into something which they can use. Perhaps several rules of thumb will be of benefit. First, a calf requires approximately 50 kcal of digestible energy/kg body weight/day just for maintenance (8). Therefore, a 50 kg calf (110 lbs.) would require:

50 kg X 50 kcal/kg/day =
2500 kcal/day for maintenance

However, this is a growing animal and livestock owners are concerned with gain not just maintenance. Approximately 3.0 kcal of digestible energy are required per gram of gain (8). So if the

(for prevention)



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desired rate of growth is 500 grams or about one pound per day the calf would require:

500 X 3 or 1500 kcal/day for gain

One kilogram or two pounds of gain would require:

1000 X 3 or 3000 kcal/day

Adding the kilocalories required for gain to the maintenance requirement gives the total daily energy requirement. To gain 500 grams/day the calf needs:

2500 kcal for maintenance + 1500 kcal for gain = 400 kcal/day

To gain 1000 grams/day the calf needs:

2500 kcal for maintenance + 3000 kcal for gain = 5500 kcal/day

The above computation still does not answer the final question of how much milk replacer is required. Most milk replacers contain approximately 4.0 kcal of digestible energy/gram of powder. If they are very high in fat content, as is often used in veal operations, they may contain up to 5.0 kcal/gram. This information can be obtained from the label. Assuming 4.0 kcal/gram as contained in the usual milk replacer, the final calculation is quite simple.

$$\text{Feed required} = \frac{\text{Maintenance requirement + gain requirement}}{\text{Digestible energy content of feed}}$$

or

$$\text{Grams of milk replacer (powder) required for 500 grams daily gain} = \frac{2500 \text{ kcal/day} + 1500 \text{ kcal/day}}{4 \text{ kcal/gram}} = \frac{4000 \text{ kcal/day}}{4 \text{ kcal/gram}} = 1000 \text{ grams/day}$$

Mineral and Vitamin Content and Requirements:

The mineral and vitamin content of milk replacers is important but hard to determine exactly. The calcium-phosphorus ratio for young calves should be 1.5:1 with the total quantity as shown in Table III, depending on the desired rate of gain (2).

TABLE III

Calcium and Phosphorus Requirements of 50-kg Calf

	Ratio	Gain 500 grams/day	1000 grams/day
Ca	1.5	9 grams	18 grams
P	1	6 grams	12 grams

Powdered skim milk is generally marginal sufficient in Ca-P but usually deficient in iron and copper as well as all of the fat soluble vitamins as they are removed during processing (5). Probably the two most important trace nutrients that need to be added to milk replacers are vitamins A and E. The inclusion of FPC as a protein source approximately doubles the vitamin E requirement (6). Either or both the addition of emulsifiers or homogenization of the milk replacer after adding water and prior to use will enhance fat digestion and the absorption of fat soluble vitamins (2).

Antibiotics:

Most, if not all, milk replacers are fortified with a broad spectrum antibiotic such as tetracycline. Calves which have been stressed by shipment or exposed to sale yard conditions and where the colostral intake is not known should receive 250 mg tetracycline/day for the first week. This can be decreased to 125 mg/day thereafter. Even with calves which have not been stressed and which have received adequate colostrum there is a definite growth stimulus due to adding these low levels of antibiotics (9). The exact mechanism by which this occurs is not positively established, but it appears to be involved with one or more of the following changes (10):

1. The microorganism responsible for subclinical infection may be suppressed.
2. The production of growth depressing toxins may be reduced.
3. A decrease in bacterial urease production may occur which would reduce the rate of NH_3 formation in the gut. Ammonia is toxic to intestinal epithelial cells.
4. The intestinal wall is known to be thinner with antibiotic feeding, and this thinning may increase the absorptive capacity of the intestine, and therefore, nutrient utilization.

Management:

The management of the calf and the methods of feeding must also be considered. Nipple feeding is preferred over bucket drinking since the closure of the esophageal groove is stimulated by the suckling reflex. This shunts the replacer directly to the abomasum. In most operations calves are fed twice a day. However, excellent results can be obtained feeding only once a day (2). This can markedly reduce labor costs, and the calves appear to gain as well. In order to feed once a day, milk replacer should be fed in a more concentrated form than it is for the more conventional twice a day feeding system, as shown in Table IV.

The calf, therefore, is given his total daily amount of milk replacer powder, as previously determined, in one feeding. If once a day feeding is practiced, free choice water must be available to the calf. The greatest potential detriment to the once a day feeding regime is that the calves may be

TABLE IV

Concentration of Milk Replacer for Once or Twice a Day Feeding

	Parts Replacer	Parts Water
Once a day	1	4-6
Twice a day	1	7-8

ignored during the rest of the day. Twice a day feeding insures that they are individually inspected twice so that illnesses may be more rapidly observed. If the owner can continue to provide good management observation of the calves and free choice water, it will probably be more economical to feed once a day.

The best results appear to be obtained when the milk replacer is near body temperature, since calves tend to reduce their intake if the replacer is chilled. If they will consume all that is presented there is no apparent harm in feeding refrigerated milk replacer.

The age or size at which weaning is best accomplished has been extensively investigated (2,5). Calves have been successfully weaned as early as two weeks of age if sufficient calf starter is being consumed, although this does not appear to be a practical step under field conditions. In most operations calves can be weaned at four to six weeks of age. Due to the increased cost of nurse feeding and the lack of benefit from this practice they probably should not be keep on milk replacer longer than seven weeks. Weaning is best accomplished by providing dry calf starter free choice for several weeks preceding weaning and then abruptly weaning the calves. A sudden cessation is less traumatic than gradual withdrawal (5). The process is probably analogous to stopping smoking by gradually decreasing versus throwing away your cigarettes. Although we recommend weaning at four to six weeks of age this practice may result in a transient decrease in rate of gain. Even when this occurs the calves appear to catch up by six months of age.

Milk Replacer Evaluation:

The preceding discussion has outlined what a neonatal calf should receive in a milk replacer and how to feed it. The last points to consider are how to evaluate a milk replacer from the label. The label has basically two portions, the guaranteed analysis lists the minimum and maximum quantities of certain ingredients but does not tell the source nor provide any information regarding quality. Different manufacturers list different items under guaranteed analysis, although there are some specific state requirements as to what must be listed, particularly with regard to minerals. A typical guaranteed analysis is shown in Table V. Crude protein is listed as a minimum of 20% of the ration which would be sufficient for most calves. However, if you refer to Figure 1 you can readily appreciate that 20% crude protein, while marginally sufficient for a 40 kg (88 lb.) calf gaining 0.5 kg/day, it is not at all adequate for an operation which is trying to get the higher one kg/day rate of gain. Most calf replacers contain 20-22% crude protein. The level of crude protein should be a major consideration in evaluating which replacer will most adequately meet the operational needs of a particular calf rearing unit.

TABLE V

Milk Replacer Labeling Guaranteed Analysis

Crude Protein (Min.)	20%
Crude Fat (Min.)	8-10%
Crude Fiber (Max.)	1%
Ash (Max.)	9-11%
Moisture	8-10%
Vitamins (A, D_3, E)	

The second item listed on the guaranteed analysis is crude fat which is listed as a minimum of 8-10%. Such a replacer would provide approximately 4.0 kcal digestible energy/gram of powder. A higher energy 5.0 kcal/gram replacer, as used in some veal operations, would contain approximately 20% crude fat.

Crude protein and crude fat are the only two components which are listed as a minimum. Crude fiber which is not particularly well utilized and ash or minerals are generally listed as a maximum. Minerals are much higher than in whole milk (Table I) because of the use of dried skim milk and whey and because extra minerals are usually added. This is based on the general understanding that marginal excesses of most minerals are not detrimental and on a desire not to formulate a mineral deficiency. Most milk replacers contain about 8-10% water and are fortified with the fat soluble vitamins A, D_3, and E.

Totaling the values given in the guaranteed analysis you find that only 50% of the ingredients are identified and, therefore, 50% are unknown. Most of the unknown portion is carbohydrate with most of this being lactose, if milk by-products are used. As can be seen in Table I, the milk replacer has a higher sugar content and a lower fat and protein content than milk.

The second item on the calf replacer label is a listing of ingredients. Unfortunately for the owner

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preliminary basis on which future international work can hope to build.

The European Commission for the Control of Foot-and-Mouth Disease at its annual session in Rome earlier this year laid down recommendations for the application of common standards for the importation of meat from disease-free areas in countries where exotic strains of foot-and-mouth disease are endemic, and also for the importation of meat from countries where non-exotic strains of foot-and-mouth disease continue to occur. If this work leads to the acceptance of common standards for the safe acceptance of meat from areas from which, at present, imports are largely barred, this should prove to be a major advance of great benefit to the whole world. I commend the report of this year's session of the commission for study by all who have an interest in this field.

I cannot conclude this talk without some reference to the impending accession of the UK to the European communities. The enlargement of the community will offer an unprecedented opportunity for the development of an area in which ten nations of the world can cooperate to achieve uniform and high standards of animal health. This must be to the advantage of all.

Conclusion

In conclusion, may I sum up in this way. Until comparatively recently, lack of knowledge stood in the way of soundly based action to bring many animal diseases under control. Growing knowledge tended to place increasing restriction on the movement of livestock and livestock products. We are now entering a new period in which greater knowledge of epidemiology and the emergence of more satisfactory tests will bring a greater liberalization of trade. The key to this potential advance lies in international cooperation in all branches and at all levels of veterinary science. I believe the foundations for this cooperation have already been laid.

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or the veterinarian who is trying to evaluate a feed, this portion is often quite uninformative. In general, the ingredients are listed in the order of their predominance in the feed. However, this is a legal requirement in only one state, California. Most feed manufacturers appear to follow this custom even when it is not a mandatory requirement. Most ingredient lists that we have examined specify dried skim milk, dried butter-milk, whey and animal fat as the first or major ingredients, but no idea is given of the percentage of each. Thus, it is difficult to predict product quality from the ingredient list.

There are several reasons for these practices. First, the manufacturer does not want to give competitors his exact formula. Second, ingredient composition may vary with the availability of components. Third, the methods used in processing may alter digestibility. The reputable manufacturers are trying to produce a good product that will support calf growth with a minimum amount of digestive upset and at a reasonably low cost. They are, of course, not intentionally adding poorly utilized components. The content and production methods of good milk replacers are, therefore, a balance between what a manufacturer knows or believes the calf requires and cost. You must determine which milk replacers are the best for a particular calf raising operation. Through careful consideration of this material some inferior milk replacers may be identified, with other observation of the calves' performance may be required for evaluation.

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