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Director's Digest

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# EXCERPTS FROM NATIONAL RESEARCH COUNCIL'S 1989 EDITION OF "NUTRIENT REQUIREMENTS OF DAIRY CATTLE"

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## Importance of Protein

The absorption of essential amino acids from digested protein is vital to the maintenance, reproduction, growth, and lactation of dairy cattle. These essential amino acids must come either from dietary protein that escapes rumen fermentation or from the microbial protein produced in rumen fermentation. When cattle are fed purified diets with only nonprotein nitrogen (NPN) as a nitrogen (N) source, there is adequate microbial protein production for growing ruminants with a functional rumen to gain at about 65 percent of the level at which they gain when they are fed practical energy ingredients and protein supplements (Oltjen, 1969). In fact, lactating cattle fed protein-free diets have produced 4,000 kg of milk per lactation (Virtanen, 1969); production increased 1,000 and 1,500 kg, respectively, however, by supplying protein for 20 and 40 percent of the nitrogen needed.

The proteins in practical dairy forage and concentrate energy sources supply some dietary protein that escapes rumen fermentation, and this protein that escapes rumen fermentation, and this protein plus the microbial protein produced from supplemental NPN may be enough to produce 20 kg of milk/day (Conrad and Hibbs, 1968; Tamminga and van Hellemond, 1977). As milk production increases, a substantial amount of additional dietary protein from protein supplements must escape rumen fermentation to meet the animal's requirement for protein. Using the requirements that will be described later, a 600-kg cow producing 40 kg of milk with 4 percent fat and 3.5 percent protein secretes 1,400 g of milk protein and 29.6 Mcal of milk energy, or 47 g of protein/Mcal of energy; a 200-kg Holstein heifer gaining

700 g day retains 148 g of tissue protein and 1.95 Mcal of tissue energy, or 76 g of protein/Mcal of energy. In these examples, both the proportional contribution of maintenance protein and energy to the total requirement and the efficiency of various productive functions vary; consequently, the ratios of protein to energy needed in the diet differ from those in the product. This proposition is demonstrated by the two previous examples: The 600-kg cow requires 3,694 g of degraded and undegraded intake protein and 17.09 kg of TDN for maintenance and milk production, or 216 g of dietary protein/kg of TDN; the 200-kg heifer requires 578 g of degraded and undegraded intake protein and 3.14 kg of TDN, or 184 g of dietary protein/kg of TDN. Increasing the ratio of intake protein to TDN will increase the ratio of undegraded to degraded intake protein needed in the diet. Also, the protein requirement for protein deposition is more rigid than the protein requirement for milk production because the growing animal cannot use tissue protein temporarily whereas the lactating cow can use such protein for a short time at the beginning of lactation.

As milk production per cow increases, it becomes more and more important that dietary protein escape degradation in rumen fermentation (Kaufmann, 1982). The same situation holds true during early rapid growth of the animal (Orskov, 1977). The increasing importance of escaping dietary protein suggests that the unit for describing the requirement should be the protein absorbed from the digestive tract, more specifically, the amino acids absorbed from the small intestine.

Effects On Energy Supply

The extensive interrelationships of protein and energy supply have been the topics of considerable discussion recently (Kaufman, 1982; Verite et al., 1982; Journet et al., 1983a; Oldham, 1984). The concentration and undegradability of dietary protein may affect the energy supply by modifying intake, digestibility, or energy efficiency. In an analysis of 23 comparisons, dry matter intake increased 0.4 kg/day for each percent of increase in intake protein in the dry matter (IPDM) from 12.5 to 15.7 percent; in an analysis based on 11 comparisons it increased 0.2 kg/day for each percent of increase in IPDM from 16 to 21 percent (Journet et al., 1983a). Supplying more dietary protein increases the ad libitum intake of corn silage-based diets (Verite et al., 1982). Tyrrell et al, (1983) also observed an increase in ad libitum intake when either untreated or formaldehydetreated alfalfa silage was substituted for one-half of the 60 percent of corn silage DM in a diet for lactating cows.

In another study, Oldham (1984) increased the digestibility of DM in diets based on corn silage, hay, and grass silage by adding protein. The DM digestibility increased 1.1 percent for each 1 percent increase in crude protein when basal corn silage or hay diets increased from 8 to 17 percent of crude protein; when the crude protein content of grass silage diets was increased from 12 to 23 percent, DM digestibility increased 0.7 percent for each 1 percent increase in crude protein. Huber and Thomas (1971) also observed increased digestibility of corn grain-corn silage diets of from 56 to 69 percent when crude protein was increased from 8 to 13 percent. Dry matter digestibility of corn grain-corn silage diets increased from 3 to 8 percent when crude protein was increased from 9 to 12 percent up to 13.5 to 14.5 percent, according to Wohlt et al. (1978). And Tyrrell and Moe (1980) observed an increase in the digestibility of diets that contained 40 percent alfalfa hay when dietary protein was increased from 14 to 17 percent. They also observed an increase in the digestibility of diets that contained 60 percent corn silage when dietary protein was increased from 11 to 14 percent. Tyrrell et al (1982) reported that the digestibility of 60 percent corn silage diets was increased by increasing dietary protein from 10.8 to 15.1 percent using soluble protein in linseed meal; digestibility increased even more when dietary protein was increased from 10.8 to 14.6 percent with more insoluble protein from corn gluten meal. In other studies, the correction of a shortage of DIP was observed to increase the digestibility of corn silage diets (Verite et al, 1982). The minimal effect of dietary protein on the efficiency of ME utilization has also been noted (Tyrrell and Moe, 1980; Tyrrell et al., 1982). Vermorel et al. (1982) found that increasing the intake protein in dry matter (IPDM) from 11.5 to 19 percent did not affect the efficiency of ME utilization, but Schneider et al. (1980) did observe a negative effect of IPDM on energy efficiency. In fact, a large excess of dietary protein may decrease the energy supply because excess protein must be deaminated to ammonia and, for the most part, transformed back into urea for excretion.

Effects On Milk Production And Weight Change

According to Verite et al. (1982) additional protein in early lactation increased weight loss when milk production increased while intake remained constant under restricted feeding. However, additional protein in early lactation decreased weight loss when milk production increased and feed intake increased under ad libitum feeding.

As reported in other studies, the correction of a shortage of degradable protein for rumen fermentation of high-energy corn-silage diets increased duodenal N flow, apparent digestibility of DM, NE concentration of the diet, and milk production, but it also decreased weight loss (Verite et al., 1982; Verite and Geay, 1986). Milk production increased the most during early lactation (0 to 8 weeks), moderately around peak yield (8 to 12 weeks), and the least in later lactation as the protein supply increased toward the requirement (Verite and Geay, 1986). Additional degradable protein or NPN above that suggested by the French PDI system had no additional effect. Journet et al. (1983a) and Oldham (1984) present a more detailed discussion of the interaction of protein on energy availability and milk production.

## Relation Of Absorbed And Crude Protein Requirements

The requirements for protein in dairy cattle are primarily calculated using the concepts described earlier in this section, which are expressed in absorbed protein units. The dietary protein input is described as the UIP and the DIP needed to supply this requirement expressed as absorbed protein. A second expression of requirement and supply is that of units of crude protein. The requirement in units of absorbed protein will always be equal to or less than the requirement in units of crude protein. To calculate the crude protein requirements, the subcommittee assumed first that the undegraded portion of intake protein is useful only if tissue need is greater than rumen need, and second, that the degraded portion of intake protein is useful only if rumen need is greater than tissue need.

Table 7-3 lists the ruminal undegradability of protein in selected feeds. Appendix Table 5 is the current recommended nutrient content of diets for dairy cattle. The suggested proportions of undegradable intake protein to degradable intake protein are given under the crude protein requirements. Please note that the undegraded intake protein percentage increases in relation to the degradable intake protein amount as milk production increases. For both lactation and growth, however, the crude protein requirements calculated in this manner are unreasonably high relative to the previous dairy (NRC, 1978) requirements and to the amounts currently used in feeding dairy cows. Consequently, the subcommittee decreased the crude protein requirement slightly by including only 50 percent of the initially calculated additional (over the requirement for absorbed protein) requirement for crude protein. This method has the effect of reducing the recommended crude protein at high milk production about 5 percent relative to factorial calculations but increasing it about 5 percent compared to the previous requirements (NRC, 1978). Lactation requirements for crude protein, then, are reasonable in relation to current practice and to changes suggested by Huber and Kung (1981) based on the previous requirements (NRC, 1978). Growth requirements for crude protein, however, are still higher than the 15.5 percent (Zerbini and Polan, 1985) or the 17 percent (Curnick et al., 1983) reported in recent experiments. Nevertheless, in this edition of the bulletin, the crude protein requirements for growth have been further restricted to a maximum of 16 percent for growing animals larger than 100 kg.

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TABLE 7-3 Ruminal Undegradability of Protein in Selected Feeds

| Feed | Number of Determinations | Undegradability | | |
|---|---|---|---|---|
| | | Mean | S.D. | C.V. |
| Alfalfa, dehydrated | 8 | 0.59 | 0.17 | 29 |
| Alfalfa hay | 12 | 0.28 | 0.07 | 25 |
| Alfalfa silage | 6 | 0.23 | 0.08 | 36 |
| Alfalfa-bromegrass | 1 | 0.21 | | |
| Barley | 16 | 0.27 | 0.10 | 37 |
| Barley, flaked | 1 | 0.67 | | |
| Barley, micronized | 1 | 0.47 | | |
| Barley silage | 1 | 0.27 | | |
| Bean meal, field | 1 | 0.46 | | |
| Beans | 2 | 0.16 | 0.02 | 14 |
| Beet pulp | 4 | 0.45 | 0.14 | 30 |
| Beet pulp molasses | 2 | 0.35 | 0.03 | 8 |
| Beets | 3 | 0.20 | 0.03 | 16 |
| Blood meal | 2 | 0.82 | 0.01 | 1 |
| Brewers dried grains | 9 | 0.49 | 0.13 | 27 |
| Bromegrass | 1 | 0.44 | | |
| Casein | 3 | 0.19 | 0.06 | 32 |
| Casein, HCHO | 2 | 0.72 | 0.08 | 11 |
| Clover, red | 3 | 0.31 | 0.04 | 12 |
| Clover, red, silage | 1 | 0.38 | | |
| Clover, white | 1 | 0.33 | | |
| Clover-grass | 2 | 0.54 | 0.11 | 21 |
| Clover-grass silage | 7 | 0.28 | 0.06 | 22 |
| Coconut | 1 | 0.57 | | |
| Coconut meal | 5 | 0.63 | 0.07 | 11 |
| Corn | 11 | 0.52 | 0.18 | 34 |
| Corn, 0% cottonseed hulls | 1 | 0.46 | | |
| Corn, 7% cottonseed hulls | 1 | 0.43 | | |
| Corn, 14% cottonseed hulls | 1 | 0.59 | | |
| Corn, 21% cottonseed hulls | 1 | 0.48 | | |
| Corn, 10.5% protein, 0% $NaHCO_3$ | 1 | 0.36 | | |
| Corn, 10.5% protein, 3.5% $NaHCO_3$ | 1 | 0.30 | | |
| Corn, 12% protein, 0% $NaHCO_3$ | 1 | 0.29 | | |
| Corn, 12% protein, 3.5% $NaHCO_3$ | 1 | 0.24 | | |
| Corn, dry rolled | 6 | 0.60 | 0.07 | 12 |
| Corn, dry rolled, 0% roughage | 1 | 0.54 | | |
| Corn, dry rolled, 21% roughage | 1 | 0.49 | | |
| Corn, flaked | 1 | 0.58 | | |
| Corn, flakes | 1 | 0.65 | | |
| Corn, high-moisture acid | 1 | 0.56 | | |
| Corn, high-moisture ground | 1 | 0.80 | | |
| Corn, micronized | 1 | 0.29 | | |
| Corn, steam flaked | 1 | 0.68 | | |
| Corn, steam flaked, 0% roughage | 1 | 0.51 | | |
| Corn, steam flaked, 21% roughage | 1 | 0.47 | | |
| Corn gluten feed | 1 | 0.25 | | |
| Corn gluten feed dry | 2 | 0.22 | 0.11 | 51 |
| Corn gluten feed wet | 1 | 0.26 | | |
| Corn gluten meal | 3 | 0.55 | 0.08 | 14 |
| Corn silage | 3 | 0.31 | 0.06 | 20 |
| Cottonseed meal | 21 | 0.43 | 0.11 | 25 |
| Cottonseed meal, HCHO | 2 | 0.64 | 0.15 | 23 |
| Cottonseed meal, prepressed | 2 | 0.36 | 0.02 | 6 |
| Cottonseed meal, screwpressed | 2 | 0.50 | 0.10 | 20 |
| Cottonseed meal, solvent | 6 | 0.41 | 0.13 | 32 |
| Distillers dried grain with solubles | 4 | 0.47 | 0.18 | 39 |
| Distillers dried grains | 1 | 0.54 | | |
| Distillers wet grains | 1 | 0.47 | | |
| Feather meal, hydrolyzed | 1 | 0.71 | | |

*Continues*

TABLE 7-3 Ruminal Undegradability of Protein in Selected Feeds—*Continued*

| Feed | Number of Determinations | Undegradability Mean | S.D. | C.V. |
|---|---|---|---|---|
| Fish meal | 26 | 0.60 | 0.16 | 26 |
| Fish meal, stale | 1 | 0.48 | | |
| Fish meal, well-preserved | 1 | 0.78 | | |
| Grapeseed meal | 1 | 0.45 | | |
| Grass | 4 | 0.40 | 0.10 | 26 |
| Grass pellets | 2 | 0.46 | 0.05 | 11 |
| Grass silage | 20 | 0.29 | 0.06 | 20 |
| Guar meal | 1 | 0.34 | | |
| Linseed | 1 | 0.18 | | |
| Linseed meal | 5 | 0.35 | 0.10 | 27 |
| Lupin meal | 1 | 0.35 | | |
| Manoic meal | 1 | 0.36 | | |
| Meat and bone meal | 5 | 0.49 | 0.18 | 37 |
| Meat meal | 1 | 0.76 | | |
| Oats | 4 | 0.17 | 0.03 | 15 |
| Palm cakes | 6 | 0.66 | 0.06 | 9 |
| Peanut meal | 8 | 0.25 | 0.11 | 45 |
| Peas | 4 | 0.22 | 0.03 | 15 |
| Rapeseed meal | 10 | 0.28 | 0.09 | 31 |
| Rapeseed meal, protected | 1 | 0.70 | | |
| Rye | 1 | 0.19 | | |
| Ryegrass, dehydrated | 4 | 0.22 | 0.14 | 66 |
| Ryegrass, dried artificially | 1 | 0.71 | | |
| Ryegrass, dried artificially, chopped | 1 | 0.30 | | |
| Ryegrass, dried artificially, ground | 1 | 0.73 | | |
| Ryegrass, dried artificially, pelleted | 1 | 0.54 | | |
| Ryegrass, fresh | 1 | 0.48 | | |
| Ryegrass, fresh or frozen | 3 | 0.41 | 0.18 | 44 |
| Ryegrass, frozen | 1 | 0.52 | | |
| Ryegrass silage, HCHO | 1 | 0.93 | | |
| Ryegrass silage, HCHO dried | 1 | 0.83 | | |
| Ryegrass silage, unwilted | 1 | 0.22 | | |
| Sanfoin | 1 | 0.81 | | |
| Sorghum grain | 2 | 0.54 | 0.02 | 4 |
| Sorghum grain, dry ground | 1 | 0.49 | | |
| Sorghum grain, dry rolled | 2 | 0.64 | 0.08 | 12 |
| Sorghum grain, micronized | 1 | 0.64 | | |
| Sorghum grain, reconstituted | 2 | 0.42 | 0.32 | 75 |
| Sorghum grain, steam flaked | 2 | 0.47 | 0.07 | 15 |
| Soybean meal | 39 | 0.35 | 0.12 | 33 |
| Soybean meal, dried 120 C | 1 | 0.59 | | |
| Soybean meal, dried 130 C | 1 | 0.71 | | |
| Soybean meal, dried 140 C | 1 | 0.82 | | |
| Soybean meal, 35% concentrate | 1 | 0.18 | | |
| Soybean meal, 65% concentrate | 1 | 0.46 | | |
| Soybean meal, HCHO | 3 | 0.80 | 0.11 | 14 |
| Soybean meal, unheated | 1 | 0.14 | | |
| Soybean-rapeseed meal, HCHO | 2 | 0.78 | 0.02 | 3 |
| Soybeans | 2 | 0.26 | 0.11 | 40 |
| Subterranean clover | 2 | 0.40 | 0.18 | 45 |
| Sunflower meal | 9 | 0.26 | 0.05 | 20 |
| Timothy, dried artificially, chopped | 1 | 0.32 | | |
| Timothy, dried artificially, pelleted | 1 | 0.53 | | |
| Wheat | 4 | 0.22 | 0.06 | 27 |
| Wheat bran | 4 | 0.29 | 0.10 | 34 |
| Wheat gluten | 1 | 0.17 | | |
| Wheat middlings | 3 | 0.21 | 0.02 | 11 |
| Yeast | 1 | 0.42 | | |
| Zein | 1 | 0.60 | | |

## APPENDIX TABLE 5 Recommended Nutrient Content of Diets for Dairy Cattle

| Cow Wt (lb) / Fat (%) / Wt Gain (lb/d) | Lactating Cow Diets — Milk Yield (lb/d) | | | | | Early Lactation (wks 0–3) | Dry Pregnant Cows | Calf Milk Replacer | Calf Starter Mix | Growing Heifers and Bulls[a] | | | Mature Bulls | Maximum Tolerable Levels[b,c] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 900 / 5.0 / 0.50 | 14 | 29 | 43 | 58 | 74 | | | | | 3–6 Mos | 6–12 Mos | > 12 Mos | | |
| 1,100 / 4.5 / 0.60 | 18 | 36 | 55 | 73 | 91 | | | | | | | | | |
| 1,300 / 4.0 / 0.72 | 23 | 47 | 70 | 93 | 117 | | | | | | | | | |
| 1,500 / 3.5 / 0.82 | 26 | 52 | 78 | 104 | 130 | | | | | | | | | |
| 1,700 / 3.5 / 0.94 | 29 | 57 | 86 | 114 | 143 | | | | | | | | | |
| Energy | | | | | | | | | | | | | | |
| NEL, Mcal/lb | 0.65 | 0.69 | 0.73 | 0.76 | 0.78 | 0.76 | 0.57 | — | — | — | — | — | — | — |
| NEM, Mcal/lb | — | — | — | — | — | — | — | 1.09 | 0.86 | 0.77 | 0.72 | 0.63 | 0.52 | — |
| NEG, Mcal/lb | — | — | — | — | — | — | — | 0.70 | 0.54 | 0.49 | 0.44 | 0.37 | — | — |
| ME, Mcal/lb | 1.07 | 1.16 | 1.25 | 1.31 | 1.31 | 1.27 | 0.93 | 1.71 | 1.41 | 1.18 | 1.12 | 1.03 | 0.91 | — |
| DE, Mcal/lb | 1.26 | 1.35 | 1.44 | 1.50 | 1.50 | 1.46 | 1.12 | 1.90 | 1.60 | 1.37 | 1.31 | 1.22 | 1.10 | — |
| TDN, % of DM | 63 | 67 | 71 | 75 | 75 | 73 | 56 | 95 | 80 | 69 | 66 | 61 | 55 | — |
| Protein equivalent | | | | | | | | | | | | | | |
| Crude protein, % | 12 | 15 | 16 | 17 | 18 | 19 | 12 | 22 | 18 | 16 | 12 | 12 | 10 | — |
| UIP, % | 4.5 | 5.4 | 5.7 | 6.0 | 6.3 | 7.2 | — | — | — | 8.2 | 4.3 | 2.1 | — | — |
| DIP, % | 7.9 | 8.8 | 9.7 | 10.4 | 10.4 | 9.7 | — | — | — | 4.6 | 6.4 | 7.2 | — | — |
| Fiber content (min.)[d] | | | | | | | | | | | | | | |
| Crude fiber, % | 17 | 17 | 17 | 15 | 15 | 17 | 22 | — | — | 13 | 15 | 15 | 15 | — |
| Acid detergent fiber, % | 21 | 21 | 21 | 19 | 19 | 21 | 27 | — | — | 16 | 19 | 19 | 19 | — |
| Neutral detergent fiber, % | 28 | 28 | 28 | 25 | 25 | 28 | 35 | — | — | 23 | 25 | 25 | 25 | — |
| Ether extract (min.), % | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 10 | 3 | 3 | 3 | 3 | 3 | — |
| Minerals | | | | | | | | | | | | | | |
| Calcium, % | 0.43 | 0.53 | 0.60 | 0.65 | 0.66 | 0.77 | 0.39[e] | 0.70 | 0.60 | 0.52 | 0.41 | 0.29 | 0.30 | 2.00 |
| Phosphorus, % | 0.28 | 0.34 | 0.38 | 0.42 | 0.41 | 0.49 | 0.24 | 0.60 | 0.40 | 0.31 | 0.30 | 0.23 | 0.19 | 1.00 |
| Magnesium, %[f] | 0.20 | 0.20 | 0.20 | 0.25 | 0.25 | 0.25 | 0.16 | 0.07 | 0.10 | 0.16 | 0.16 | 0.16 | 0.16 | 0.50 |
| Potassium, %[g] | 0.90 | 0.90 | 0.90 | 1.00 | 1.00 | 1.00 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 3.00 |
| Sodium, % | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | — |
| Chlorine, % | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | — |
| Sulfur, % | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.25 | 0.16 | 0.29 | 0.20 | 0.16 | 0.16 | 0.16 | 0.16 | 0.40 |
| Iron, ppm | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 100 | 50 | 50 | 50 | 50 | 50 | 1,000 |
| Cobalt, ppm | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 10.00 |
| Copper, ppm[h] | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 100 |
| Manganese, ppm | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 1,000 |
| Zinc, ppm | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 500 |
| Iodine, ppm[i] | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 50.00[j] |
| Selenium, ppm | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 2.00 |
| Vitamins[k] | | | | | | | | | | | | | | |
| A, IU/lb | 1,450 | 1,450 | 1,450 | 1,450 | 1,450 | 1,800 | 1,800 | 1,700 | 1,000 | 1,000 | 1,000 | 1,000 | 1,450 | 30,000 |
| D, IU/lb | 450 | 450 | 450 | 450 | 450 | 450 | 540 | 270 | 140 | 140 | 140 | 140 | 140 | 4,500 |
| E, IU/lb | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 18 | 11 | 11 | 11 | 11 | 7 | 900 |

NOTE: The values presented in this table are intended as guidelines for the use of professionals in diet formulation. Because of the many factors affecting such values, they are not intended and should not be used as a legal or regulatory base.

[a]The approximate weight for growing heifers and bulls at 3–6 mos is 331 lb; at 6–12 mos, it is 559 lb; and at more than 12 mos, it is 881 lb. The approximate average daily gain is 1.543 lb/day.
[b]The maximum safe levels for many of the mineral elements are not well defined and may be substantially affected by specific feeding conditions. Additional information is available in *Mineral Tolerance of Domestic Animals* (NRC, 1980).
[c]Vitamin tolerances are discussed in detail in *Vitamin Tolerance of Animals* (NRC, 1987b).
[d]It is recommended that 75 percent of the NDF in lactating cow diets be provided as forage. If this recommendation is not followed, a depression in milk fat may occur.
[e]The value for calcium assumes that the cow is in calcium balance at the beginning of the dry period. If the cow is not in balance, then the dietary calcium requirement should be increased by 25 to 33 percent.
[f]Under conditions conducive to grass tetany (see text), magnesium should be increased to 0.25 or 0.30 percent.
[g]Under conditions of heat stress, potassium should be increased to 1.2 percent (see text).
[h]The cow's copper requirement is influenced by molybdenum and sulfur in the diet (see text).
[i]If the diet contains as much as 25 percent strongly goitrogenic feed on a dry basis, the iodine provided should be increased two times or more.
[j]Although cattle can tolerate this level of iodine, lower levels may be desirable to reduce the iodine content of milk.
[k]The following minimum quantities of B-complex vitamins are suggested per unit of milk replacer: niacin, 2.6 ppm; pantothenic acid, 13 ppm; riboflavin, 6.5 ppm; pyridoxine, 6.5 ppm; folic acid, 0.5 ppm; biotin, 0.1 ppm; vitamin $B_{12}$, 0.07 ppm; thiamin, 6.5 ppm; and choline, 0.26 percent. It appears that adequate amounts of these vitamins are furnished when calves have functional rumens (usually at 6 weeks of age) by a combination of rumen synthesis and natural feedstuffs.