Many dairy producers and calf growers evaluate milk replacers on the basis of cost without considering what value is received for the dollars spent. When someone sells a milk replacer at substantially lower prices than the competition, producers are confused and can't see why prices differ so much. Frequently the old adage, “if something sounds too good to be true, it probably is” fits well in this situation. The purpose of this presentation is to review some of the basic principles regarding the quality of ingredients used in milk replacers. These principles become especially important as one considers adopting the philosophy of feeding calves to their nutrient requirements for biological growth rather than as a means to limit intake to encourage them to consume dry food more quickly.

The dairy cow synthesizes an ideal diet for the calf containing casein, various whey proteins (B-lactoglobulin, a – lactalbumin, IG, serum albumin and other minor proteins) lactose, fat, vitamins and minerals. When fed in adequate amounts it’s remarkable how well calves grow. The only problem for the dairy producer is that it’s too expensive. Conventional feeding rates would cost about $1.40/day and at more biologically normal rates about double this amount.

The science and practice of milk replacer formulation has advanced rapidly with several companies producing a wide variety of products to suit the market needs for varying levels of quality and cost. Most of the cost of milk replacers is concerned with supplying energy and protein and our discussion will focus in these two areas.

Energy. Lactose represents the only source of carbohydrate for growing calves. It’s not until they are more than a month old that they begin to develop the ability to digest other carbohydrates such as starch. Never feed sucrose or fructose to baby calves, it won’t be digested and can encourage microbial growth and diarrhea. Whole milk contains about 39% lactose and most milk replacers contain this much or more. Calves can probably tolerate consuming close to 1 lb. of lactose per day without adverse side effects. Lactose is the carbohydrate of choice because it’s highly digestible and economically provided by many of the whey products used in milk replacer formulas. The other source of energy is provided by fat. The cost of milk fat makes it too expensive to use in milk replacers. Consequently tallow, lard and choice white grease are the major fats used in milk replacers. Coconut and palm oil are also used, particularly in veal milk replacers. Blending animal fats with an emulsifier such as lecithin improves
digestibility of tallow or lard to about 88%, although it’s usually a little less digestible than milk fat (95%). Coconut oil can replace some, but not all of the animal fat in a milk replacer. In general vegetable fats are not well tolerated, although some recent small studies suggest that hydrogenated vegetable oils can replace some of the animal fats in milk replacers. A major factor influencing digestibility of fat is adequate dispersion throughout the replacer. Homogenization of fat to produce droplets in the 3 – 4 micron size is essential for high digestibility.

**Protein sources.** Milk replacers contain between 18 to 28% crude protein. Protein sources are generally classified as milk or non milk proteins. Usually milk proteins are more digestible and possess more desirable amino acid profiles than non milk sources. It’s important to note amino acid requirements for limit fed calves (1 lb. of DMI/day) are different than for calves fed for higher rates of gain because amino acid requirements for tissue growth differ from those for maintenance. As with milk fat, casein is too expensive to use in most milk replacer formulations. A variety of ingredients are used as substitutes for skim milk as a protein source. They are shown in Table 1 below.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>DM%</th>
<th>CP%</th>
<th>Fat%</th>
<th>Crude Fiber%</th>
<th>Lactose%</th>
<th>Ash%</th>
<th>Calcium%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk solids</td>
<td>100</td>
<td>25.6</td>
<td>29.6</td>
<td>-</td>
<td>39.2</td>
<td>5.6</td>
<td>0.95</td>
</tr>
<tr>
<td>Skim milk</td>
<td>98</td>
<td>34</td>
<td>0.1</td>
<td>-</td>
<td>54</td>
<td>7.9</td>
<td>1.06</td>
</tr>
<tr>
<td>Whey protein concentrate</td>
<td>98</td>
<td>34*</td>
<td>3.5</td>
<td>-</td>
<td>52</td>
<td>6.0</td>
<td>0.67</td>
</tr>
<tr>
<td>Dried whey</td>
<td>98</td>
<td>12</td>
<td>0.2</td>
<td>-</td>
<td>74</td>
<td>8.5</td>
<td>0.81</td>
</tr>
<tr>
<td>Delactosed whey</td>
<td>98</td>
<td>23</td>
<td>1.5</td>
<td>-</td>
<td>55</td>
<td>16</td>
<td>1.95</td>
</tr>
<tr>
<td>Casein</td>
<td>96</td>
<td>85</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Soy protein isolate</td>
<td>94</td>
<td>86</td>
<td>0.5</td>
<td>0.2</td>
<td>-</td>
<td>4.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Soy protein concentrate</td>
<td>95</td>
<td>67</td>
<td>.3</td>
<td>3.6</td>
<td>-</td>
<td>7.0</td>
<td>0.35</td>
</tr>
<tr>
<td>Soy flour</td>
<td>95</td>
<td>53</td>
<td>0.2</td>
<td>2.9</td>
<td>-</td>
<td>6.3</td>
<td>0.35</td>
</tr>
<tr>
<td>Mod. Wheat protein</td>
<td>94</td>
<td>82</td>
<td>2.0</td>
<td>0.5</td>
<td>-</td>
<td>3.0</td>
<td>0.04</td>
</tr>
<tr>
<td>Porcine plasma protein</td>
<td>97</td>
<td>67</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.14</td>
</tr>
<tr>
<td>Bovine plasma protein</td>
<td>97</td>
<td>68</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Whey proteins are the principle protein sources used in high quality milk replacers with very small amount of skim milk or other milk protein solids. Dried whey is the byproduct of cheese making and is formed by drying the residue after extraction of the fluid from the curds and cheese. It's high in lactose and minerals. When the lactose is crystallized and removed the substance is called delactosed whey or dried whey product. From the table above it's evident that lactose content drops, and protein and mineral content increases. When whey is subjected to ultrafiltration the retentate is called whey protein concentrate (WPC) and this is a very popular ingredient of high quality milk replacers. Although the table shows it to contain 34% it may reach 80% protein depending on the aggressiveness of the filtration process. Many of the high protein (over 25% CP) milk replacers contain more of the higher protein WPC than replacers with only 18 to 20% CP. Research by Heinrichs et al (1995) and Lammers et al (1998) has demonstrated equal performance in calves fed milk replacers containing either WPC or dried skim milk powder. There can be considerable variability in quality of WPC. In addition to level of protein, fat, and mineral content are affected by the type of cheese made, culture used and processing conditions. Ash content can vary from 1 to 12%. High levels of sulfates in some WPC have been associated with diarrhea in calves. In addition, temperature control during drying can influence solubility of the product and its usefulness as milk replacer ingredient. The major milk replacer manufacturers know their whey sources and constantly test to assure quality.

For many years, whey was considered as a waste product and it was a real problem for the cheese industry. However, through advances in processing by ultrafiltration and reverse osmosis it is possible for the cheese manufacturers to isolate the proteins in whey into the high protein WPC and whey protein isolate. In their highest purity (whey protein isolate) these products have found use as intravenous supplements for hospital patients and at lower levels of purity as sports drinks, protein bars and Atkins diet foods. As a result, price for whey proteins has increased and competition for the supply of the higher quality whey proteins has increased.

**Alternate milk proteins.** Milk replacer manufacturers have continually sought ingredients which might provide proteins of sufficient digestibility and amino acid content to substitute for milk proteins. Proteins of soy origin provide the most promise. Soybean protein is less digestible and contains slightly inferior amino acid profiles as compared to skim milk or whey proteins. Also, they contain various factors detrimental to calf performance. Soybeans have a trypsin inhibitor which must be deactivated by heat treatment. The calf also reacts to antigens present in the soy protein resulting in gut inflammation, depressed immune response and decreased absorptive capacity of the gut. Indigestible carbohydrates, tannins and phenolic compounds encourage diarrhea and impairment of gut function. The various forms of soy proteins used in milk replacers are:
- **Soy flour** is produced by dehulling, cleaning and removing the fat from the bean by mechanical or solvent extraction. This product is then finely ground. Unfortunately, it’s one of the more poorly digested sources of protein for young calves.
- Further aqueous alcohol treatment results in modified soy flour which is found in some low cost replacers. Due to its lower digestibility and residual antigenic effects on the gut it’s probably not recommended for “intensive” replacers.
- Extraction of most of the soluble carbohydrates by further aqueous alcohol extraction results in **soy protein concentrate** with at least 66% CP.
- **Soy protein isolate** is the highest quality soy protein containing more than 90% CP. It’s appears to be an acceptable protein source for calves. However, Dutch workers (Yuangklang et al., 2005) have observed depressed fat digestion in calves fed milk replacers containing soy protein isolate. Unfortunately the cost of processing to produce the soy isolate makes it nearly equal in price to whey protein concentrate and not quite as desirable in amino acid content.
- Research has shown that the more highly purified forms of soy protein are better tolerated by calves more than one month old.

**Bovine and porcine plasma** (~70% CP) have been used very successfully as sources of protein for calves when they substituted for 20% of the protein provided by WPC. Quigley and Wolfe (2003) compared performance of 120 calves fed milk replacers containing either WPC or WPC plus 5% bovine plasma or WPC plus 5% porcine plasma. Mortality was lower (10%, 3%, 2%) and morbidity, as measured by days with diarrhea, was lower (6.9, 3.9, 4.7) for calves fed replacers with bovine or porcine plasma as compared to calves fed replacers with only WPC as the protein source. Calves fed the porcine plasma gained .1 lb. less / day than calves receiving the other replacers. Although this work looks promising, research at higher feeding rates associated with more intensive rearing programs has not been conducted. Quigley et al. (2000) have also demonstrated that hydrolyzed spray dried red blood cells can replace up to 40% of the protein from WPC successfully in conventional calf feeding programs. However, the recent concerns with BSE have resulted in this product being withdrawn from the market. Plasma products are still used by milk replacer manufacturers until there is an FDA ruling against using them.

**Spray dried whole egg** has been proposed as a partial substitute for WPC. Touchette et al (2003) fed diets containing up to 15% egg in liquid diets fed at 1 lb. of DM/day reconstituted to 12% DM. They found that gains were indistinguishable from WPC diets up to 10% egg in the diet. However, Quigley (2002) found that inclusion of spray dried whole egg in the diets caused a linear decrease in average daily gains over a 56 day feeding period. Further work by Catherman (2002) suggests that substances contain in the egg white are responsible for depression in performance of calves. At the present time it
appears the use of whole egg products in not advised in milk replacers formulated for intensive rearing programs.

Miscellaneous

The feed tags commonly found on the bag of milk replacers provide the basic information regarding milk replacer composition, such as active drug ingredients, crude protein, fat and fiber levels and vitamin content. Ingredients are listed below, but need not be listed in the order of predominance in all states of the U.S. Therefore the ingredient listed first may not be the primary ingredient. Some manufacturers include components such as skim milk or butter milk ingredients as "tag dressing" for the purpose of implying a higher quality product when they may comprise less than 1% of the formula. Crude fiber used to

![Calf Milk Replacer](image)

**Calf Milk Replacer**

**MEDICATED**

For aid in the prevention of bacterial diarrhea (scours) when fed as directed

**ACTIVE DRUG INGREDIENTS**

- Oxytetracycline 100 grams per ton
- Neomycin Base 200 grams per ton
  (from Neomycin Sulfate)

*WARNING: Withdraw this feed 30 days before slaughter. >

**GUARANTEED ANALYSIS**

- Crude Protein 22.0%
- Crude Fat, not less than 20.0%
- Crude Fiber, not more than 0.5%
- Vitamin A, not less than 25000 IU/lb
- Vitamin D₃, not less than 4500 IU/lb
- Vitamin E, not less than 20 IU/lb

**INGREDIENTS**

Dried whey, dried whey protein concentrate, dried whey product, dried skimmed milk, animal fat (preserved with citric acid, BHA and BHT), dried milk protein, lecinth, polyethylene glycol (400) mono- and diolates, disodium phosphate, calcium carbonate, l-lysine dihydrochloride, dl-methionine, sodium aluminosilicate, ferrous sulfate, copper sulfate, cobalt sulfate, zinc sulfate, manganese sulfate, magnesium sulfate, calcium iodate, sodium selenite, folic acid, ascorbic acid, vitamin B12 supplement, choline chloride, d-calcium pantothenate, niacin supplement, pyridoxine hydrochloride, riboflavin supplement, thiamine mononitrate, vitamin A supplement, vitamin D₃ supplement, vitamin E supplement, artificial flavors.

Manufactured For
Dairytown Company
Your Town, State

50 LBS. NET WEIGHT
FEEDING DIRECTIONS ON REVERSE SIDE
The presence of crude fiber used to indicate the presence of soy proteins. Usually, milk replacers can be categorized into three categories according to Quigley (2001).

- 0.15% crude fiber or less – no vegetable protein
- 0.15 to .50% - low to moderate levels of vegetable protein
- Above .5% - high levels of vegetable protein

However, some manufacturers include soluble fiber and have found it to be an adjunct to better gut health. In addition, soy protein isolate contains very little, if any fiber. Therefore these guidelines must be used with caution. Another test formerly used to evaluate milk replacer quality was the rennet coagulation test. This was used to determine if replacers contained skim milk or casein. Then a small amount of rennet was added to the replacer it would clot much like whole milk clots in the abomasum of the calf. However, this test is no longer valid as years of research have shown equal performance on calves fed skim milk proteins.

**Take home message**

Surprisingly, little research has been conducted with the use of alternate protein and fat sources in calves fed more intensively. Current research suggest that we should expect better growth in calves when they are fed milk replacers based upon milk proteins and animal fats.

“Intensive” milk replacers are more expensive on a per lb. of dry matter basis and also on a daily basis. Milk replacers essentially contain protein, fat, lactose and ash (minerals) and trace amounts of vitamins on a quantitative basis. Levels of fat content have not changed appreciably. However, more protein is found in “intensive” milk replacers. Increasing protein and holding fat constant means that less lactose is present. This represents a substantial cost shift. However, calf raisers should view it as increased value. When examining the feed tags of all milk replacers it’s safe to expect lower performance from replacers containing egg or vegetable proteins.

The best measure of quality is how well calves perform. Expect greater differences in responses to quality of ingredients in calves under “intensive” calf feeding programs.
References.


