Feeding Early Lactation Cows for Maximum Performance

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Summary

Meeting the energy and protein requirements of high producing cows in early lactation becomes a greater challenge as production per cow increases. Methods to increase energy intake are discussed in this paper with an emphasis on feeding management, fiber requirements, fiber digestibility and site of starch digestion. Considerations for meeting the requirements for rumen degraded and undegraded protein are presented as well as a discussion of current limitations of balancing rations for protein degradability.

Introduction

The art of feeding dairy cattle is gradually being replaced by the basic and applied science of dairy cattle nutrition. Scientific information regarding dairy cattle feeding is accumulating constantly and nutritionists use this information to refine their recommendations. Genetic progress and technological advances force us to constantly review these recommendations. However, there are many aspects of feeding cows such as maximizing energy intake that may still be considered an art. Interactions among feedstuffs, rumen microbes, animal physiology and feeding behavior make it difficult to simplify our feeding guidelines. Science will continue to replace the art of feeding dairy cows but there will always be differences among managers which will be attributed to the art of feeding. The objectives of this paper are to take a look at what is not being adequately considered in our feeding recommendations and to discuss methods to implement this knowledge.

Fiber vs. Energy

Cows in early lactation generally require more energy than they are able to consume and must mobilize body energy reserves for the production of milk. Attempts to increase the energy density of the diet by feeding grain often results in decreased energy intakes and further condition loss. A summary of the results of 12 experiments from the literature with dairy cattle showed that high concentrate diets decreased digestible energy intakes from 5 to 23% (Grovum, 1987). Problems related to feeding high energy density rations are commonly observed in high producing herds. These rations often result in a less than optimal energy intake because they have insufficient fiber and excess non-structural carbohydrate, both of which prevent the animal from maintaining an optimal rumen environment. These situations are usually due to an effort to decrease the loss of body condition: although the high energy content of the ration may depress energy intake, the "natural" response is to feed more grain to thin cows. This of course makes matters worse.

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Fat

Fat supplementation to milking cows has become a common practice in high producing herds. Fat has about 3 times the energy (2.65 Mcal/lb) as cracked corn (0.84 Mcal/lb) and is often used to replace a portion of the grain to increase the energy density of the ration. Common forms of added fat are whole oilseeds (soybeans and cottonseeds) which provide protein as well as unsaturated fat, tallow (saturated fat), and rumen inert fats which are manufactured to have minimal affect on rumen fermentation. Adverse effects of fat supplementation on rumen fermentation and whole tract digestibility have been reported but appear to be minimal as long as slow release (whole oilseeds) or saturated fats (tallow) are added in reasonable quantities (3-4% additional fat). Rumen inert fat is often added to increase energy density further. Before fat is added to the ration it is important to realize that fat can cost up to 2 to 3 times per Mcal of energy more than grain and less expensive ways to increase energy density should be thoroughly explored (Table 1).

Table 1. What is a megacalorie of NE_L worth?

	Mcal/lb	$/lb	$/Mcal
Cracked corn	0.84	$.043	$.05
Fat, animal	2.65	$.24	$.09
Fat, rumen inert	2.65	$.42	$.16

Fiber Requirements

It is well established that dairy cattle have a requirement for fibrous feeds in the diet (Davis and Brown, 1970; Wangsness and Muller, 1981). However, defining these requirements has been a difficult process. In the past this requirement was measured in terms of forage to concentrate ratio (F:C). Because the fiber content of forages is extremely variable, many nutritionists have switched from balancing rations based on F:C to systems which directly measure the fiber content of the diet. Which measure of fiber to use when balancing rations is controversial. Most nutritionists have abandoned crude fiber because it is inconsistent across feeds. Crude fiber does not measure the entire fiber fraction and variable amounts of lignin and hemicellulose are extracted during analyses depending upon forage type and maturity (Van Soest, 1982). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) are rapid and repeatable measures of fiber which are routinely used for balancing rations. ADF is a relatively consistent measure of lignin and cellulose and NDF is a relatively consistent measure of total plant cell wall (Van Soest, 1982). Of the two, NDF seems to be more suitable for determining fiber requirements. The optimal fiber level resulting in maximum fat corrected milk has been shown to be more consistent across forages for NDF than for ADF (Mertens, 1983; Allen and Mertens, 1988). However, the requirement for fiber involves both the chemical and physical properties of feeds as well as physiological and behavioral aspects of the cow. It is unrealistic to expect that one fiber measure can accurately measure all properties required by the cow. The factors affecting the fiber requirements of dairy cattle are summarized in Table 2. An understanding of these factors is needed to maximize energy intake in early lactation cows.

Table 2. Factors affecting the fiber requirements of lactating dairy cattle.

- Dry matter intake
- Particle size distribution
- Fiber digestibility
- Amount of and type of non-structural carbohydrates
- Bulk density
- Buffering capacity of the feeds
- Buffers
- Feeding systems
- Rumen size

As the requirement for fiber may be most appropriately expressed as the amount of fiber needed per day, level of intake will directly affect the requirement for fiber on a percentage basis. For optimal fat-corrected milk, the fiber requirement as a fraction of the diet decreases as intake and production increases (Allen and Mertens, 1988). Kawas *et al.* (1983) suggested an optimum NDF content of the diet of 28 to 31% for cows between 10 and 26 weeks of lactation. For cows later in lactation producing 16 to 24 kg of 4% fat corrected milk, Mertens (1983) suggested an optimum NDF content of 34 to 38%. Although the fiber requirement as a percent of dry matter decreases as production increases, the importance of fiber is more critical at higher production levels.

Chopping forages too finely, while desirable for well preserved silage, is a serious problem for lactating cows - particularly cows in early lactation. Reducing particle size will decrease saliva secretion (Bailey, 1961) as well as decrease rumen pH (Davis, 1979). Because of the reduction in rumen buffering considerably less grain can be fed. To feed the same amount of energy, more fat must be fed increasing ration costs.

Fiber fermentation characteristics may have a significant effect on the optimal fiber level in a ration. When cows in early lactation were fed two sources of fiber varying in rate and extent of digestion, the rumen dry matter pool size was significantly ($P<.05$) lower for the low fill diet (8.3 kg) compared to the high fill (14.0 kg) diet (Varga *et al.*, 1984). Cows may have a greater requirement for fiber that is highly fermentable to replace that which leaves the rumen by fermentation and passage. The fiber concentration of the diet may have to be increased when feeding a highly fermentable fiber unless fiber requirements are met by an increase in dry matter intake.

Fiber requirements may be influenced by the amount of non-structural carbohydrates (NSC) in the diet. Poore *et al.* (1989) substituted wheat straw for alfalfa hay in total mixed diets formulated to 30% NDF. Forage NDF was from 1) all alfalfa hay, 2) 2/3 alfalfa hay, 1/3 wheat straw, 3) 1/3 alfalfa hay, 2/3 wheat straw, 4) all wheat straw. A significant ($P<0.05$) reduction in milk fat % and 3.5% fat-corrected milk was observed when the source of forage NDF was wheat straw only. No significant differences were observed for milk production or dry matter intake. If fiber requirements decrease as fiber digestibility decreases, one would have expected milk fat percentage to increase as fiber from wheat straw increased, as wheat straw fiber is considerably less digestible than alfalfa fiber. However, starch from grain increased as wheat straw increased NDF may be required in diets with low quality forage to counteract the negative effects of the increased NSC content on the rumen environment.

Feeding systems and feeding behavior probably have an effect on fiber requirements. Cows that consume grain continuously in small quantities may require less fiber in the diet than cows that consume grain in few large meals. Cows have a limited ability to buffer the lactic acid produced from starch fermentation. Only a certain amount of starch can be fermented per hour so that the buffering ability of the rumen is not exceeded. Once this happens the pH in the rumen will decrease and intake and digestibility may decrease. Feeding large amounts of grain in two meals per day is undesirable. Total mixed rations (TMR) restrict the amount of grain cows can eat in a meal. However, limited bunk space and animal competition can cause slug feeding with TMR's which is undesirable.

Physical characteristics of fiber other than particle size may affect fiber requirements. Fiber has been shown to be necessary for proper rumen function, however the mechanism by which fiber stimulates rumen movements and rumination is not clear. Weight and volume of rumen contents may play a role and may be affected by fiber bulk density, water holding capacity and functional specific gravity. These factors have not been investigated.

Fibrous feedstuffs are important in buffering the rumen (McBurney *et al.*, 1983). Differences in the direct buffering capacity of forages are significant and may have important implications for controlling the rumen environment of high producing cows. Alfalfa NDF has a greater buffering capacity than corn silage, timothy hay or wheat straw NDF. Cows consuming forages with high rumen buffering capacity such as alfalfa may have a lower requirement for fiber than cows consuming forages with lower buffering capacities such as corn silage. Buffer supplementation may also allow lower fiber levels and higher levels of grain to be fed. As grain is an inexpensive energy source compared to fat, supplementing rations with buffers to increase energy intake may be economically more advantageous than supplementing fat.

A significant problem that needs to be overcome when balancing rations for the optimum fiber level is how we account for differences among animals. Some nutritionists determine NDF requirements as a percentage of body weight (1.1% of BW seems to be common for mature animals). However, there has been no research to show that large mature cows require more (or less) fiber than small mature cows. It is commonly believed that larger cows have larger rumens and therefore may require more fiber to stimulate rumen movements and rumination. Although gut size is linearly related to body weight across all herbivores (Demment and Van Soest, 1982) there is no research to suggest that rumen size or capacity is related to body weight within a breed of cows. In fact there is evidence that shows that they are not related (Allen, 1990). Cows with larger rumens may actually require less fiber than those with small rumens at a given level of intake. When non-structural carbohydrates (especially starch) are fermented in the rumen considerable quantities of lactic acid may be formed reducing pH and increasing the risk of acidosis. Russell and Allen (1983) reported that much greater levels of lactic acid are produced by Streptococcus bovis at high liquid dilution rates. Cows with large rumens have a slower liquid dilution rate than cows with small rumens at the same level of intake. This may mean that less lactic acid is produced and less fiber may be needed in the diet to stimulate rumination and rumen buffering.

Robinson *et al.* (1986) found that cows in early lactation had considerably lower rumen pH than later in lactation when consuming the same diets. Cows in the first two months of lactation have considerably lower rumen capacity than later in lactation (Remond, 1988) and should have considerably higher dilution rates at the same level of intake. Dairy cattle in early lactation are more prone to fiber related problems such as acidosis than late lactation cattle and this may be at least partially due to a combination of low rumen capacity, high dilution rate and high lactic acid production. At this point there is no evidence to suggest that balancing rations for fiber requirements as a proportion of body weight is superior to balancing based on concentration of the diet dry matter.

Fiber Digestibility

Fiber digestibility differences can have a dramatic affect on intake, ration costs, and milk production. In the early 1970's Purdue researchers evaluated brown midrib corn vs normal corn (Muller *et al.*, 1972). Both of the corn forages were ensiled without ears and fed to growing lambs. The NDF contents of the silages were the same, however the two silages varied in lignin content (Table 3). The digestibility of the BMR was 10% greater than the NORMAL due to differences in fiber digestibility. The researchers found that the lambs eating the BMR silage had 29% greater dry matter intake than those eating the NORMAL silage. Because the BMR was more digestible, the digestible energy intake was 41% greater for the BMR. The few studies that have been done with dairy cattle have had confounded treatments (fiber levels varied) and the results are inconclusive.

Table 3. Composition, intake and digestibility of brown midrib vs. normal corn ensiled without ears.*

	BMR	NORMAL
Composition:		
Neutral-Detergent Fiber (%)	59.7	60.7
Crude Protein (%)	7.4	6.8
Lignin (%)	4.5	6.8
Dry Matter Digestibility (apparent)	61.4	55.9
Dry Matter Intake (% BW)	2.43	1.88
Digestible DM Intake (% BW)	1.51	1.07

* from Muller *et al.*, 1972

Regardless of any effect on dry matter intake of cows in early lactation, highly digestible fiber may increase milk production or reduce ration costs considerably. Fiber digestibilities of forages can vary by over 30% of DM depending upon type (grass, legume), maturity, hybrid (corn), and environment. A variation half this amount (15%) would result in a difference of 2.3 lbs of TDN per day (2.4 Mcal of NE_L) for a high producing cow consuming 15 lbs of NDF per day. This additional energy could theoretically be used by the cow to produce over 7 lbs of 3.5% fat corrected milk. Some of this additional energy may be used to replenish body condition. If this were the case less supplemental energy would be required for this purpose reducing ration costs considerably. If fat is being supplemented, the value of the additional energy from the fiber would be worth $.22 (animal fat) to $.38 (rumen inert fat) per cow per day using values from Table 1. The value of this amount of energy from corn would be $.12 per cow per day. Although fiber digestibility is greatly affected by the environment it can also be considerably affected by management. High grain yielding corn hybrids vary in fiber digestibility (Allen *et al.*, 1990) and there may be considerable opportunity to improve this trait by breeding. The effects of agronomic management (population, sowing date, N fertilization, etc.) on fiber digestibility for corn are just beginning to be explored. It is well established that fiber digestibility decreases as grasses and legumes mature. Fiber digestibility is rarely (if ever) considered when evaluating the whole farm economics of different forage cutting schedules. However, it can have significant impact on profitability by increasing production or reducing ration costs.

Site of Digestion of NSC

Just as there is a minimum fiber level which is necessary for normal rumen function there is a maximum amount of ruminally degraded NSC which can be added to increase energy density without upsetting rumen function. The physical and chemical properties of NSC affect this level. Rate of fermentation is an index of NSC availability and is affected by type of NSC and physical form. Sugars ferment rapidly in the rumen and rate of fermentation is limited to accessibility by microbes. Rate of starch digestion varies considerably with source. Corn starch is fermented slowly compared to the more easily solubilized starch from barley or wheat. Starch from waxy corn hybrids (nearly 100% amylopectin) is more quickly fermented than starch from hybrids with higher amylose contents. Sorghum starch is generally more slowly digested than corn starch. Grinding and high moisture fermentation have been reported to increase ruminal starch digestibility (Nocek, 1987). Steam flaking ruptures starch grains making virtually all starch ruminally fermentable (Nocek and Russell, 1988).

Although grain which is rapidly fermented has greater whole tract digestibility, it may be more desirable to feed some slower fermenting or rumen bypass starch. Starch that escapes rumen fermentation may be digested and absorbed as glucose in the small intestine. That which escapes digestion in the small intestine may be fermented in the large intestine. There is considerable opportunity to manipulate site of digestion of starch by grain processing. A recent study by University of Illinois researchers (McCarthy *et al.*, 1989) showed that considerable quantities of starch can be digested post-ruminally by dairy cattle in early lactation (Table 4).

Table 4. Site of starch digestion of ground shelled corn or steam rolled barley fed to Holstein cows in early lactation.*

	Corn	Barley
Dry matter intake (lb/day)	52.3	45.5
Starch intake (lb/day)	23.4	18.5
Rumen starch digestibility:		
Amount (lb/day)	11.4	14.3
Percent of starch intake	48.8%	77.4%
Rumen escape starch (lb/day)	11.9	4.2
Post-ruminal starch digestibility:		
Amount (lb/day)	10.2	3.5
Percent of rumen escape	86.1%	84.2%
Apparent total tract digestibility	93.2%	96.8%

* from McCarthy *et al.*, 1989

The cows were fed rations ad libitum consisting of alfalfa-grass silage (26%), corn silage (19%) and either ground shelled corn (45%) or steam rolled barley (49%) on a dry matter basis. The starch from corn had considerably lower ruminal digestibility than starch from barley (49 vs. 77%). However, dry matter intake as well as starch intake was significantly higher for the corn supplemented diet. This may be because intake was partially limited by the amount of starch digested in the rumen per hour. The slower rate of fermentation of corn starch may have been responsible for the increase in dry matter and starch intake. Because of the large increase in post-ruminal starch digestion for the corn supplemented diet, the whole tract digestibility of corn starch was less than 4% lower than for barley starch.

There are several implications of feeding rumen bypass starch:

1) If starch intake is kept constant, microbial protein production will decrease as rumen escape starch increases increasing the requirement for UIP. However, increases in dry matter and starch intake could actually increase microbial protein production.

2) If starch intake is kept constant, rumen pH should increase as rumen escape starch increases, decreasing risk of acidosis and possibly increasing milk fat and dry matter digestibility. The decrease in apparent starch digestibility as rumen escape starch increases may be more than offset by increases in the efficiency of rumen fermentation.

3) Increasing the ruminal escape starch concentration in the diet could increase energy intake by allowing considerably higher grain levels to be fed, reducing the need for fat supplementation and decreasing ration costs.

4) Heat stress may be reduced by increasing rumen escape starch by decreasing the heat of fermentation.

5) There is evidence to suggest that starch digested post ruminally may be used more efficiently than starch digested in the rumen (Nocek, 1990).

The effect of increasing rumen escape starch on the efficiency of starch digestion and absorption in the small intestine are largely unknown for high producing cows in early lactation. There is clearly a need for more research in this area. The efficiency of starch utilization from ruminal fermentation or from intestinal absorption must also be investigated. However, there is some evidence that energy intake can be significantly increased by increasing the rumen escape starch content of the ration of high producing cows in early lactation. When supplementing corn silage with high moisture corn, it may be advantageous to replace a portion of the high moisture corn with cracked or ground dried shelled corn to reduce the amount of starch fermented in the rumen.

Protein Degradability

Meeting the protein needs of high producing cows is a challenge. Sufficient degraded intake protein (DIP) must be provided to support microbial growth (NRC, 1989). Undegraded intake protein (UIP) must be provided to balance any deficit between the intestinal supply of microbial protein synthesized in the rumen and the requirements of the cow. Cows in negative energy balance often require a supplemental source of slowly degraded protein to balance this deficit (Nocek and Russell, 1988). Supplementation is not generally required with cows in positive energy balance (Ørskov, 1987; Robinson and Kennelly, 1988). An accurate estimate of UIP requirements is important for high producing cows. It is impractical to overfeed UIP as feeds high in UIP are expensive. However, milk production will decrease to the extent that UIP is limiting, significantly affecting profitability with UIP deficient diets.

Although ruminal degradability of protein clearly must be considered when balancing rations for high producing dairy cattle several problems limit our ability to do this with any precision:

1) The degradability of protein in feeds is extremely variable (especially for processed feeds and forages), limiting the usefulness of book values.

2) Repeatable, accurate and inexpensive laboratory methods to predict protein degradability are not currently available.

3) We currently have a poor understanding of the factors affecting microbial protein production which is necessary to determine UIP and DIP requirements:

   a) Variations in microbial growth rates (.04 to .25 /h) can cause a 44% variation in yield (Nocek and Russell, 1988).
   b) Microbial yield may be increased as much as 18.7% as peptide concentration is increased with sufficient non-structural carbohydrate (Russell and Sniffen, 1984).
   c) Microbial yield may vary as much as 100% as the ratio of NSC to rumen degradable CP is altered (Hoover, 1987).

The effectiveness of supplemental resistant protein depends to a large extent on the forage source. Silage based diets require greater levels of UIP than rations utilizing hay (Voss *et al.*, 1988). Replacement of grain with fat may increase the requirement for undegraded intake protein (UIP) by 57 grams per Mcal of NE_L from fat because of a decrease in rumen fermentable organic matter and a subsequent decrease in rumen microbial yield. However, fat addition has been reported to increase microbial efficiency and alter feed protein degradation in the rumen (Hoover, 1987). Recommendations for increasing UIP when feeding fat are difficult as the effects of the added fat on rumen protein metabolism are not completely understood. It appears that <u>up to</u> a third of a pound of UIP should be added per pound of fat in the ration above 3% of dry matter.

It often difficult to meet the requirements for UIP without exceeding the requirements for DIP when feeding a high quality legume silage (>20% CP) as the only forage. Excess rumen degradable protein may reduce reproductive performance (Ferguson and Chalupa, 1989) and must be excreted at an energy cost of over 12 kcal of DE /g nitrogen (Tyrrell *et al.*, 1970). Overfeeding protein by 2% of DM may cost a cow consuming 50 pounds of dry matter 0.36 Mcal of NE_L to excrete. In these cases it is desirable to partially substitute a lower protein forage such as corn silage for alfalfa in the ration to allow supplemental UIP without overfeeding DIP. It is rare that insufficient DIP is included in the diet of high producing cows consuming legume silage. However, with hay or corn silage based diets DIP may be limiting at times during the day, particularly if the NSC and the protein source are fed separately. Insufficient DIP will reduce the mass of fiber digesting microbes which may reduce fiber digestion and decrease DMI when physical factors influence intake. Total mixed rations should provide even rumen ammonia levels and allow a more efficient utilization of DIP.

The quality of the protein reaching the small intestine must be considered when feeding high producing cows. Although amino acid (AA) requirements for ruminants have not been established, lactating dairy cattle have responded to post-ruminal infusions of individual amino acids (Schwab *et al.*, 1976). It appears that lysine and methionine may be limiting in certain rations (Schwab *et al.*, 1976; Schwab *et al.*, 1988; Bozak and Schwab, 1988). Protein supplements should be chosen with AA compositions which will complement the forage. Corn silage based diets should not be supplemented with corn based by-products because lysine may be limiting. Corn byproducts may be used to supplement alfalfa based diets. Animal byproducts such as meat, blood and fish meal are high in UIP and contain a balanced array of amino acids. Depending upon price they may be an excellent way of providing high quality protein to the intestine.

Consistency of Forage Quality

The success of a feeding program for high producing cows depends to a large extent on the consistency of the feed supply. The optimal frequency of feed testing and ration adjustment is directly dependent on the variation expected in feed quality over time. This is particularly true for forages as quality is extremely variable with type, maturity and variety. If variation in forage quality over time is extreme, rations cannot be properly balanced. By the time the forage is tested and the ration is adjusted, forage quality will have changed. An unnoticed decrease in forage quality will reduce milk production and body condition as energy and protein intake will be limited for high producing cows. An increase in forage quality which is unnoticed will not only cause inefficient nutrient utilization but will result in inadequate fiber levels to support optimal rumen function. The loss in production from milk fat depression and a decreased DMI can significantly affect profitability. Storing forages by quality will reduce variation at feeding and will decrease feed costs by allowing high quality forages to be fed to animals with the greatest nutritional requirements.

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