

Optimizing and Evaluating Dry Matter Intake of Dairy Cows

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■ Take Home Messages

- ▶ Dry matter intake (DMI) is largely regulated by the filling effect of the diet and by the supply of dietary energy relative to energy requirements of the cow.
- ▶ For diets based on hay-crop forages, concentrations of forage NDF >25% of the diet DM can substantially limit intake. Early lactation cows are especially sensitive to high concentrations of forage NDF.
- ▶ For corn silage-based diets, forage NDF concentration is not a major factor affecting intake; in vitro NDF digestibility is a better index of intake.
- ▶ Diets that contain excessive quantities of highly digestible starch and long chain fatty acids can depress DMI because the supply of energy-yielding compounds exceeds the capacity of the animal to metabolize them.
- ▶ Poor facilities and management practices such as improperly designed feed bunks, limited water availability, overcrowding, and incorrect cow grouping can be major barriers to high DMI.
- ▶ Dry matter intake is clearly the most important factor affecting milk yield and it needs to be evaluated when attempting to solve production and other nutrition problems; however, group feeding limits the value of DMI data in ration formulation and evaluation.

■ Introduction

Dry matter intake (DMI) is the single most important factor affecting milk production, feed costs, and ultimately profitability. On average a 1 kg/day increase in DMI can support 2 to 2.5 kg of additional milk. Feed costs are often less (per unit of milk produced) as DMI increases because greater DMI means that nutrient concentrations of the diet can be reduced to maintain intake of specific nutrients. Less nutrient-dense diets are generally less

expensive than more nutrient-dense diets. In most situations, greater DMI is desirable because it results in increased milk yield or improved body condition; however, with some diets, greater DMI reduces digestive efficiency, does not increase milk yield, and can increase feed costs per unit of milk. Formulating efficient and profitable diets requires accurate estimates of DMI; therefore, the factors influencing DMI must be understood.

■ Factors Affecting Dry Matter Intake

Dry matter intake is a function of the cow, the diet, environment, facilities and management and an almost infinite number of interactions among those factors. Actual intake is a function of the first limiting factors. For example, intake of a very good diet may be low because feeding management is such that it doesn't allow cows to eat enough (Figure 1).

Animal Factors

The primary animal factors that affect DMI are milk yield, stage of lactation, and body weight (BW). Sickness and injury have substantial negative effects on DMI but they are beyond the scope of this article. Milk yield is the major source of variation in DMI among cows in a herd. A difference of 20 kg/d in milk yield (many herds will have a greater range in daily milk yields) could cause a difference in DMI of 6 to 7 kg/d. Although milk production drives DMI, in the short term cows can mobilize body fat to provide energy to support milk production, which allows DMI to lag behind milk production. If DMI is limited by diet or management, once body energy stores are depleted milk yield will drop to match dietary supply of energy. Within a breed, BW is the least important animal source of variation for DMI; a difference in 100 kg of BW would likely result in approximately 1.5 kg of DMI change (at equal milk yield and days in milk). Stage of lactation has significant effects on DMI. Daily DMI of a cow may be 5 kg less in early lactation than in later lactation, even when the cow is producing similar amounts of milk.

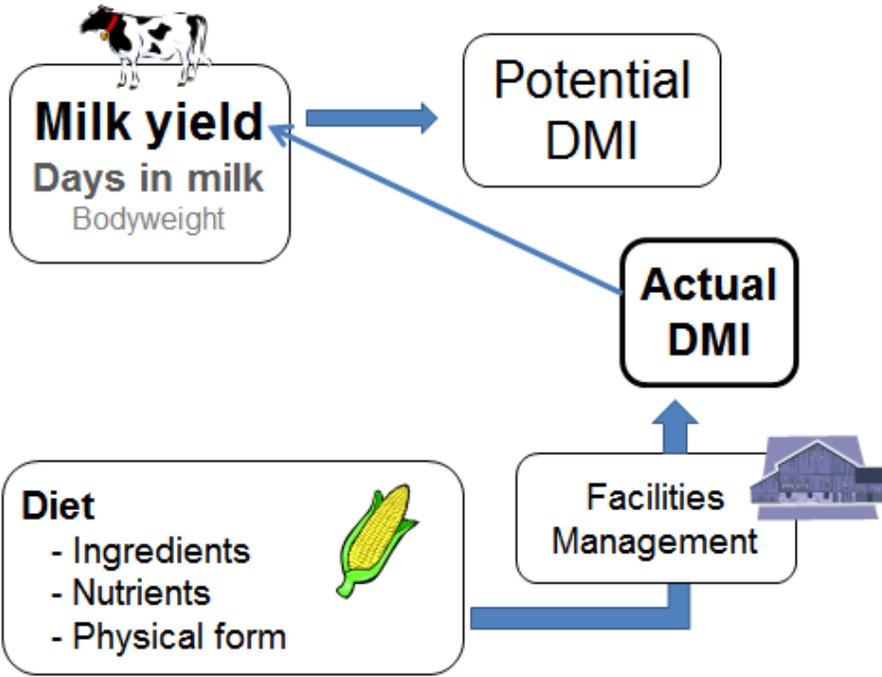


Figure 1. Potential dry matter intake is a function of the cow but actual intake depends on the diet, facilities, environment and management and will never be greater than potential intake (usually it is less). The goal is to provide a good diet and remove facilities and management factors that limit intake.

Diet Factors

Substantial deficiencies or excesses of minerals (especially sodium, potassium and sulfur) can reduce DMI, but for most situations these should not occur (i.e., formulate diets to provide approximately NRC (2001) requirements). Several studies have shown that increasing rumen degradable protein (RDP) concentration stimulates DMI. Using the NRC model, diets should contain at least 10% RDP to maximize DMI (some studies show positive responses up to 11.5% RDP). Spoiled and moldy feeds and feeds that are difficult or painful to chew (e.g., woody plants) reduce DMI, and diet formulation cannot overcome these problems. Those types of feeds should not be fed.

Diet digestibility is probably the most important factor controlling DMI. Almost 50 years ago, researchers described how digestibility regulates DMI and although significant advancements have been made in our understanding of the physiological and biochemical factors involved, the basic concepts remain

valid. They determined that DMI increased with increasing diet digestibility until a certain point and then DMI decreased as digestibility continued to increase (Figure 2). The response of DMI to changing digestibility is divided into a phase in which gut fill limits DMI (lower digestibility) and a phase in which substrate utilization or oxidation limits DMI (higher digestibility). The digestibility at which DMI control changes from fill-limiting to substrate oxidation limiting is not constant. Higher producing cows have a greater capacity to metabolize nutrients; therefore, fill limits DMI at a greater digestibility than it would for lower producing cows. Other diet factors such as forage particle size also can influence the point at which regulation switches from fill to oxidation limited.

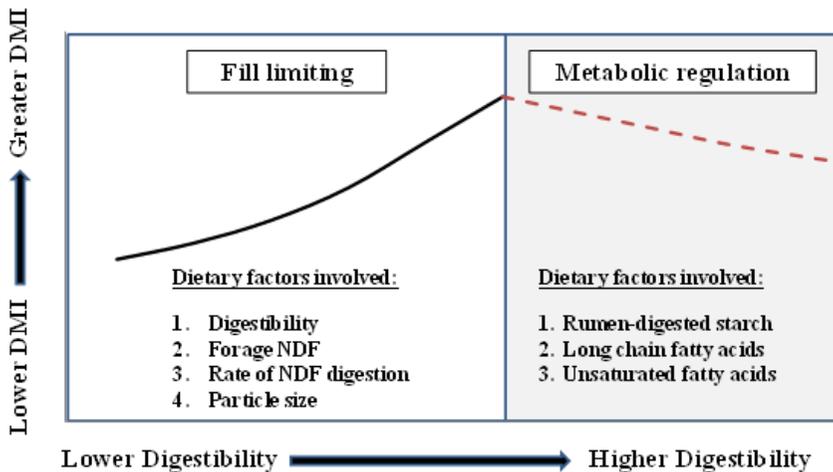


Figure 2. Relationship between diet digestibility and DMI. At lower digestibility, fill limits DMI but at a point (which is dependent on cow and diet factors) DMI becomes controlled by the balance between energy supply and energy requirements (Derived from Conrad et al., 1964 and other sources).

Fill-Limitation

The digestive system has a finite capacity and once full, more feed can be consumed only after feed present in the tract is either digested or passed. The primary dietary factors affecting fill are inherent digestibility (i.e., digestibility when measured at approximately a maintenance level of DMI), rate of digestion, particle size, and rate of particle size breakdown. Because most forages have lower inherent digestibility than most concentrates and because forages usually have larger particle size, reducing the forage to concentrate ratio (F:C) by replacing various forages with concentrates usually increases DMI. However, F:C is a very crude descriptor because of substantial variation in nutritional quality among forages and concentrates and

often DMI responses to changes in the forage to concentrate ratio are inconsistent. For example, decreasing F:C increases DMI much more when immature grass silage is fed than when an immature legume silage is fed (Figure 3). The effect of F:C on DMI also differs between hay crop forages and corn silage and on whether the concentrate is starch or fibrous. Because of these issues, F:C is a poor indicator of potential DMI of a diet.

To account for differences among forages, the concentration of forage NDF (fNDF) is a better index of fill potential of a diet and a better predictor of DMI than forage to concentrate ratio. Numerous studies have shown that as the concentration of fNDF increases, DMI decreases (see review by Allen, 2000). The concentration of fNDF in a diet can be reduced by replacing forage with concentrate and by improving the quality of the forage. When a more mature (i.e., high NDF) hay-crop forage replaces an equal quantity of a less mature forage in a mixed diet, the concentration of fNDF increases and DMI usually decreases; however, if the forage replacement is on an NDF basis so that fNDF concentration is constant, DMI is often not affected by forage maturity. For corn silage-based diets, varying the concentration of NDF in the silage and subsequently the concentration of fNDF in the total diet has little effect on DMI. A primary reason for the difference in the DMI response to increasing fNDF concentrations between hay-crop and corn silage is that for hay-crop forage, the concentration of NDF is negatively correlated with NDF digestibility. For corn silage, NDF concentration is not well correlated with maturity or digestibility. The concentration of fNDF accounts for more variation in DMI than does F:C, but because of differences in both the rate and extent of NDF digestibility among forage classes concentration of fNDF is not always adequate.

Many labs can now measure in vitro NDF digestibility (IVNDFD) of forages. The IVNDFD of a forage is positively correlated with DMI; however the correlation is limited to within forages classes such as grass, legumes, and corn silage. On average, a 1 unit increase in IVNDFD was associated with an increase of 0.14 kg/d in DMI and 0.22 kg/d increase in milk yield (Oba and Allen, 2005). This relationship is only valid within forage class comparisons and when diets do not differ greatly in fNDF concentration. If a diet has high IVNDFD and a very high concentration of fNDF, DMI may be less than if the diet has lower IVNDFD and lower fNDF (Figure 4).

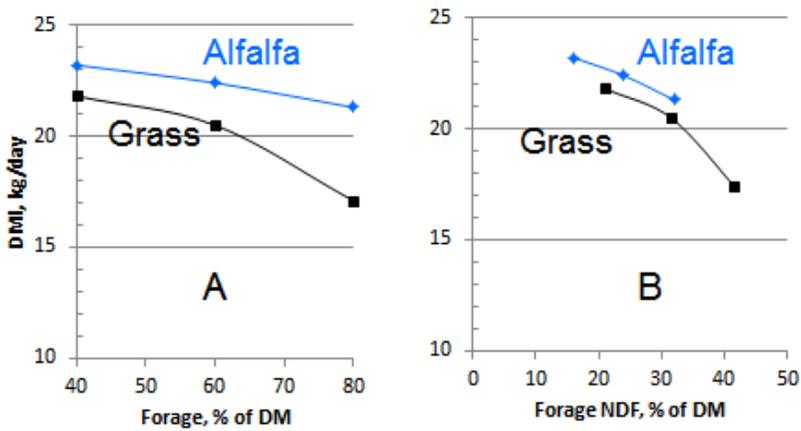


Figure 3. Increasing the percentage of forage in diets (increasing the forage to concentrate ratio) usually reduces feed intake but the effect depends on the type of forage (Panel A). When data are expressed on an NDF basis, the effect of increasing forage on intake is more constant across forage types (Panel B). Data derived from Weiss and Shockey (1991)

Particle size of forage can influence rumen retention, fill, and DMI, but DMI responses to changing forage particle size are inconsistent. Often, decreasing forage particle size increases DMI but just as often it has no effect. Generally, but not always, reducing particle size of forage increases DMI when fed in high forage diets that include lower quality forage (i.e., diets with high fNDF concentrations). Reducing forage particle size in diets with high concentrations of starch often has no effect on DMI.

Practical Implications: Fill is often a major limitation of DMI resulting in low milk yields and poor body condition. Fill is most likely to restrict DMI in the first half of lactation. To increase DMI when it is restricted by fill:

- ▶ Harvest and feed immature forages. Forage is usually the limiting factor on most farms. Improving forage quality will almost always improve milk production and body condition. Always feed the most digestible forages to cows in early lactation. For hay-crop forages NDF concentration is a good index of quality but for corn or sorghum silage IVNDFD is a better index of quality.
- ▶ Avoid feeding diets with >25% fNDF because they will reduce DMI. The concentration of fNDF should probably be closer to 20% in the first third of lactation and when mature forages are fed.

- Excessively long forage particles can increase fill and reduce DMI, especially when fNDF concentrations are high (lower quality forages and high forage diets).

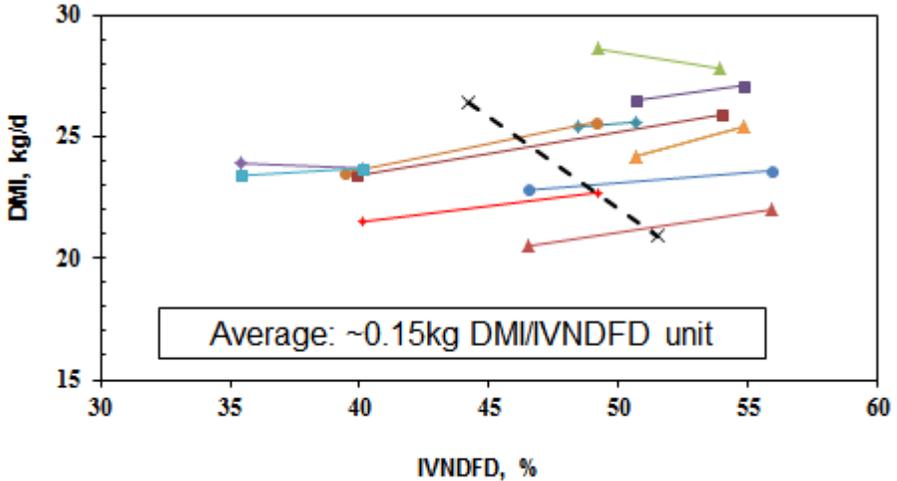


Figure 4. Relationship between in vitro NDF digestibility (IVNDFD) and dry matter intake within several studies (figure derived from Oba and Allen, 2005). The bold, dashed line is from a study (Dann et al., 2008) in which the concentration of forage NDF increased from 18 to 28% of diet DM as IVNDFD increased. This shows that although high IVNDFD is related to high DMI, its effect can be overwhelmed by large increases in the concentration of dietary forage fiber.

Substrate Oxidation Limited

The premise of this mode of intake regulation is that cows have a finite capacity to metabolize energy yielding substrates (i.e., milk yield and rate of growth and body fattening have genetically set limits) and once that limit is reached, feedback responses occur and the cow stops eating (Allen et al., 2009). Under typical conditions, long chain fatty acids (LCFA), propionate, and amino acids are the major substrates for liver metabolism of dairy cows. Under most practical situations, amino acid supply appears to have little influence on DMI. However, increasing dietary concentrations of LCFA often reduces DMI. This effect is, at least in part, caused by limits on liver oxidation of LCFA. The effect of dietary LCFA on DMI is influenced by milk fat yield (greater yields of milk fat should allow increased supplementation of LCFA without adversely affecting DMI) and on body fat mobilization. In early lactation, body fat is mobilized providing additional LCFA to the liver thereby

making DMI depression more likely when supplemental LCFA are fed. Some but not all studies have found greater DMI depression when less saturated LCFA were fed compared with saturated LCFA.

The primary dietary factor that promotes increased ruminal production of propionate is the amount of ruminal fermentable starch (RFS) consumed. A standard analytical method to measure RFS does not exist currently so qualitative, rather than quantitative, relationships will be discussed. The concentration of RFS is a function of the concentration of total starch and the fermentability of starch. Fermentability is dependent on type of grain (cereal grains > corn), particle size (small particles > large particles), storage system (high moisture > dry) and steam flaking (less dense flakes > more dense flakes). Based on the oxidation theory, when cows reach their capacity for the liver to oxidize substrate, increasing the concentration of RFS will reduce DMI. For example, in diets with high concentrations of starch, replacing a less fermentable starch source (e.g., dry ground corn) with a highly fermentable source (e.g., high moisture corn or barley) can reduce DMI.

Replacing starchy feeds with concentrate byproducts (e.g., distiller grains and soyhulls) reduces dietary starch concentration but DMI responses have been variable. In general, replacing starch concentrates with fibrous concentrate usually increases DMI (assuming no change in fNDF concentration or other nutrients). This means that diets based on byproducts tend to have higher DMI but equal milk yields as corn or barley grain based diets. Therefore, feed efficiency (milk/DMI) tends to be lower.

Practical Implications: In the first half of lactation, the goal of diet formulation is usually to maximize energy intake because much of the energy is partitioned towards milk rather than body stores. Therefore, diets should contain substantial concentrations of non-filling fermentable energy (this is usually starch) and in some situations increased concentrations of LCFA. Excessive concentrations of starch and LCFA must be avoided because they decrease DMI and can result in reduced energy intake. In later lactation, energy is partitioned more toward body stores and excessive energy intake can lead to fat cows that are at high risk for numerous problems. In later lactation, energy intake should be regulated via altering fill potential.

- Limit the concentration of LCFA (from basal ingredients and supplements to less than 5% in early lactation (approximately the first 4 weeks) because the depression in DMI usually eliminates the effect of increased energy density. Unsaturated LCFA often have a greater effect than saturated LCFA.
- At later stages of lactation higher concentration of dietary LCFA often reduces DMI but can increase energy intake. Diets with higher LCFA

should be formulated assuming a lower than expected DMI (i.e., increased concentrations of nutrients).

- In moderate starch diets (22-28%) replacing starchy concentrates with fibrous concentrates often increases DMI by high producing cows, but, because of lower digestibility of fibrous feeds, may not increase energy intake (feed efficiency may decrease). Diet formulation should be based on expected higher DMI (projected feed costs should also assume higher DMI).
- In moderate to high starch diets (25 to 30%) replacing dry ground corn with high moisture corn, steam-flaked corn, or wheat or barley) often decreases DMI. Diet formulation should be based on reduced DMI.

Management and Facilities

Intake of a good diet will not be optimal when access to feed and water is limited. Facilities and management practices should encourage feed consumption. Replicating experimental units is difficult when studying effects of facilities and management on production, which limits the amount of experimental data that is available. However, several factors have been identified that affect DMI and feeding behavior. With Holstein cows producing <18 kg of milk/day, bunk space did not affect milk yield until it was <30 cm/cow. More recent data with higher producing cows is not available but studies have shown that feeding behavior is affected (e.g., rate of eating increased) when bunk space is less than 60 cm/cow. Feed bunk design including barrier system may also affect intake but experimental data are limited. Studies have shown that increasing the number of times cows are fed each day can increase DMI but results have not been consistent. It appears that increased number of feedings is most beneficial when highly fermentable diets are fed and bunk space is limiting. Grouping first lactation cows separate from mature cows may not affect DMI but can improve feed efficiency. Ensuring feed is available at least 22 hour per day (i.e., feeding for 2 or 3% feed refusal or weighbacks) may increase DMI and separating time of fresh feed delivery from milking time may alter feeding behavior and increase DMI. Heat stress significantly reduces milk production which then leads to reduced DMI (not vice versa) and diet formulation cannot overcome heat stress. Effective heat abatement programs must be implemented to maintain high production and high DMI during hot seasons.

■ Evaluating DMI on Farms

Although DMI is critical to ration formulation and evaluation and to solving nutritional problems, actual cow DMI is rarely known on commercial farms because cows are fed in pens. Farmers may know the amount of DM consumed by a pen of cows but they will not know how much a particular cow consumed. In large pens, a very significant change in DMI by a subset of

cows (e.g., fresh cows) may have almost no effect on DMI of the pen and problems may go unnoticed and unresolved for long periods. The average cow in a pen might be fed adequately but a fresh cow within that pen may not and poor nutrition in early lactation can have a substantial negative effect on milk yield for the entire lactation.

Value of DMI Data for Pen Fed Cows

Pen average DMI is an important metric for evaluating diets when cows within the pen are similar (same parity: first lactation vs. all others; same stage of lactation: <1 month after calving vs. all others; and somewhat similar in milk yields). However, cow grouping within pens cannot be done solely on nutritional needs. Facilities (e.g., pen and milking parlor size), feed mixer capacity, and labor costs and availability must be considered. Because of these factors, pens of cows are often quite heterogeneous. The greater the diversity of cows in a pen, the less value should be placed on pen average DMI. With large pens of cattle, pen average DMI is essentially useless in detecting one or two sick cows. For example, in a pen of 100 cows, if one cow became so sick it stopped eating completely; pen average intake would decrease by only 1% (e.g., 22.5 kg/day to 22.3 kg/day). Pen average DMI can even be insensitive to changes in DMI of subsets of cows within the pen. For a typical herd with an average production of 10,000 kg/305 day lactation, approximately 10% of the DM consumed by the lactating herd will be by cows <1 month in lactation. If the farm had a single pen for all lactating cows and if something drastic happened to the fresh cows that caused a 20% decrease in DMI, pen average intake would only decrease from 22.7 kg/d to 22.4 kg/day. This small change would probably not be noticed by most farmers or nutritionists even though a 20% decrease in DMI in early lactation cows could severely impact long term herd production. Smaller, more homogenous (based on stage of lactation) groups of cows make it much easier to detect DMI problems (Figure 2). High DMI is critical in early lactation because it will prevent excessive losses of body condition which should improve fertility and allows high peak milk production (increasing peak milk by 1 kg/d results in a 225 kg increase in milk yield for the lactation).

Evaluating Nutrition in Pen-Fed Herds

Evaluating the adequacy of a diet using pen average DMI and pen average milk yield is often insufficient to discover current and potential nutrition-related problems. However, body condition score (BCS) can be monitored on individual cows and can be used as a proxy to individual DMI. The BCS profile (degree of loss in BCS and the stage of lactation when the nadir occurs) can be used to evaluate nutrition and feeding management of early lactation cows in pen situations. Cows in early lactation are expected to lose some body condition; however, if many cows lose more than 0.5 points (a loss of 0.25 is a good average), fresh cows are likely not eating enough.

Forage quality, dietary NDF and especially fNDF, RDP and LCFA should be evaluated. Dry matter intake by fresh cows will be reduced more than DMI of later lactation cows when diets have too much fNDF or LCFA. Feeding facilities and feeding management should also be investigated if fresh cows are losing too much body condition in early lactation.

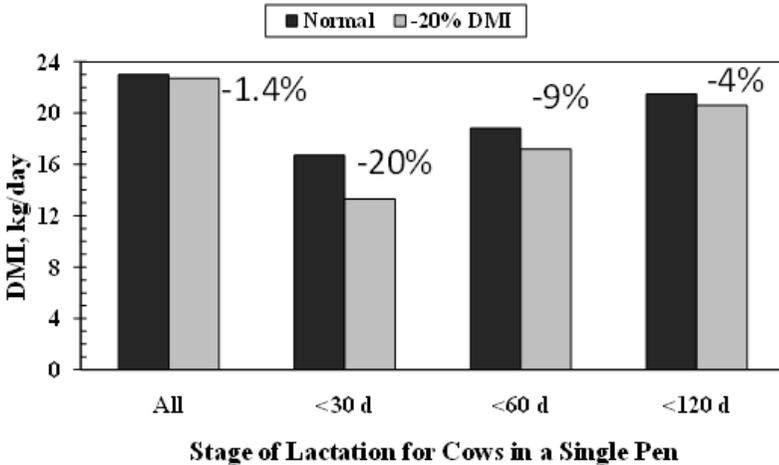


Figure 4. Effect of cow grouping (1. All cows in the herd in a single pen, 2. All cows <30 days in milk in a single pen; 3. All cows <60 DIM in a single pen and 4. All cows <120 DIM in a single pen) on the ability to detect changes in DMI of early lactation cows (<30 DIM). The dark bars show the expected pen average DMI if all cows within the pen were consuming normally. The light bars show the expected pen average DMI if only cows <30 DIM consumed 20% less dry matter than expected. As groups become more diverse with respect to stage of lactation, pen average DMI becomes insensitive to a substantial decrease in DMI of early lactation cows.

■ Conclusions

In early lactation, fill usually limits DMI; therefore, diets must be formulated using the highest quality forage available and contain adequate but not excessive amounts of forage NDF. Excess supply of rumen fermentable starch and long chain fatty acids can reduce DMI, especially in later lactation, and diet formulation should reflect the expected decrease in intake. Intake is a critical measure but pen average DIM can be insensitive to important changes in intake by subsets of cows such as early lactation cows. If possible, cows at similar stages of lactation should be grouped together; however, monitoring individual cow BCS can be used to evaluate energy intake, especially in early lactation.

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