Protein and Energy Nutrition of the Neonatal Calf

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Introduction

Choices made by nutritionists and milk replacer manufacturers of nutrient levels and milk replacer ingredients, coupled with choices by calf feeders about feeding rate and calf body weight, largely determine calf growth rate, efficiency of feed conversion, and cost of gain. These choices also largely determine later feedlot performance and carcass composition. For example, early calf nutrition may greatly influence the rib eye area and amount of marbling when the calf ultimately goes to market, and in the case of heifers, timing of first conception and amount of milk produced. Today's discussion will focus on a broad spectrum of research regarding protein and energy nutrition and their interrelationship for the young calf, some surprising findings about the benefits and economics of increasing protein relative to energy, then some information about different milk replacer ingredients, feeding recommendations, and nutrient requirements of calves.

Veal, Dairy Beef, Replacement Heifers

Much of the technology employed by the Holstein beef and replacement heifer industries has come from research and experience with veal calves. For those not familiar with the veal industry, let me provide a brief comparison. Holstein calves, whether for veal, beef, or replacement heifers have the same birth weights, around 90-100 lb. During the first 20-22 weeks of life, Holstein beef calves consume about 35-50 lb of milk replacer per calf plus 1100 lb. of grain-based solid feed. Milk-fed veal calves consume about 600-650 lb milk replacer and no grain during the same time period.

Figure 1 is a compilation of data from three different research studies comparing all milk vs milk plus starter feed programs. The data has been statistically adjusted to equalize calf starting weights. The purpose of combining data from different published sources is only to illustrate the live weights of milk-fed veal calves, grain-fed Holstein beef calves, and calves on an accelerated feeding program taken from Carolina Diaz's masters work at Cornell University. At 20 weeks of age, veal calves weigh about 100 lb more than Holstein beef calves. Importantly, both groups are considerably lighter than calves on the accelerated program in which calves weigh approximately 50 lb of body weight more than veal calves at 45 days of age. This illustrates a few important points: 1) calves can consume more milk replacer than most Holstein beef and/or heifer growers normally feed; 2) calves gain weight more rapidly when fed higher amounts of highly nutritious milk or milk replacer; 3) veal calves utilize a milk replacer diet more efficiently than Holstein beef calves fed milk replacer plus grain because milk replacers are more nutritious and digestible than grain, and veal calves do not have the inefficiencies associated with rumen fermentation and stress associated with weaning from milk to solid feed; 4) Based on Diaz's data, more research is needed to determine optimum balance among feeding rates, nutrient levels, growth potential and economics.

The Protein:Calorie Ratio Concept

One of the great breakthroughs of modern nutrition occurred in the early 1950's. It was shown by poultry researchers, at the University of Maryland, that the relationship of energy and protein in poultry feed influenced carcass fat content, growth rate, efficiency of feed utilization, and feathering characteristics (Anonymous). It is interesting that fifty years after this discovery in chickens, we have largely ignored this concept in designing our feeding programs for young calves. (I guess we calf nutritionists decided that this protein:calorie ratio is for the birds.)

Velasco *et al*. (2000) reported an experiment with shrimp fed three protein levels (10, 18, or 25%) at two levels of lipid (3 or 11%). Growth rates and survival rates of shrimp were higher and feed conversion improved for shrimp fed higher protein levels. Survival rates for shrimp were higher when 3% lipid was fed versus 11% lipid (Figure 2). At both levels of lipid, performance was superior when higher protein levels were fed (Table 1). This research demonstrates both the interaction of protein and energy in shrimp and a relationship of improved performance at higher protein:calorie ratios.

Research with pigs has gone beyond the protein:calorie ratio to Lysine:Digestible Energy ratio (Lys:DE). Szabó *et al*. (2001) demonstrated the effect of Lys:DE ratio on the rate of gain, efficiency of gain, and carcass lean meat percentage in the carcass (Table 2). As the Lys:DE ratio increased, pigs had significantly higher daily gain, more efficient gain, and an increase in carcass protein and decrease in carcass fat content.

Turning to calves, let's consider what primarily influences energy intake? Contrary to the popular premise, the amount of energy the calf consumes is almost entirely determined by the amount of milk or milk replacer the calf consumes - not by the fat level of the milk replacer. In the formulation of milk replacer, addition of fat results in a reduction in lactose in the final product. As an example, if the fat content is doubled, from 10 to 20%, the energy density of milk replacer increases from 1740 to 1900 kCal/lb - a 9.2% increase. However, an increase in amount of milk replacer from 8 to 10 ounces per feeding increases the energy intake from 1740 to 2175 kCal/lb - a 25% increase These differences are illustrated in Figure 3. This has a tremendous implication for calves especially during cold weather. Increasing the amount of fat in a milk replacer will not meet the increased maintenance energy requirement for calves under cold stress. Only by increasing the amount of milk replacer fed to the calf can we meet the increased needs for energy under cold stress conditions. Generally, this means increasing total daily milk replacer and feeding calves three times per day instead of twice per day. Our challenge is always to determine the required energy for maintenance plus our desired rate of gain and provide adequate feed intake to meet this rate of gain. Then we must provide the amount of protein required to meet this rate of gain at the established feed intake level.

The combination of protein and energy consumed by the calf (protein:energy ratio) determines rate of gain, composition of gain and, ultimately, body composition. The concept that clearly has great nutritional and economic importance and documentation in chickens, shrimp, and pigs also applies to calves. In 1973, two studies were published by researchers from Ottawa, Ontario, Canada (Lodge and Lister, 1973 and Lister and Lodge, 1973) showed that changing the protein:energy ratio by the addition of dextrose or butterfat to cow's milk had several affects on digestion and performance in milk-fed calves. Biological value of milk protein increased as energy level increased relative to whole milk. Rate of gain was significantly increased (about +20%) when milk was supplemented with either dextrose or butterfat. The authors concluded that the addition of 6% dextrose to whole milk was well tolerated by calves, produced more efficient growth per unit of protein, provided a more suitable energy:protein ratio than common liquid diets, resulted in improved protein utilization and, therefore, improved economic value. They indicated that the higher fat in their diets likely had a beneficial effect in preventing diarrhea which had been observed with high carbohydrate diets in other studies. In other words, energy can be a limiting factor when protein needs are already met.

In the 1970's and early 1980's a series of experiments in New Zealand led by P.E. Donnelly showed that the performance and body composition of milk fed calves could be profoundly affected by changing the amount and ratio of protein and energy fed to the calf. In a classic study, 12-day old calves were fed for 49 days on either a high or low level of milk replacer designed to achieve average daily gains of 2.0 or 1.3 lb/day, respectively. Calves were fed milk replacers containing 15.7, 18.1, 21.8, 25.4, 29.6, or 31.5 % protein. Calves fed 29.6% protein milk replacer were only fed at the high level. They found that final weight increased with increasing protein content and with higher feeding level, shown in Figure 4. Feed conversion improved with increasing protein content and with higher feeding level, shown in Figure 5. But more importantly, composition of gain was profoundly affected by protein level, as shown in Figure 6 and 7. Calves fed a higher protein level gained a significantly higher proportion of weight as protein and a lower proportion of weight as fat than calves fed lower protein levels. Proportion of water and fat was higher in calves fed at the high intake level than calves fed the low level of intake. Interestingly, calves on all treatments gained about 1 lb of fat per week, but calves fed higher amounts of protein gained about 50% more protein, water and ash in their carcass than calves fed low protein diets at the same level of feed intake.

Further research in Canada was published by Johnson *et al.* (1988) in which skim milk was supplemented with varying levels of fat to evaluate the effect on carcass and sensory characteristics of veal calves. They found that calves fed skim milk powder with supplemental fat had higher dressing percent and improved carcass characteristics compared to calves fed skim milk powder without supplemental fat. Increasing the energy density of the diets by adding fat improved palatability characteristics of the meat such as lower shear force and higher scores for tenderness and juiciness.

More recently, research at several U.S. universities have demonstrated the effect of protein:energy interactions in young milk-fed calves. Diaz *et al.*, (1998) hypothesized that in calves weighing less than 100 kg (220.4 lb), energy is limiting and that protein requirements are higher than current recommendations. They fed calves milk replacers at a level to achieve 1.1, 2.1, or 3.1 lb gain per day. Calves were fed to 65, 85, or 105 kg live weight (143.3, 187.4, 231.5 lb, respectively). Calves gained 580, 1010, and 1290 g/day (1.3, 2.2, and 2.8 lb/d, respectively) for the three levels of intake. Compared to calves fed the lowest intake level, calves on the highest intake level reached their target weight of 105 kg, 50 days sooner. At each body weight, calves fed the lowest rate of milk replacer intake had less fat and more protein and less gross energy than calves on the other two treatment groups, even though they had much lower rates of gain. Efficiency of feed conversion was highest for calves fed at the highest level of intake. This demonstrated that calves could be fed at much higher rates of intake and, as a result, could and did gain weight at a faster and more efficient rate.

The interaction of feed intake level and crude protein level was demonstrated by Bartlett (2001) at the University of Illinois. Calves were fed isocaloric milk replacer diets formulated to contain 14, 18, 22, or 26% crude protein and fed at 10 or 14% of body weight (MR reconstituted to 12.5% solids) to determine effect of protein:energy ratio on performance and body composition. Calves fed 14% of body weight intake level gained weight at a more rapid rate than calves fed 10% of body weight (Figure 8). Whole body gains of water, protein, fat, and ash were also greater for calves fed at 14% of body weight than for calves fed at 10% ($P<.0001$). As the percentage of crude protein increased, final whole body protein % and water % increased and fat % decreased ($P<.002$ or less). In similar results to those reported by Donnelly and Hutten (1976b), Bartlett reported that increasing the protein content of the diet resulted in an increase in the percentage of water and protein and a decrease in the percentage of fat in the gain of calves in the experiment. Calves grew faster and more efficiently when fed higher intake and higher protein levels. Using data from Bartlett, calculated cost of gain was less at all protein levels when calves were fed at 14% of body weight compared with calves fed 10% of body weight (Figure 9).

Blome *et al.*, (2003) compared four levels of protein (16.1, 18.5, 22.9, or 25.8%CP) in milk replacer fed at 12% of calf body weight (reconstituted at 12.5% solids) over a 56-day trial. For two weeks prior to the trial, calves were fed at 10% of body weight and gained an average of 3.05 lb/calf over the two week period. Calves were moved to metabolism stalls from day 31 to 42 for collection of urine and feces. Calves were weighed weekly and adjustments made to feed intake based on body weight. As protein content increased, average daily gain increased ($P<.001$), efficiency of gain increased ($P<.001$), the rate of change in heart girth increased ($P<.001$), final body length increased ($P=.07$), and rate of change of body length increased ($P=.03$). Final body weights were heavier in calves fed higher amounts of protein (Figure 10). Calves fed 16.1, 18.5, 22.9, or 25.8% CP had total live weight gains of 34.4, 42.5, 51.3, and 55.6 lb, respectively ($P<.001$), over the 56 day course of the experiment with feed:gain of 1.97, 1.70, 1.41, 1.29, respectively ($P<.001$). Interestingly, during the period when calves were in metabolism stalls, calves gained 4.4, 5.5, 10.0, and 11.4 lb for the 16.1, 18.5, 22.9, and 25.8 % CP diets, respectively, which represented a gain of 3.9, 4.8, 8.6, and 9.6% of the calves' body weight upon entry into the metabolism stalls. (Perhaps calves are able to more readily deal with stress when fed higher protein.) As protein content of milk replacer increased, there was a linear increase in water %, ash %, and energy Mcal/kg in the gain, and a linear decrease in fat % in the gain. Weight of water and protein gained were linearly increased ($P<.001$) with increasing protein % in the milk replacer.

Fat appears to be preferentially used by the young calf for body fat deposition, rather than growth. Tikofsky (2001) fed calves one of three isocaloric and isonitrogenous diets with varying amounts of carbohydrate and fat. Gross energy and crude protein intakes were similar among calves fed the three diets. (Dry matter and fat intakes were different among treatments, as expected under the experimental design.) Empty body weight gains, protein, water, and ash gains were not different among treatments. However, empty body gross energy was 27.2% and fat gain was 57.7% greater for calves consuming high fat compared to low fat diet. This study suggests that at fat levels above 15% in the young calf diet, fat is preferentially used for body fat deposition.

Protein:energy ratio has a profound effect on veal calf performance. In a study conducted jointly with a client, Vermeire (2003) fed 174 calves one of two milk replacers that differed in protein:calorie ratio (45.4 and 36.5 g CP/Mcal DE). Both groups of calves were fed using the same feed intake schedule, but actual amount feed offered each day was dependant upon feed refusal rates of the calves. Calves fed the lower protein:calorie milk replacer had lower feed intake because of more feed refusals than calves fed the higher protein milk replacer. Interestingly, live animal conformation was profoundly affected by protein content. Calves fed the higher protein level had very blocky live conformation, while calves on the lower protein milk replacer had a very angular conformation. At 141 days of age, live weight (224.6 vs 212.1 lb), hot carcass weight (135.4 vs 127.4), and total gain (274.5 vs 260.5) were higher for calves fed 45.4 g CP/Mcal DE diet compared to calves fed 36.5 g CP/Mcal DE diet, respectively ($P<.0001$). Efficiency of feed conversion was not different for the two groups (1.54 vs 1.58 feed:gain, respectively).

The influence of fat and protein ratios on body composition of Jersey bulls was studied by Bascom (2002). Calves were fed milk, or milk replacers containing 21% CP/21% fat (21/21), 27% CP/33% fat (27/33) or 29% CP/16% fat (29/16). Calves were provided diets designed to deliver equal amounts of protein to calves fed milk, or milk replacers containing 27/33 or 29/16. The diets were designed to include equal amounts of fat for calves fed milk or milk replacer containing 27/33 fat. Calves fed milk had superior feed efficiency, average daily gain, and total weight gain to other diets. Calves fed 29/16 or 27/33 milk replacers had similar performance, but calves fed the 29/16 milk replacer did not increase body fat percentage. Calves fed the 21/21 MR gained 0.24^{a} lb/day compared to 0.79^{b}, 0.81^{b}, and 1.09^{c} lb/day for calves fed 27/33 MR, 29/16 MR, or milk, respectively ($P<.05$). Only the ether extract as a % of empty body weight was significantly different among treatments. Calves fed 21/21 MR or 29/16 had less fat in the empty body than calves fed 27/33 MR or milk (3.6^{a} and 4.7^{a}% vs 6.8^{b} and 8.2^{b}%, respectively). Calves fed 21/21 MR gained only 0.35 lb body fat over the entire trial, demonstrating that Jersey calves require higher nutrient density than 21/21 MR can provide.

Amino Acids

Proteins are composed of 20 amino acids, many of which the calf can synthesize in adequate amounts to meet its needs. But several amino acids must be consumed in the diet because the calf cannot synthesize these amino acids. These amino acids are often termed "essential" or "dispensible" and include lysine, histidine, leucine, isoleucine, valine, methionine, threonine, tryptophan, tyrosine, and phenylalanine. Milk replacers must contain these amino acids in amounts sufficient to meet the needs for maintenance and growth of young calves.

Amino acid imbalances result in reduced animal performance. Imbalances can be due to deficiency or excess of one or more amino acids. In calves, even a small excess of methionine, for example, results in reduced feed intake and disproportionately larger reduction in rate of growth (Abe *et al.*, 2000). In calves fed DL-methionine at 0, 6, 12, 18, or 24 g/day, dry matter intake and average daily gain increased in calves fed 6 g/d compared to calves in the control group fed 0 g/d of methionine. But, gain decreased dramatically (P=.02) in calves fed 12, 18, or 24 g/d of methionine. Furthermore, feed intake decreased (P=.05) by up to 22% compared to control calves (Table 3).

While methionine is considered the most toxic amino acid, lysine is considered one of the least toxic amino acids. Imbalances of lysine also reduce calf performance. In a second trial of Abe *et al.* (2001), inclusion of 16 g/d of L-Lysine HCL resulted in an increased ADG from 268 to 750 g/d. Clearly a deficiency of lysine results in reduced performance. Excessive amounts of lysine do not result in the dramatic decrease in gain observed with methionine, however, Abe *et al.* (2001) showed that excessive dietary lysine resulted in reduced DMI and increased excretion of lysine, ornathine, and ammonia N.

Metabolism of methionine and lysine have been extensively studied in calves and daily needs estimated by many researchers (Patureau-Mirand *et al.*, 1973a, b, c; Patureau-Mirand, *et al.*, 1977, Williams and Hewett, 1979). Williams (1994) proposed the following amino acid requirements for milk-fed veal calves (50-58 kg) gaining 0.25 kg/d (0.55 lb/d): methionine, 2.1; cystine, 1.6; lysine, 7.8; threonine, 4.9; valine, 4.8; isoleucine, 3.4; leucine, 8.4; tyrosine, 3.0; phenylananine, 5.4; histidine, 3.0; arginine, 8.5; and tryptophan, 1.0 g/day (Table 4).

While we generally think of amino acids in terms of protein composition to meet needs for growth, some emerging concepts indicate that certain amino acids may have other effects on antibody production, hormone concentrations, and mature body composition. Arginine, for example, has been shown to increase weight gain, and decrease IgG concentrations and leukocyte numbers (Fligger *et al.*, 1997). More recently, Takahashi, *et al.* (2002) demonstrated the concept of "amino acid imprinting" in which short-term feeding of amino acids to the neonate has a positive effect much later in life. They have shown that feeding a mixture of amino acids including glucogenic and branched chain amino acids, in milk replace for the first 14 days, increased the accumulation of fat between muscle fibers during the finishing period resulting in improved carcass grade because of increased marbling.

Combining Protein and Energy Needs

Protein requirements depend upon the body weight and rate of gain. As a general rule, the protein requirement for maintenance is relatively low, but the requirement for gain is relatively high. The opposite is true for energy – requirement is high for maintenance and relatively low for additional gain. The metabolizable energy requirement of calves for maintenance has been estimated as 115 kcal/kg$^{0.75}$ (Agricultural Research Council, 1980). Energy required for gain of veal calves was described by Toullec (1989) by the following equation: $ME=0.1\ LW^{0.75} + 0.84\ (LW^{0.355})\ (LWG^{1.2})$ where ME is the metabolizable energy requirement in kcal; LW is the live weight in kg, and LWG is the live weight gain in kg.

The protein requirement of calves was described in terms of apparently digestible protein (ADP) by Blaxter and Mitchell (1948) as: ADP (g/d) =6.25[1/BV*(E+G+M*D)-M*D] where 6.25 is the factor to convert nitrogen to crude protein; BV is the biological value of the protein; E is the endogenous urinary N excretion (g/d); G is the amount of N (g/d) stored in live weight gain; M is the metabolic fecal N (g/kg DM ingested); and D is dry matter intake (kg/d). For biological value, Van Amburgh (personal communication) suggests a value of 0.73. In comparison, 0.80 was suggested by Davis and Drackley (1998). For other variables, Davis and Drackley (1998) suggest $E=0.2*LW^{0.75}$; G=30 g/kg LWG; and M=2.2 g N/kg DM consumed.

In order to estimate the energy and protein needs of calves under various scenarios, the body weight, feed intake amount, and feed composition must be known. Then, maintenance energy needs and live weight gain can be estimated using Toullec's equation and protein needs estimated by using the equation of Blaxter and Mitchell. In the example to follow, the protein required in milk replacer has been estimated for a 95 lb calf fed twice per day at various levels of milk replacer intake. As one can quickly see, the amount of protein required in the milk replacer quickly increases from 9.5% (maintenance requirement) to approximately 15, 18, and 20% as milk replacer powder increases from 7 to 8, 9, and 10 ounces per feeding, respectively (Table 5). Assuming the milk replacer contains enough protein to meet the demands of growth, the increased growth rate results in a reduction of cost of gain.

The Importance of Body Weight

Calf body weight has a profound influence on protein requirements at a given level of intake. For example, a 95 lb calf given 10 oz per feeding twice per day of a milk replacer containing 20% fat requires 20.1% protein in the milk replacer, so based on the equations of Toullec (1989) and Blaxter and Mitchell (1948), a 20/20 MR would meet the calf's needs at this level of feed intake. However, an 85 lb calf given 10 oz of the same milk replacer would provide a greater amount of energy available for gain because of the lighter body weight and lower maintenance requirement. As a result, energy available for gain is higher and the amount of protein required for this higher potential gain results a milk replacer with 22.3% CP for the 85 lb calf. For a 75 lb calf, this same scenario means the milk replacer needs to have 24.8% CP. Feed intake and protein should be matched to fit the calves being raised.

Amount of Milk Feeding Affects Weaning and Beyond

For the milk-fed calf, increasing rate and efficiency of gain reduces the cost of gain. However, if the goal is to produce Holstein beef or replacement heifer calves, feeding higher intake levels of milk or milk replacer can eventually result in a reduction in intake of solid feed. Lower dry feed intake delays weaning, increases total amount of milk replacer fed, and increases cost of gain.

However, benefits of earlier conception and greater milk production were shown in heifers fed higher levels of milk via suckling. In research reported by Bar-Peled *et al* (1997), heifer calves were allowed to suckle their dams for 15 minutes, three times per day. Heifers consumed 16.9 kg (37.3 lb) of milk per day on average through weaning at 42 days of age. The authors observed "the suckled calves did not consume concentrates or vetch hay, *although feed was freely available*" (emphasis added). At 6 weeks of age, heifers fed milk replacer weighed 136.5 lb compared to 161.8 lb for heifers allowed to suckle their dams. After weaning, the suckled heifers lost weight because they had not been eating solid feed. At 12 weeks of age, calves fed milk replacer weighed 216.5 lb and calves allowed to suckle weighed 194.7 lb ($P<.05$). At conception, weights of milk replacer-fed calves and suckled calves were not significantly different (721.3 vs 790.6 lb, respectively). But, when compared to calves fed milk replacer, calves allowed to suckle conceived in fewer days (426 vs 394, respectively, $P=.05$) and produced more milk during the first 300 day lactation (20,218 vs 21,217 lb, respectively, $P=.08$). Clearly, early calf nutrition has implications later in life, but we must develop feeding strategies that integrate milk and grain feeding to maximize lifetime performance and minimize cost of production. Note that heifers allowed to suckle consumed liquid milk equal to 4.66 lb of milk solids per day. Calf growers entrenched in feeding 1 lb of milk replacer per day often claim that calves cannot consume more than 1 lb per day. Obviously the heifers in this study were unaware of the 1 lb maximum rule of thumb.

Weaning Calves

Weaning is a stressful time for calves, however, it is less stressful for Holstein beef and heifer calves than it is for beef calves being separated from their dams and changing feed supplies simultaneously. Two studies by researchers of the *Institut National de la Recherche Agronomique* laboratories in France examined nutrition of calves during weaning (Kuamé *et al.*, 1984 a, b). Their study compared sources of protein which differed in nitrogen solubility and PDI (protein digestible in the intestine) and fed in isocaloric diets. Live weight gains, blood glucose levels and blood levels of non esterified fatty acids decreased as intake of milk decreased and solid feed intake increased. Plasma acetate levels and ß-hydroxybutyrate levels increased rapidly after weaning. Calves underwent an energy deficiency in the last 2 weeks before weaning and during the first week after weaning. Amino acid composition of duodenal contents was similar to milk before weaning and became more similar to compositon of rumen bacteria after weaning. Blood urea levels remained nearly constant until one week post weaning and then decreased. Lysine and methionine seemed to be the limiting amino acids during the weaning period. Growers should understand that calves are undergoing tremendous metabolic changes associated with the change in nutrient supply from milk to solid feed during the entire 3-4 week period around weaning.

Like the French researchers, Luchini *et al*., (1989) concluded that energy was limiting calf performance during weaning. Using both bulls and heifers, they compared weaning at 26 or 42 days of age, low or high protein starter feed and offering starter from day 1 or day 21 on trial. They found when calves were weaned at 26 days of age, providing starter feed from day 1 minimized the weight loss immediately after weaning compared to calves offered starter for only the last 5 days prior to weaning. Calves weaned at 42 days of age had heavier weights at all ages (with the exception of day 14), but differences in live weight were significant only at days 29, 35, and 42. Starter intake during the first 14 days was negligible for calves offered starter from day 1 and calves offered starter beginning on day 21 readily consumed it. On day 25, calves on all treatments consumed the same amount of starter as a percentage of body weight, regardless of how long they had been offered starter feed. After weaning, dry matter intake in calves weaned on day 26 dropped by 50% and calves lost weight for several days until starter intake, which increased rapidly, reached a level to again support gain. Their data showed that calves could be weaned as early as day 26, but gain and body weights were higher in calves weaned at 42 days of age. Calves provided starter from day 1 had some slight advantages in gain compared to calves provided starter beginning on day 21. Protein level in starter feed had no effect on variables measured in this study and supports the conclusion that energy is limiting, rather than protein.

Many researchers and calf growers have different "thumb rules" for when calves should be weaned based on a fixed amount of feed intake per day and/or other criteria. Researchers at Kansas State University compared weaning strategies in Holstein heifers and bulls (Greenwood *et al*., 1997). They compared weaning calves based on calves consuming 1, 1.5, or 2% of the calves' initial body weight to calves using the previous criterion used at Kansas State that were: 1) calves must be consuming 1.5 lb of starter feed for 3 consecutive days; 2) total starter feed intake must be ≥7.5 lb; 3) calves must have accumulated gain of 10 lb above initial body weight. The researchers found that heifer calves consumed more feed during weeks 5-8 and during the entire trial ($P<.01$), and heifers gained more weight than bull calves during the same periods ($P=.02$ or less). Based on their results, the following weaning criteria can be recommended for heifers and bulls: 1) calves are a minimum of 3 weeks old; 2) calves consume starter feed at a rate of 1% of initial body weight for 3 consecutive days; 3) total dry feed intake is ≥9% of initial body weight; and body weight gain is ≥12% of initial body weight.

<u>Personal Calf Feeding Recommendations</u>

Frequently, I am asked the question: What should I feed my calves? My answer is based on 95 lb calves. First, life is a lot easier if calves have received adequate amounts of colostrum. This is often out of the buyer's control and once calves have been delivered to a calf ranch, there is little one can do to provide colostrum. Testing calves for immunoglobulin status can help with buying decisions for future purchases based on track record. With shipped-in calves, we have found that calves have improved health when they are provided with electrolytes, such as our *Travel-Lyte*™, for the first four days after arrival. In one of our studies, calves fed *Travel-Lyte*™ between meals for the first for days had significantly lower incidence of scours than calves in the control group fed only milk replacer (14.9 vs 30.4%, respectively). Additionally, among those calves that became sick had one-third of the relapse rate of the control group (8 vs 26%, respectively). For stressed calves, *Travel-Lyte*™ (a Generation-II electrolyte) is well-suited, but for calves with scours we have a Generation-III oral electrolyte called *C.H.E.E.R.S.*™ which stands for "Concentrated High Energy Electrolyte Rehydration Solution". *C.H.E.E.R.S.*™ has superior technology which allows calves to be fed milk or milk replacer continually without digestive interference from the electrolyte. This is important because no electrolyte contains enough energy to even meet maintenance requirements of calves. The superior technology also allows severely dehydrated calves to be fed *C.H.E.E.R.S.*™ instead of needing to give intravenous fluids. This is not a commercial, this is a plea. Calf death losses due to scours and dehydration cost millions of dollars per year and account for more than half of all calf death losses according to USDA (1993). Calf growers need to make a priority of providing a much greater amount of electrolytes to keep calves alive than current industry practices.

Secondly, the question of intake of milk replacer per day. I developed recommendations (available on our website) for a "Professional Calf Ranch Milk Replacer" which contains 24% protein and 16% fat and is fed at the rate of 12-14 ounces per feeding, twice per day in 2 quarts of total solution. This equates to about 1.60-1.85% of body weight in dry milk replacer powder per day. For many of our clients, milk replacer needs to fit into a 2 quart bottle. Based on our experience and some published data, 12-14 ounces of milk replacer powder in 2 quarts is the maximum and most cost-effective concentration for calves under most circumstances. I recommend feeding this level of milk replacer twice per day until day 28, then once per day until weaning at day 35, as long as calves are healthy. This is a standard recommendation, however, in my opinion; the guidelines of Greenwood *et al*., (1997) are valid and supercede the standard recommendations of twice daily feeding to day 28, then feeding once daily and weaning calves on day 35. High quality textured starter feed of ≥18% CP should be provided fresh everyday beginning on day 3. Some operations will be able to wean calves earlier while others may not.

With the cost of milk replacer protein increasing over the last few years, many non-milk protein sources such as blood plasma and/or soluble wheat gluten protein have received renewed interest. Nouriche Nutrition Ltd. imports soluble wheat gluten protein, called "Nutrior", from France which is widely accepted in Europe and well-received in North America. In fact, Nouriche recommends the Professional Calf Ranch Milk Replacer, our second company, BABY DOLL Nutrition Ltd. uses this formula for milk replacer, which also contains about 33% of its protein from Nutrior. This is an economical level of wheat gluten protein while maintaining excellent calf performance. The milk replacer also contains our most technically advanced premix called "DynaMix". It contains all organic trace minerals, plus vitamins, and flavor agents that improve calf intake.

My goal as a calf nutritionist has always been focused on reducing the cost of production while maintaining or improving calf quality. As an advisor, I know that there are some practices which might be possible but are not practical for an entire system. Years ago there were products sold to wean calves at 14 days of age. These products worked reasonably well for most calves, but under field conditions we need to implement systems that work 99.9% of the time for the entire system. While it is possible to wean at 14 days, it is more practical to recommend a system with a target of weaning 100% of calves at 35 days, and then make adjustments on a case-by-case basis based on the capabilities of management, by calf status, season, performance, etc.

Summary

The primary points revealed from a survey of the literature on Protein and Energy relate to 1) the Protein:Energy interrelationship, 2) the Amount of Feed impact and interaction with Protein and Energy and 3) the Economics.

1. Protein:Energy Ratio: An important relationship exists between the ratio of protein and energy. Today's 20/20 milk replacer formulations are fed at levels which tend to limit potential growth because of limited energy intake. At higher intake levels which provide enough energy for growth, protein tends to limit gain.

One must consider many variables when formulating to optimize the Protein and Energy ratios such as calf body weight, amount of feed in the program, weight and timing goals for gain, season, and economics. As a general rule, the protein requirement for maintenance is relatively low, but the requirement for gain is relatively high. The opposite is true for energy. The metabolizable energy requirements for maintenance are relatively high, but additional energy requirements for gain are relatively low.

Research shows that Protein and Energy ratios and their specific composition, such as amino acid levels along with source of calories such as fat vs dextrose, can affect calves' rate of growth, feed efficiency, live conformation, ability to handle stress, feed refusals, carcass composition and even palatability characteristics of meat.

Recent research has also shown that certain amino acids, such as methionine, lysine, mixtures of amino acids including glucogenic and branched chain amino acids, and argenine can affect growth, carcass quality and/or immune system function.

2. Amount of Feed: While milk replacers are more digestible and nutrient rich than grain based starter feeds, standard amounts of milk replacers provided at 1 lb per day are well below what the calf is capable of consuming and what the calf needs for optimal growth.

Nature intended calves to consume more than 1 pound dry matter per day, provided that the composition is balanced and easily digestible. Research has shown that baby Holstein calves allowed to nurse their dams consume as much as two to four plus pounds of dry matter per day.

Since the 1940's, when crudely formulated milk replacers were introduced, the objective was to get calves on calf starter as economically as possible. Unfortunately, little was understood about the long term consequences of inadequate early feeding. Despite, improvements in nutrient balance and digestibility, 8 oz per feeding became so widely accepted, it was not questioned until well into the 1990's. In fact, we now know that 8 oz per feeding is barely sufficient to maintain the calf.

Increasing the amount of ounces more dynamically impacts the Protein:Energy ratio than increasing the level of fat. For example, a 25% increase in powder, from 8 to 10 oz, yields a 25% increase in formulated energy while a 100% increase in fat content, from 10% to 20%, yields only a 9% increase in energy.

3. Economics: Increasing the rate and efficiency of gain tends to reduce the cost of gain and has been shown to improve various performance variables beyond the calf stage. Alternative protein sources such as Soluble Wheat Protein and blood plasma may contribute to affordably allowing calf growers to cost-effectively increase protein levels. However, more research is needed to understand the benefits of increased milk protein and energy versus potential delay of weaning and other costs.

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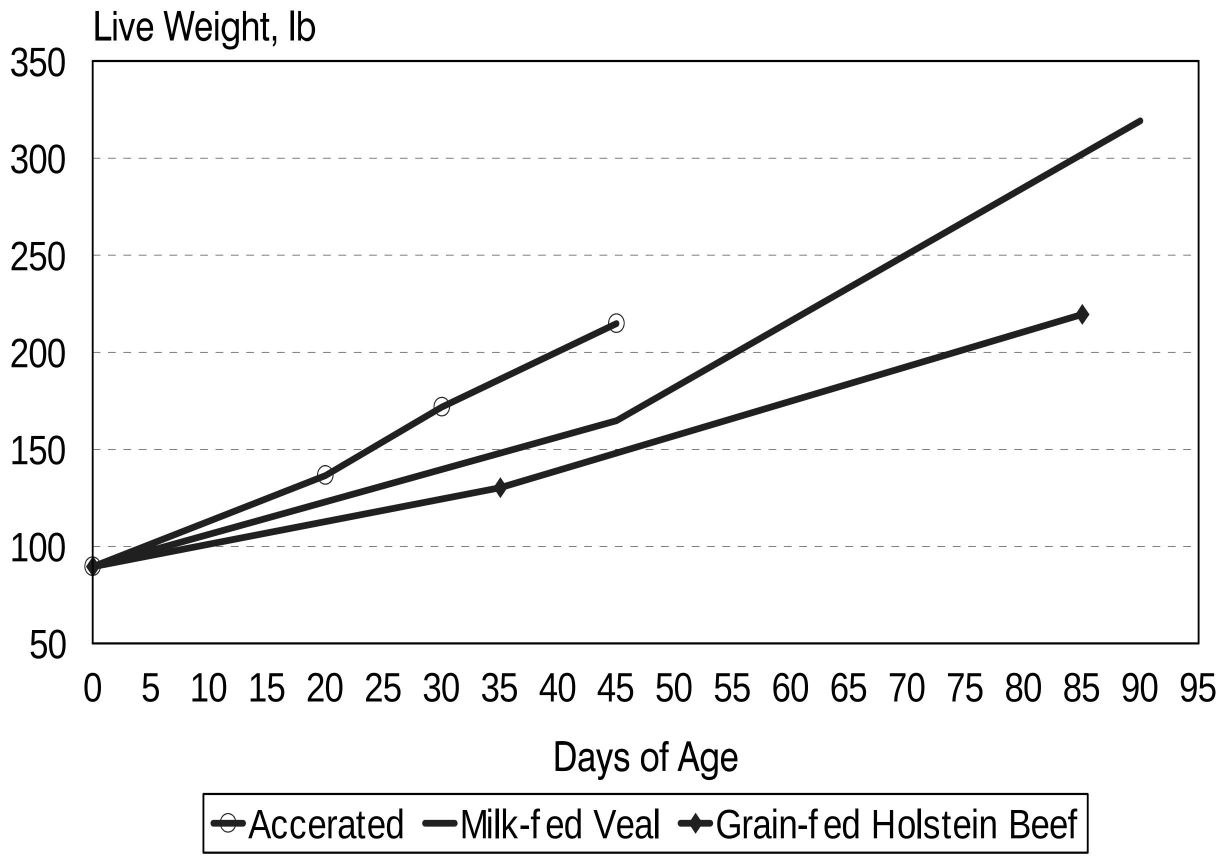
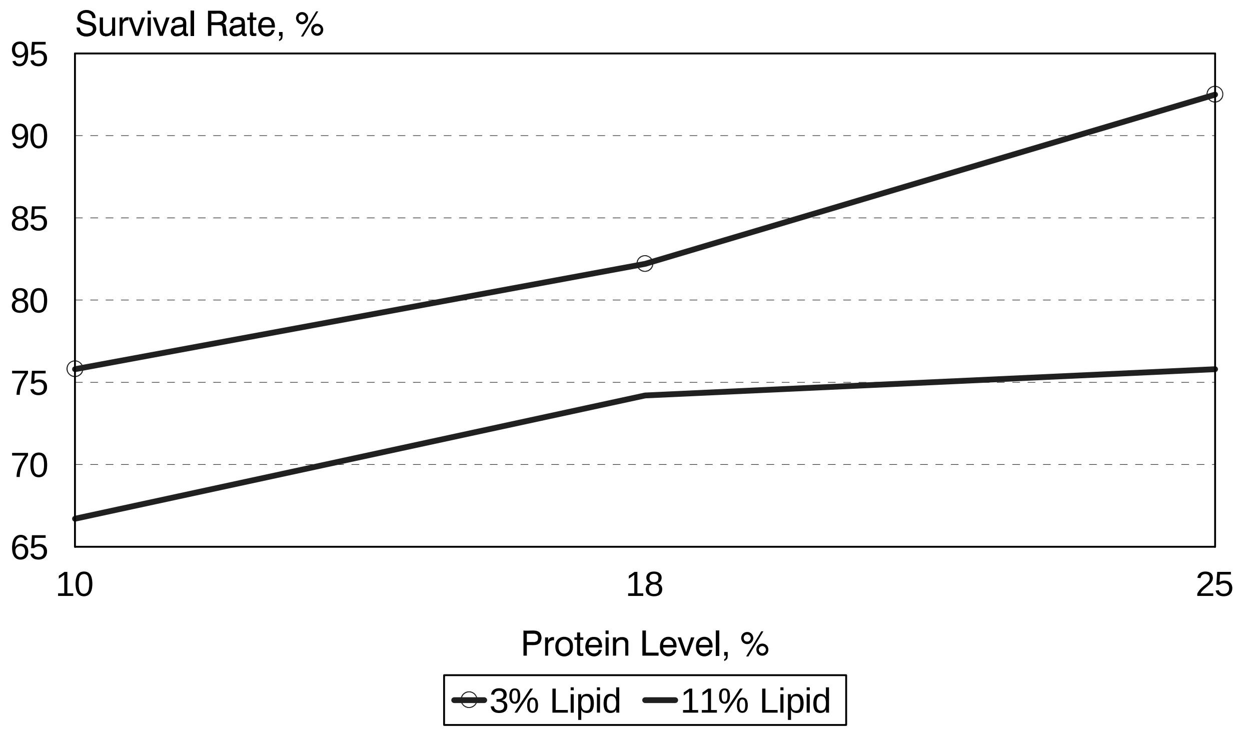
Figure 1. Live Weight of Calves Fed Accelerated, Veal, or Holstein Beef Program.



Source: Diaz *et al*., 1998; Vermeire, 2000; Vermeire, 1998.

Figure 2. Protein and lipid levels vs survival rates in *Litopenaeus vannamei*



Source: Velasco *et al*., 2000.

Table 1. Protein and lipid level vs biological performance of *Litopenaeus vannamei*

Lipid Level	3	3	3	11	11	11
Protein Level	10	18	25	10	18	25
Survival Rate, %	75.8	82.2	92.5	66.7	74.2	75.8
Weight Gain, mg	64.4	72.4	76.7	58.3	74.1	71.4
Feed Conversion	2.4	1.9	1.6	3.0	2.1	2.1

Source: Velasco, *et al*., 2000

Table 2. Performance and Carcass Composition of Pigs vs Lys:DE Ratio

Lys :DE Ratio	Low	Medium	High
Average Daily Gain (65-230 lb), lb	1.32[a]	1.47[b]	1.61[c]
Feed:Gain Ratio (65-230 lb)	3.16[a]	2.86[b]	2.67[c]
Empty Body Wt,.kg	99.8	100.2	100.1
Carcass DM, %	43.3[a]	41.1[b]	38.8[c]
Carcass CP, %	14.1[a]	14.5[ab]	14.8[b]
Carcass Fat, %	25.9[a]	23.5[b]	20.7[c]
Carcass Ash, %	2.72[a]	2.80[a]	2.77[a]

[a,b,c] Within a row, means without a common superscript letter differ (P<.05).
Source: Szabó *et al*., 2001

Figure 3. Energy Intake : 10 vs 20% Fat Compared with 8 vs 10 oz/feeding (Calves)

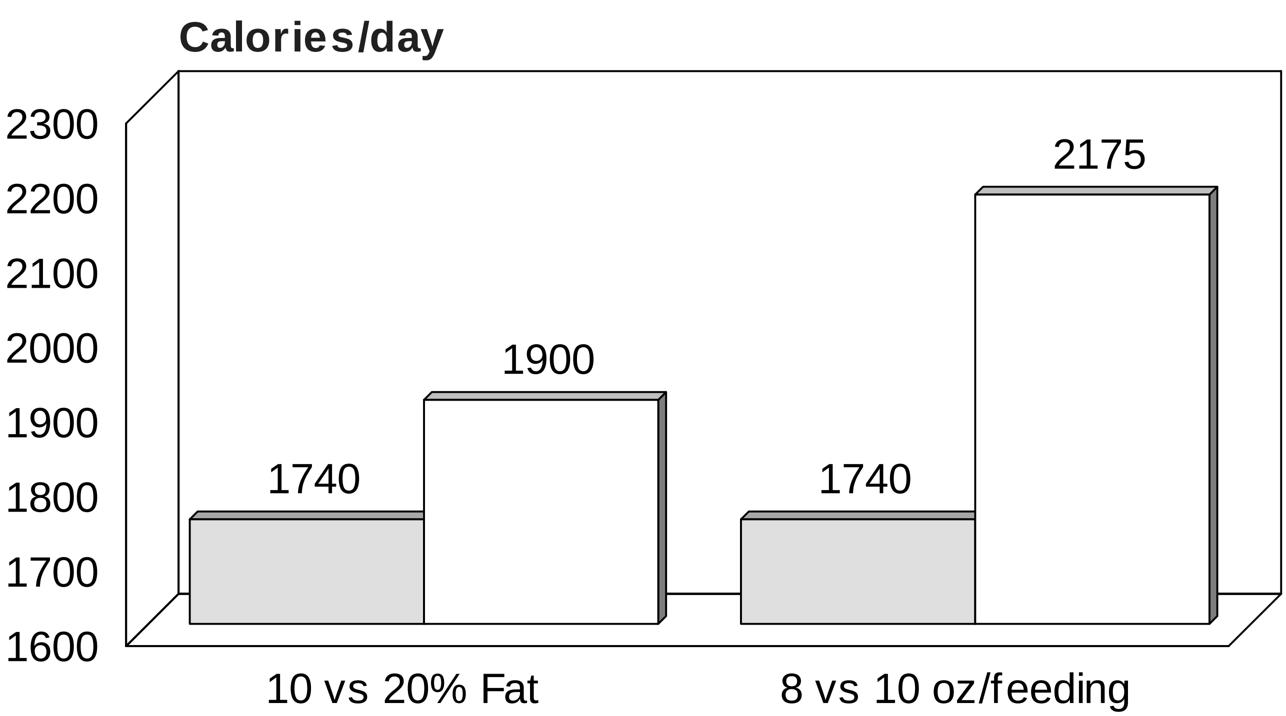
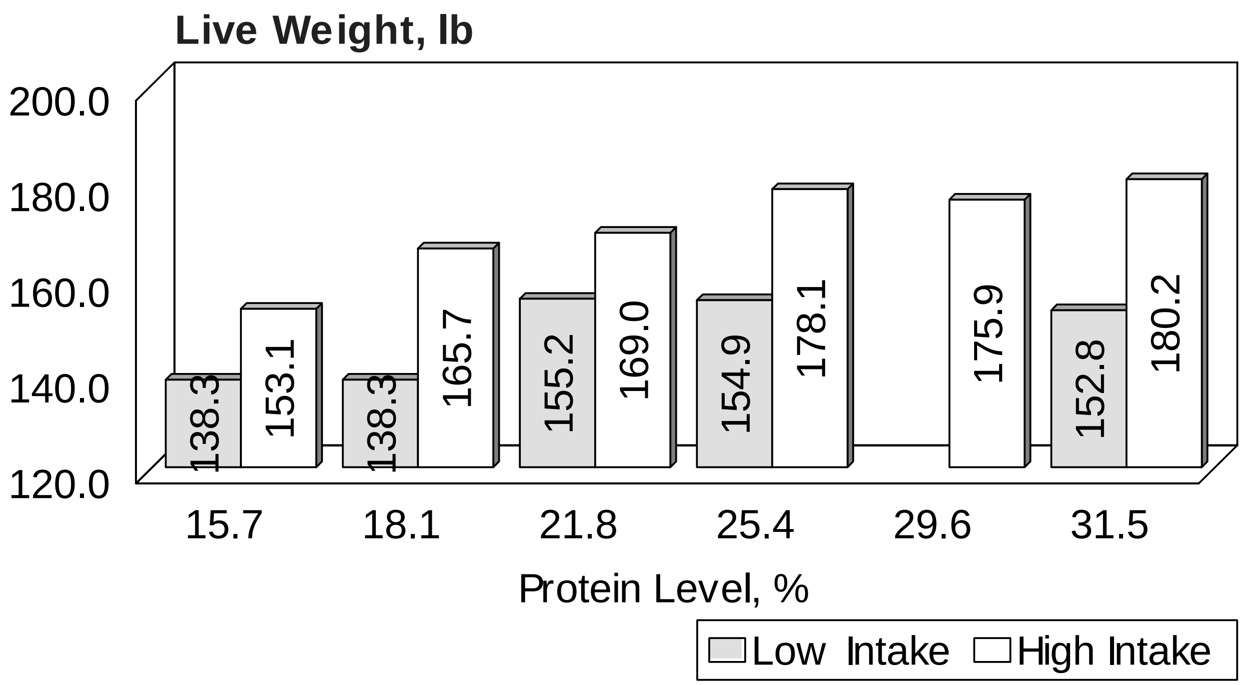
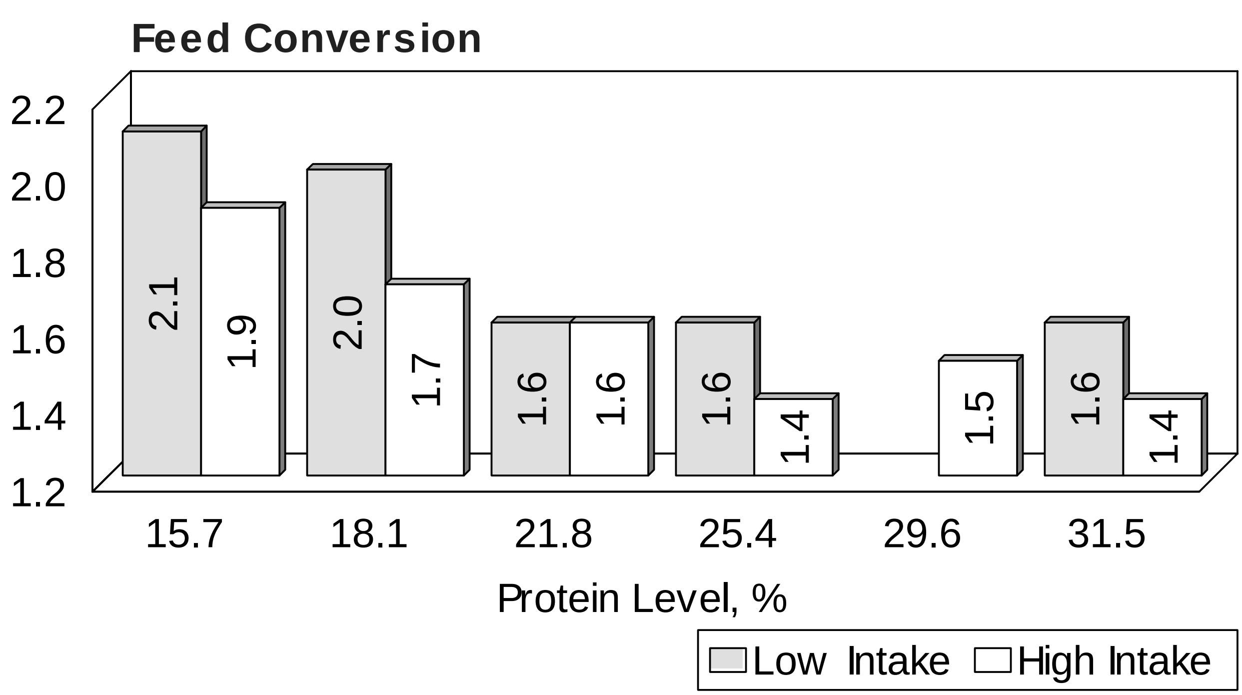


Figure 4. Final Weight (lb) vs Protein Level at Two Levels of Intake in Milk-fed Calves



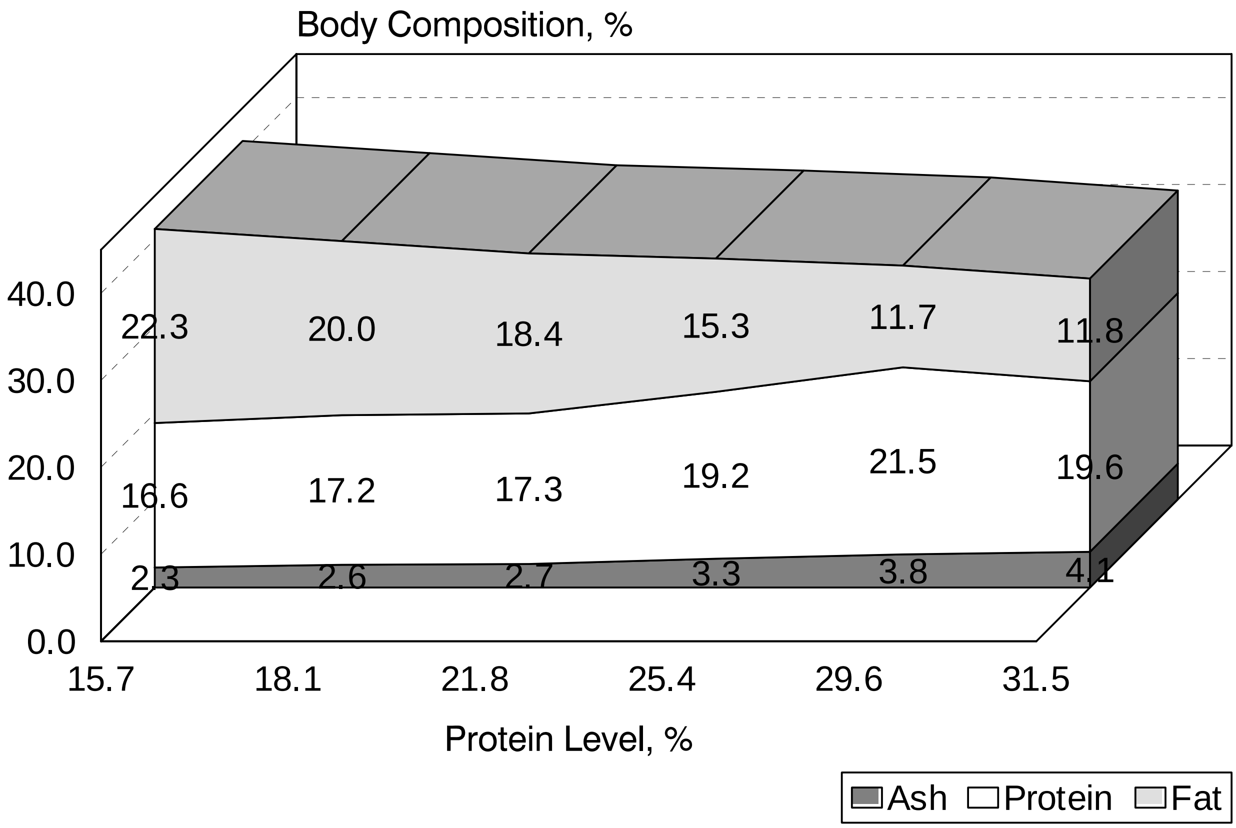
Source: Donnelly and Hutton, 1976a. NZ J Agric Res 19:289-297

Figure 5. Feed Conversion vs Protein Level at Two Levels of Intake in Milk-fed Calves



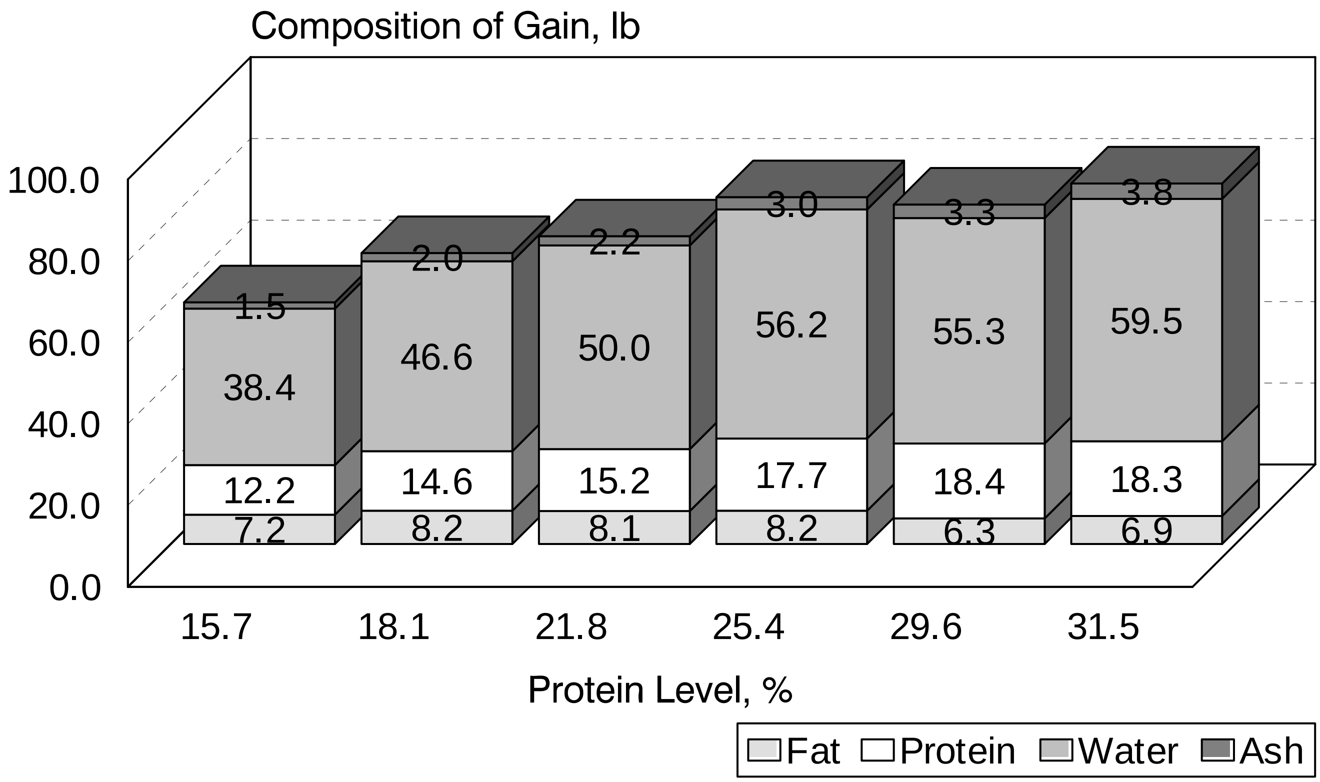
Source: Donnelly and Hutton, 1976a. NZ J Agric Res 19:289-297

Figure 6. Body Composition (% of Carcass) vs Protein Level in Milk-fed Calves



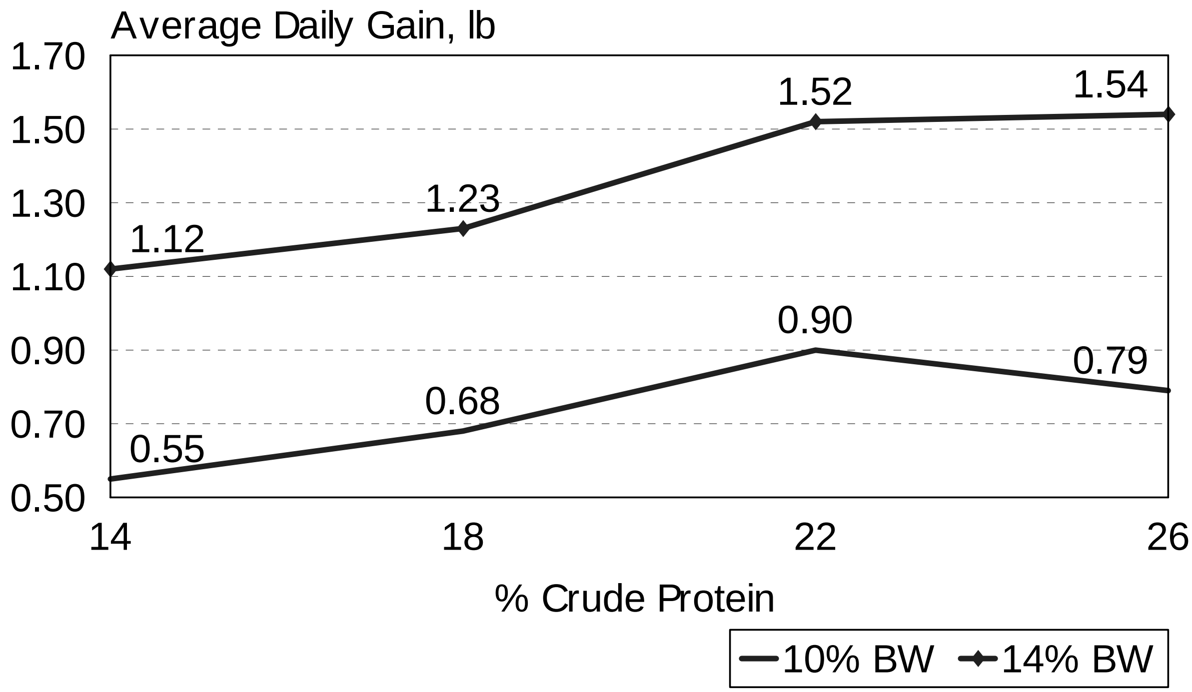
Source: Donnelly and Hutton, 1976b. NZ J Agric Res 19:409-414

Figure 7. Composition of Gain (lb of Component) vs Protein Level in Milk-fed Calves



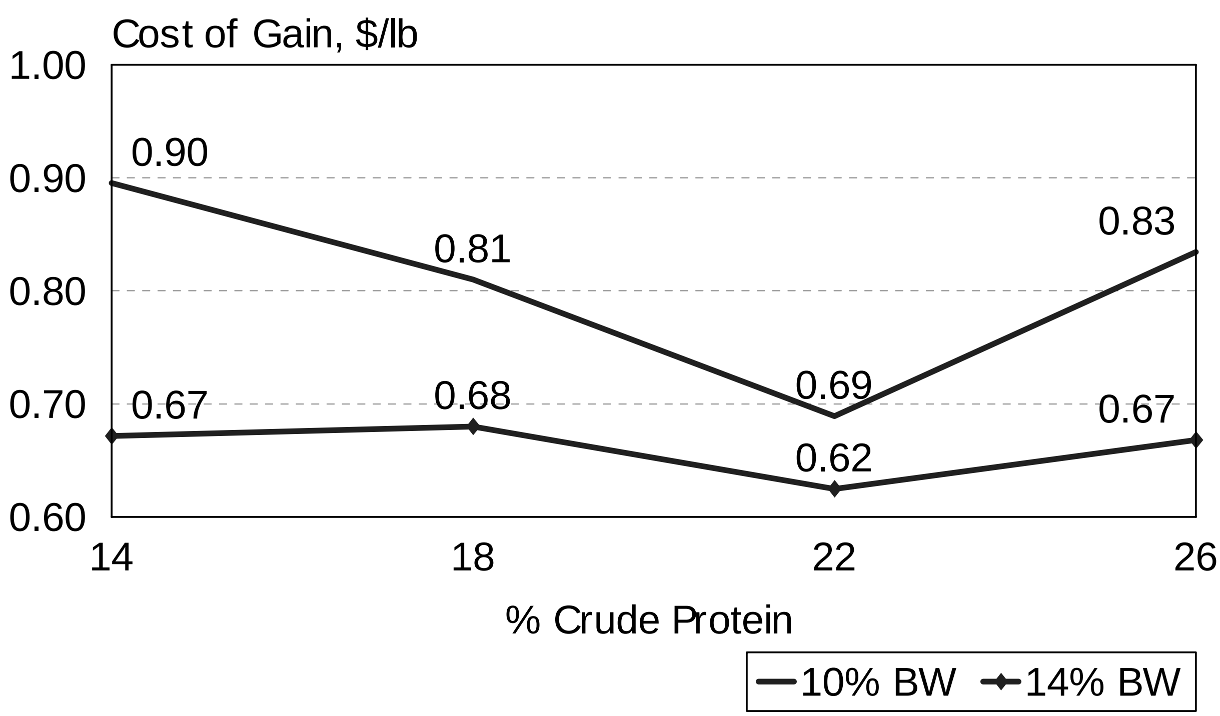
Source: Donnelly and Hutton, 1976b. NZ J Agric Res 19:409-414

Figure 8. Protein Level vs Daily Gain by Calves Fed at Two Levels of Intake



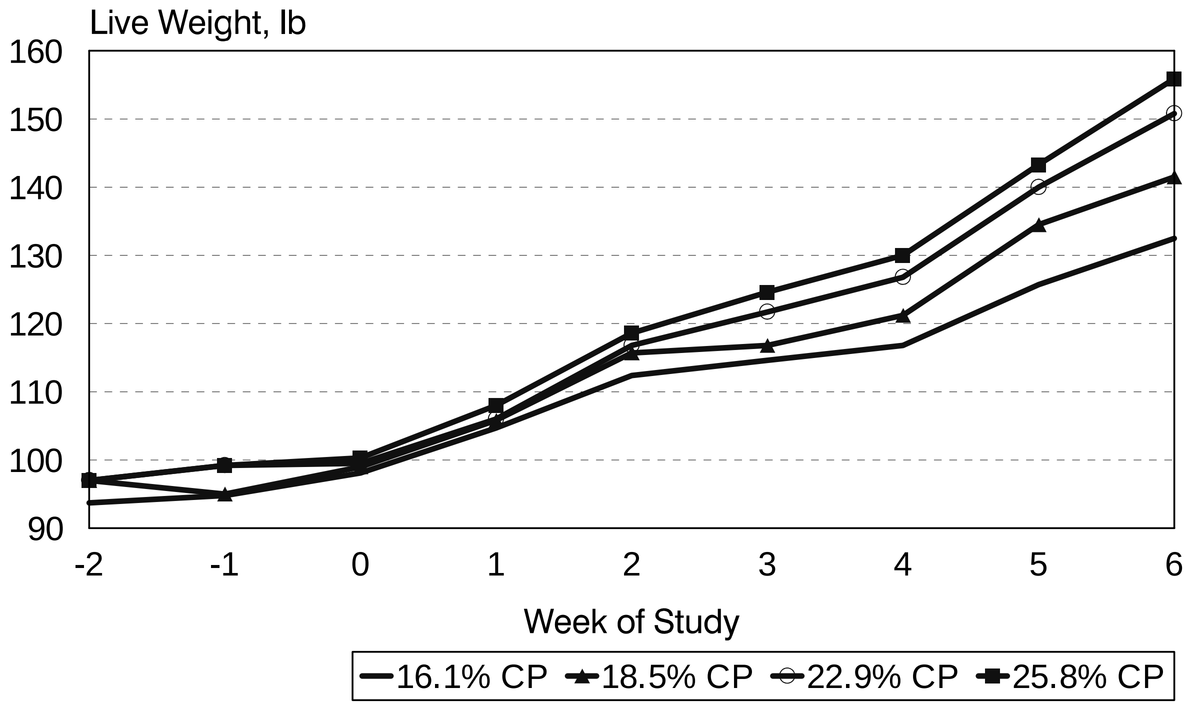
Source: Bartlett. 2001. University of Illinois

Figure 9. Protein Level vs Cost of Gain of Calves Fed at Two Levels of Intake



Source: Bartlett. 2001. University of Illinois

Figure 10. Protein Level vs Live Weight (lb) of Calves Fed at Two Levels of Intake



Source: Blome *et al*., 2003. J Anim Sci 81:1641-1655

Table 3. Toxicity of Methionine in Neonatal Calves: Methionine Intake vs Performance

g/d DL-Met	0	6	12	18	24
DMI, kg/d	1.55	1.59	1.55	1.24	1.21
ADG, g/d	261	400	243	-229	-129
g gain/kg feed	169	251	157	-185	-107

Source: Abe *et al*. (2000) J Anim Sci 78:2722-2730

Table 4. Amino Acid Composition[1] of Milk Replacer Ingredients and Calf Requirements

	Skim Milk Powder	Whey Protein Concen-trate	Soluble Wheat Gluten Protein	Spray Dried Egg Powder	Soy Protein Concen-trate	Calf Require-ments[2]
Crude Protein, %	33.50	34.29	81.47	51.0	69.0	
Crude Fat, %	10.0	3.0	0.09	34.0	1.0	
Crude Fiber, %	0	0	0.39	0.1	4.0	
Ash, %	5.50	5.80	1.63	5.5	6.0	
Moisture, %	6.95	7.89	4.34	5.0	9.0	
Calcium, %	1.00	0.51	0.05	0.21	0.35	
Phosphorus, %	0.69	0.47	0.17	0.68	0.80	
Arginine, %	1.21	0.82	2.68	3.32	4.83	8.5
Lysine, %	2.31	3.00	1.30	3.10	4.21	7.8
Histidine, %	0.81	0.58	1.67	1.21	1.73	3.0
Leucine, %	3.33	3.82	5.62	4.13	5.18	8.4
Isoleucine, %	1.75	2.21	3.00	3.17	3.24	3.4
Valine, %	2.22	2.27	3.20	3.57	3.38	4.8
Methionine, %	0.88	0.74	1.27	1.47	0.90	2.1
Threonine, %	1.57	2.68	1.95	2.32	2.55	4.9
Tryptophan, %	0.52	0.67	1.00	0.77	0.83	1.0
Tyrosine, %	1.81	1.06	2.61	2.00	2.35	3.0
Phenylalanine, %	1.52	1.14	4.16	2.79	3.31	5.4

[1] Composition on an as-fed basis.
[2] Amino acid requirements in grams per day from Williams (1994) for milk-fed veal calves (50-58 kg) gaining 0.25 kg/d (0.55 lb/d)

Table 5. Effect of Feed Intake on Protein Required in Milk Replacer, ADG, and COG

oz MR/ feeding	% CP Required	ADG, lb/d	Cost of MR, $/lb	Cost of Gain, $/lb
7	9.5	0.06	0.614	8.96
8	14.7	0.30	0.746	2.49
9	17.9	0.50	0.826	1.85
10	20.1	0.68	0.881	1.62
11	21.7	0.85	0.923	1.49
12	23.0	1.02	0.956	1.41
13	23.9	1.18	0.978	1.35
14	24.7	1.34	1.000	1.30
15	25.3	1.50	1.014	1.27
16	25.8	1.65	1.026	1.24
17	26.2	1.80	1.036	1.22
18	26.5	1.94	1.043	1.21
19	26.8	2.09	1.051	1.19
20	27.1	2.23	1.058	1.19

Assumptions: 95 lb calf, twice per day feeding; milk replacer contains 2050 kcal/lb ME and 96% dry matter. Gain estimated using equations of Toullec (1989), and Blaxter and Mitchell (1948).