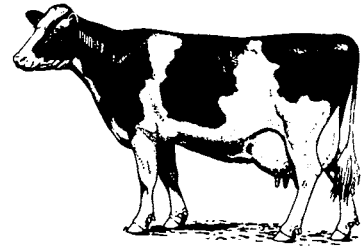


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Dairy Update

**DRY MATTER INTAKE AND FEEDING MANAGEMENT
OF LACTATING DAIRY COWS**

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High producing dairy cows require and have a strong drive to consume feed (nutrients). The selection of dairy cattle for increased milk production has propagated this drive for nutrients (7). Therefore, maximum dry matter intake (DMI) can be attained by keeping mangers or bunks full of feed. This is a feasible approach, but many factors besides this affect DMI. Also, feed is the single most expensive item in producing milk. Thus, many questions about optimizing DMI and how dairy cattle are fed deserve attention. How much do dairy cattle eat in relationship to milk production? What nutrients affect DMI? Does method of feeding or the feeding environment affect intake? This paper will provide some insight into these questions and others that will help you in feeding dairy cows more effectively and efficiently.

EATING BEHAVIOR

Research at Michigan State University (20) compared eating habits of high and low producing dairy cows. Twelve Holstein cows with milk productions between 50 and 100 lb/day were monitored for 10 days starting the ninth week of lactation. The six highest producing cows averaged 24 lb more milk per day than the six lowest cows. The high producing cows had the following characteristics:

1. Ate more. The top six cows consumed an average of 13 lb more dry matter (DM) per day than the lowest six cows (55 vs 42 lb/day).
2. Ate larger meals. Top cows did not eat more times per day (average of 11 meals/day) than the lower producing cows, but they ate more per meal (5.0 vs 3.8 lb DM).
3. Ate faster. Time spent eating was similar for all cows at 27 minutes per meal or 300 minutes per day. If high producing cows do not spend any more time eating per day but consume more DM per day, they must eat faster. Top cows ate aggressively consuming an average of 11 lb of DM per hour of eating compared to 8.4 lb for low producers.

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4. Ruminate longer and more feed per hour. Average time spent ruminating by all cows was 7.5 hours or 31% of the day. High producers spent 459 minutes ruminating and did it in 13 periods per day compared to low producers at 436 minutes in 14.5 periods. Thus, top cows averaged 7 lb of DM per hour ruminated compared to 6 lb for low producers.
5. Drank more water. High producing cows averaged 15 drinking periods per day with an average intake of 1.5 gallons per drink. High cows consumed 6 gallons more water per day for 24 lb more milk per day than lower producing cows.

Some findings by Albright (2) in a summary of eating and feeding behavior of dairy cattle are:

1. Cattle eat more when in a group than when individually isolated.
2. Most eating and the largest consumption of feed occurs at sunrise and secondarily at sunset.
3. Cows eat faster when large quantities of feed are fed than when small amounts (< 3 lb) are fed.
4. The optimum position for eating is with the head down in a grazing position. Little or no sorting or tossing of feed occurs when offered at ground level.

FEED INTAKE

The most commonly accepted theory regarding feed intake regulation in dairy cows today is related to gut fill and physiological feedback. When highly digestible feeds are fed, energy intake is expected to reach a plateau and DMI may actually decline with increasing energy density in the diet. Metabolic forces apparently regulate intake under high energy feeding conditions. Rumen fill appears to be the limiting DMI factor when low quality, indigestible feeds are fed (44). Recently, Ketelaars and Tolkamp (35) reviewed data based on and related to these concepts. They determined gut fill and physiological regulations (energy feedback) are incomplete and an unsatisfactory explanation for observed variations in feed intakes. Their conclusion was feed intake is more related to basal metabolism and efficiency of energy utilization (genetically determined) as relations between DMI, rates of digesta passage and rumen fill do not support physical limitation theories.

DMI is the foundation on which rations are formulated. Over the years, several equations have been developed in an attempt to predict DMI's of dairy cows during various phases of lactation. Common variables used in equations to refine intake predictions are: daily milk, body weight (BW), milk fat test and days in milk (DIM) or stage of lactation. Other variables such as environment, body condition and individual nutrients (fiber, lignin) have been incorporated into some models to improve predictions. Below are some example prediction equations.

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National Research Council

In the most recent publishing (47), the committee acknowledged criticism that the 1978 estimates of DMI were lower than field observations. Thus, the most recent equation predicts amounts cattle are required to consume to achieve energy equilibrium.

$$[1] \quad \text{DMI, kg} = \frac{\text{NE}_L \text{ required (Mcal)}}{\text{NE}_L \text{ concentration of diet (Mcal / kg)}}$$

Net energy required is defined as that necessary for maintenance, milk yield and replenishment of lost weight. Suggested modifications for expected DMI are: an 18% reduction during the first three weeks of lactation and .02 kg DM reduction per 100 kg live weight for each 1% increase in moisture content of the diet above 50% when fermented feeds are being fed.

Agricultural Research Council

The Agricultural Research Council (1) has based their prediction of DMI on metabolic live weight ($\text{BW}^{0.75}$), 4% FCM (kg/day) and month of lactation:

$$[2] \quad \text{DMI, kg} = [.135 (\text{BW}^{0.75} \text{ kg}) + (\text{FCM1})] \times (\text{MONTH1})$$

Modifications to DMI are $\pm .2$ kg for each 4% FCM above or below 16 kg respectively and a month of lactation factor ranging from a low of .81 during the first month of lactation to a high of 1.09 during the fifth month of lactation.

Net Carbohydrate and Protein System

A recent paper by Fox et al. (25) reported a prediction equation by Milligan et al. (46) for use with the net carbohydrate and protein system. Main factors used were BW and 4% FCM (kg/day) with temperature and mud as modifying factors:

$$[3] \quad \text{DMI, kg} = [.0185 (\text{BW kg}) + .305 (4\% \text{ FCM})] \times (\text{TEMP1}) \times (\text{MUD1})$$

Temperature modifiers ranged from .65 at greater than 35°C to 1.16 at less than -15°C, and mud modifiers were .85 and .7 for exposure to 10 to 20 cm and 30 to 60 cm of mud, respectively.

Neutral Detergent Fiber (NDF) Intake

DMI in dairy cows is thought to be regulated by two physiological conditions, eat to satisfy energy requirements or fill capacity, whichever occurs first. Mertens (43, 44) has proposed that NDF is the nutrient component regulating gut fill and has proposed the following maximum DMI, as regulated by gut fill:

$$[4] \quad \text{DMI, kg} = \frac{.011 (\text{BW kg})}{\% \text{NDF in diet (DM basis)}}$$

Kertz Equation

Kertz et al. (34) developed a set of equations that incorporated the factors: week postpartum, 4% FCM (kg/day), BW (kg) and a first lactation correction factor. They are defined as follows:

$$[5] \quad \text{DMI for week postpartum (kg/day)} = \text{Intercept} + \text{kg FCM} \times \text{FCM factor} + \text{BW} \times \text{BW factor}$$

| Week postpartum | Factors | | |
|-----------------|-----------|----------------|----------|
| | Intercept | 4% FCM, kg/day | BW, kg |
| 1 | 13.08 | .1468 | -.003912 |
| 2 | 12.04 | .1951 | -.001136 |
| 3 | 10.89 | .2061 | .002867 |
| 4 | 0.19 | .2365 | .004073 |
| 5 | 9.32 | .3031 | .003478 |
| 6 to 8 | 9.09 | .3090 | .005115 |
| 9 to 13 | 7.43 | .3008 | .010060 |
| 14 to 20 | 6.65 | .3428 | .010553 |

The adjustment for first lactation animals is -1.3 for all periods.

May Equation

Feed intake data from 13 lactating cow studies in University of Minnesota facilities were summarized by May (42). A total of 798 cows (40% first lactation) were included in the analysis which covered weeks 1 to 44 of lactation. The derived equation for multiparous cows is:

$$[6] \quad \text{DMI, kg} = .959 + 1.05 \times \text{week} - .042 \times \text{week}^2 + .0005 \times \text{week}^3 + .012 \times \text{BW (kg)} + .354 \times 4\% \text{ FCM (kg/day)} - 1.966 \times \text{milk fat \%} + .941 \times \text{milk protein \%}$$

week = week of lactation

Edwards Equation

Edwards (24) modified a DMI equation developed by Conrad (17) adjusting for DIM.

$$[7] \quad \text{DMI, kg} = -3.056 + .011 \times \text{BW (kg)} + .03636 \times \text{BW}^{0.75} (\text{kg}) + .3364 \times 4\% \text{ FCM} + .0364 \times \text{DIM} - .000071 \times \text{DIM}^2$$

Spartan Dairy Ration Equation

The equation for DMI of lactating cows used in the Spartan Dairy Ration program (58) is:

$$[8] \quad \text{DMI, kg} = A \times [.02 \times \text{BW (kg)}] + .3 \times 4\% \text{ FCM} + B \times \text{gain / d}$$

$$A = 1 \text{ if DIM} > 80 \text{ DIM}$$

$$A = \frac{20 - .25 \times \text{DIM}}{100} \text{ if } < 80 \text{ DIM}$$

$$B = 1 \text{ if gain is positive and } 0 \text{ if gain is negative or no gain}$$

A comparison of six equations for a 1,350 lb cow at 90 DIM producing milk of a 3.6% fat and 3.2% protein with no weight gain is shown in Table 1. Equations 5 and 6 are very close in their predictions and suggest the highest DMI. Equations 7 and 8 are very similar in their predictions but are slightly lower than equations 5 and 6. Equation 3 is lower than 7 and 8 in predicted DMI but not as low as equation 2. The variations in DMI predicted by these equations indicate nutritionists cannot rely on DMI based on equations to formulate rations. These are only guidelines and are to be used as such. DMI needs to be measured on farms if accurate ration formulations are to occur. When DMI deviates considerably from an accepted equation prediction, nutritionists must investigate causes of the discrepancies and analyze reasons for the difference. The remainder of this paper will identify some causes or reasons why DMI on a farm may vary from predicted values. The true DMI, however, is an accurate measure of what cows are actually consuming on the farm.

Table 1. Comparison of DMI predicted by 6 equations

| 4% FCM | Equation number | | | | | |
|--------|----------------------|------|------|------|------|------|
| | 2 | 3 | 5 | 6 | 7 | 8 |
| lb | -----lb DMI/day----- | | | | | |
| 60 | 40.7 | 43.3 | 48.0 | 47.5 | 44.1 | 45.0 |
| 70 | 42.6 | 46.3 | 51.0 | 51.0 | 47.5 | 48.0 |
| 80 | 44.6 | 49.4 | 54.0 | 54.5 | 50.8 | 51.0 |
| 90 | 46.5 | 52.4 | 57.0 | 58.0 | 54.2 | 54.0 |

NUTRIENTS RELATED TO FEED INTAKE

Moisture or dry matter (DM)

Labor efficient methods of feeding dairy herds today result in a higher proportion of fermented feeds such as corn silage, haylage, high moisture grains and wet by-product feeds being utilized. Concerns are often raised as to what feasible levels of moisture are tolerable in diets. Studies reviewed by Chase (14) indicate a negative relationship between DMI and diets high in moisture content. A decrease in total DMI of .02% of body weight for each 1% increase in moisture content of the diet above 50% was indicated when fermented feeds were included in the ration.

Intake depression is generally thought to result from fermentation end-products and not water per se. However, when feeding diets identical in ingredient composition except for the addition of water (78, 64, 52 or 40% DM in diets), Lahr et al. (36) found DMI of cows increased linearly ($P < .01$) as ration DM increased. Cows fed the diet containing 78% DM consumed 4 lb/day more DM than cows fed the 64% DM diet (Figure 1). In a study using alfalfa silage to vary diet DM, Kellems et al. (33) found a similar trend in DMI reduction with increasing moisture in the diet although differences were not significant. Thus, 65 to 75% DM may be the optimum DM content of diets, although extremes in DM content probably have to occur before significant decreases in DMI are observed.

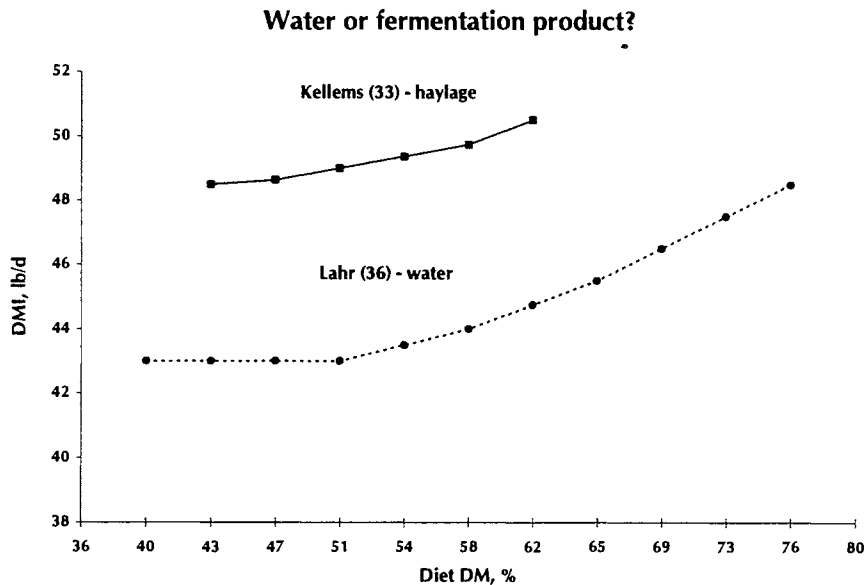


Figure 1. Effects of moisture on DMI.

Fiber

Fiber is an essential part of the diet needed to stimulate rumination, balance the needs of the microbial population, and provide buffering capability. Data reviewed by Clark and Davis (15) suggests crude fiber level of the diet influences DMI. The optimum level of crude fiber needed to enhance digestion without impairing intake was found to be 16 to 17% of the dietary DM.

Currently, the NRC (47) recommends a minimum acid detergent fiber (ADF) of 19% and NDF of 28% in the dietary DM of lactating cows. Early lactation or high producing cow diets may be decreased to 25% NDF. Seventy-five percent of the total NDF in diets is recommended to come from forage (21% of the DM). Mertens (43) has suggested optimum intakes of DM occur at NDF intakes of 1.2% of body weight. A review (32) of 28 studies containing 99 observations indicated DMI's were extremely variable with NDF concentrations in the diet ($r^2 = .16$). Maximum milk production was observed when NDF intake was .95% of body weight rather than the 1.1 to 1.2% suggested. Across forage sources (alfalfa or corn silage), NDF intake as a percentage of body

weight was not a good predictor of DMI; however, 4% milk production peaked at NDF intakes of 1.2% of body weight in alfalfa based diets and at 1.05% in corn silage based diets.

In recent reviews on fiber usage in dairy rations, particularly NDF, both Allen (3) and Mertens (45) concluded fiber optimums in rations are dynamic and variable depending on particle size and source of the NDF. The filling effect and physical effectiveness of NDF in the rumen are factors that affect DMI. Dado and Allen (21) demonstrated cows fed 35% NDF diets in early lactation had intakes limited by physical capacity of the rumen. Physical or rumen fill capacity did not limit DMI when 25% NDF diets were fed with or without rumen inert bulk. Thus, quantity, quality (digestibility) and particle size of forages and other NDF sources affect DMI.

Forage and Concentration Ratio

One way to increase energy density of the diet is to decrease the ratio of forage to concentrate (F:C). In alfalfa or orchardgrass diets, cows fed 20% of the dietary DM as concentrate produced less milk ($P < .01$) than cows fed 40 or 60% concentrate diets (60). DMI increased linearly ($P < .01$) with increasing concentrate in diets regardless of forage type (Table 3). Digestible DM also increased linearly ($P < .01$) with increasing concentrate levels. Because intake of undigested DM was not affected by concentrate amount, rates of passage, digestion and physical characteristics of the feedstuffs are probable causes of DMI differences.

Table 3. Intake and performance by cows fed different forages with varying percentages of concentrates.

| | Orchardgrass | | | Alfalfa | | | P ¹ | |
|----------------------|--------------|------|------|---------|------|------|----------------|-----|
| | 20% | 40% | 60% | 20% | 40% | 60% | F | C |
| Intake (lb/day) | | | | | | | | |
| DM ² | 37.7 | 45.2 | 48.1 | 47.0 | 49.4 | 51.1 | .01 | .01 |
| Dig. DM ² | 24.9 | 29.5 | 33.1 | 29.5 | 30.4 | 32.8 | .17 | .01 |
| Undig. DM | 12.8 | 15.9 | 15.2 | 17.4 | 18.7 | 18.3 | .01 | .11 |
| Production (lb/day) | | | | | | | | |
| Milk ³ | 46.5 | 59.1 | 58.6 | 52.5 | 60.2 | 61.1 | .25 | .01 |

¹ Probability of difference: F = forage effect, C = concentrate effect.

² Linear effect of concentrate percentage ($P < 0.05$).

³ Concentrate effect: 20 < 40 = 60 by stated P value.

Reference (60)

Llamas-Lamas and Combs (38) fed three forage (alfalfa haylage) to concentrate ratios (86:14, 71:29 and 56:44). DMI's were greatest for the diet highest in concentrate but similar for the other two diets. Petit and Veira (53) fed concentrate at either 1.3 or 1.8% BW and alfalfa haylage *ad libitum* to dairy cows. Cows ate similar amounts of haylage regardless of treatment. F:C ratios were 63:37 for the low concentrate diet and 56:46 for the high concentrate diet. Because both groups of cows had similar haylage intakes, cows consuming the high concentrate diet gained weight while animals consuming the low concentrate diet lost weight. These results were confirmed by Johnson and Combs (31). Cows fed a diet containing 74% forage (2:1 alfalfa haylage to corn silage) ate 2.7 kg

less DM than cows fed a diet containing 50% forage. In general, increasing concentrate in diets up to about 60% of the DM results in increased DMI.

Fat Effects

Assessing effects of fat on DMI is difficult because they are usually confounded with energy effects. Because cows consume DM to meet their energy requirements (Baile and Forbes (6); Conrad et al (16); Mertens (44); NRC (47)), less DM is often consumed when fat begins to replace carbohydrates as an energy source in diets (Gagliostro and Chilliard (28)). However, fats may also decrease rumen fermentation and fiber digestion (Palmquist and Jenkins (51); Chalupa et al. (11, 12)) contributing to rumen fill and a decreased rate of passage. Palmquist and Jenkins (51) indicated that increased saturation of fatty acids usually decreases negative ruminal effects associated with fats. Saturated fats also appear to be more palatable than unsaturated fats. Palmquist and Conrad (50) compared DMI of cows fed grain mixes containing no added fat or 10% hydrolyzed fat. No effects on DMI were observed. On the other hand, Jenkins and Jenny (30) evaluated four iso-caloric diets containing no added fat, 5% yellow grease, 3% hydrogenated yellow grease or 5% hydrogenated yellow grease. Cows fed the diet containing 5% yellow grease consumed less (2.4 kg/day) DM per day than cows fed diets with no added fat. DMI's of the other diets did not differ from the control. The authors suggested palatability problems associated with the yellow grease may have affected DMI. Chalupa and Ferguson (13) indicated an overall slight decrease in DMI when fat from several different sources was added to dairy rations.

Protein

Protein in the diet affects digestibility. Crude protein (CP) concentration in the ration beyond 10 to 12% in the DM has little effect in non-lactating animals; however, an increase from 10.8 to 15% CP in the DM increased digestibility of energy .04 to .08 digestibility units (49). In most cases, increased CP concentration results in increased feed intake. The effects of protein on feed intake are a result of increased digestibility which, in turn, increases voluntary intake. Improved amino acid supply or balance also may stimulate intake.

Energy and protein are the two major nutrients driving milk production. Because 70 to 80% of the energy in feeds is of carbohydrate origin, diets must be properly balanced for CP for optimum rumen microbial digestion of feedstuffs. With increased protein intake, increased microbial growth rate and increased efficiency of microbial synthesis occur (48). This increases the rate of DM digestion and rate of passage resulting in increased DM and energy intake. An increase in milk production will result (Figure 2).

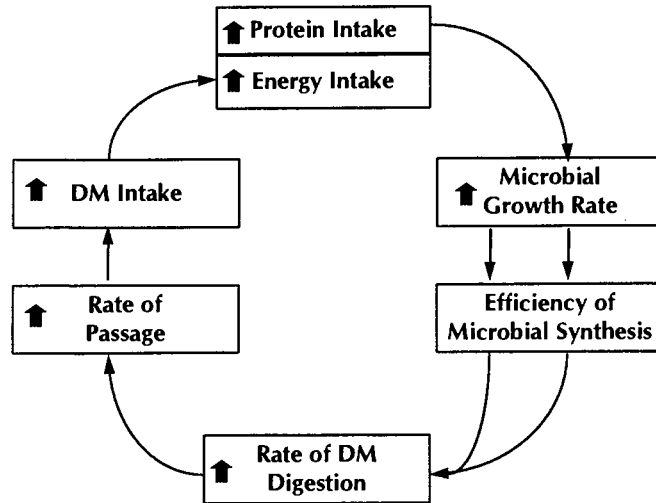


Figure 2. Effect of protein intake on rumen dynamics as it relates to energy intake. Reference (48)

ENVIRONMENTAL FACTORS AFFECTING FEED INTAKE

Grouping

Grouping cows by similar stages of production, reproduction or age can increase management efficiency in a free-stall operation. With grouping, the preciseness of feeding an individual ration to an individual cow is lost. In addition, dominant cows in groups may influence social behavior. Heifers tend to be low in the social hierarchy of the herd and gradually rise in the order as more enter the herd or as older cows leave (59). Drew (22) reported a 1,600 lb milk advantage to grouping first lactation heifers separately compared to mixing heifers and older cows. Grouping first calf heifers separately is recommended.

Regrouping cows can result in disruption in milk production. It has been indicated that production of cows drastically declines when they are moved to another group (8). However, these drops in production may be associated with diet change rather than social change. The effect of change in the social order, by incorporating four cows into a group of 20 cows at 28-day intervals, was studied in groups of cows fed identical rations (10). Although antagonistic encounters did occur with the introduction of new cows, 4% FCM of the transferred cows decreased by only 1.12 pounds (3%) on day 1. After day 1, no effect on milk yield was seen due to regrouping. It is suggested that many (probably more than 4) cows moved together to a new group results in less aggressive behavior than moving single or small numbers of cows.

To determine optimal stocking rates of free-stalls, situations of 1.0, .83, .67, .50 and .33 available stalls per cow were observed (27). Time spent resting and number of resting periods by the cow as well as percent utilization of the stall (use/time available x 100) did not change until less than .67 stalls per cow were available (Table 4). Therefore, production or behavior of groups is not changed until group size is increased to 30% more cows than free-stalls.

Table 4. Effect of stocking rate on free stall use.

| | Free stalls per cow | | | | |
|--|---------------------|------|------|-------------------|------------------|
| | 1.0 | .83 | .67 | .50 | .33 |
| Avg. time resting (h) | 14.2 | 14.2 | 13.2 | 10.4 ^a | 6.9 ^a |
| Correlation with dominance | -.26 | .15 | .18 | .17 | .23 |
| Percent utilization (use/time available) x 100 | 66.9 | 80.3 | 93.2 | 97.8 | 98.1 |
| Avg. no. resting periods | 10.7 | 11.3 | 10.5 | 7.9 ^a | 6.4 ^a |
| Correlation with dominance | -.37 | .11 | .09 | .65 ^b | .43 |

^aDiffers from 1.0 free stalls per cows (Dunnett's test).

^bDiffers from zero (P < 0.05).

Reference (27)

Behavior at the feed bunk may be controlled by social dominance. Dominant cows, usually those which are older and larger, tend to have priority in a competitive situation such as limited bunk space. Socially dominant animals, not necessarily the highest producers, tend to consume more feed at the bunk in these situations (26).

Feed bunk spacings of 20, 16, 12, 8 or 4 inches per cow have been evaluated (27). Average time spent at the feed bunk (3.7 hours/day) did not decrease until 4 inches of space per cow was available (Table 5). In the 8 and 4 inch bunk space per cow situations, the correlation of dominance to duration of eating periods increased. In a situation where herd numbers increase without altering existing facilities, 8 inches of bunk space per cow may be adequate. Generally, it is recommended that mature cows have 28 to 30 inches of bunk space available (9). This should accommodate about one-half to two-thirds of the cows to eat at one time. Adequate space is most important in lactation stages where maximum DMI is crucial.

Table 5. Effect of bunk length on utilization.

| | Feed bunk length per cow (in) | | | | |
|--|-------------------------------|------|------|------------------|-------------------|
| | 20 | 16 | 12 | 8 | 4 |
| Time at feed bunk (h) | 3.82 | 3.73 | 3.73 | 3.76 | 2.57 ^a |
| Correlation with dominance | .46 | .32 | .30 | .67 ^b | .71 ^c |
| Percent utilization (use/time available) x 100 | 21.5 | 26.9 | 34.6 | 51.9 | 70.6 |
| Avg. daily feed intake (lb as fed) | 82.2 | 82.4 | 83.3 | 79.4 | 73.4 |

^aDiffers from 20 in. feed bunk/cow (Dunnett's test).

^bDiffers from zero (P < 0.05).

^cDiffers from zero (P < 0.01).

Reference (27)

Barn effects

Position of the bunk is an important factor. Manger preferences of cattle are those that allow them to eat in a natural grazing-like position. Feed wasting activities associated with elevated bunks, such as feed tossing, are eliminated with this type of bunk (2).

Accessibility and availability of water are important for optimal production since it is an essential part of the diet and comprises 87% of milk. Decreased water intake decreases feed consumption. One watering space or two feet of tank perimeter is recommended for every 15 to 20 cows. Each group of cows should have access to at least two locations for water. More may be needed if first-calf heifers are housed with older cows. A water depth of 6 to 8 inches ensures a fresher supply containing less debris (2).

In the barn or parlor, stray voltage may decrease production. Stray voltage, often a cause of unexplained poor performance, affects the feeding behavior of cows. Cows consumed less water and took fewer drinks from waterers containing 3 and 6 volts of electricity than from waterers with no voltage (19). A reluctance to use waterers or metallic feeders or the "lapping" of water are indications stray voltage may be present (5).

Supplemental lighting in the barn has shown to increase production (52). Cows exposed to 16 hours of light a day produced more milk than cows exposed to the natural light photoperiod. Supplemental light increased milk production by over 6.5 lb from day 1 to day 100 of lactation. Switching cows from the natural light to supplemental light on day 100 appeared to retard their decline in milk yield.

Weather

Fluctuations in weather conditions can alter eating behavior. Energy utilization and productivity are functions of metabolizable energy intake and heat production. Climatic factors that influence intake or heat production also influence productivity and utilization efficiency.

Cold weather increases thermal insulation and metabolic rate. An increase in rumination activity, reticula-rumen motility and rate of passage also occur (61). Stimulation of intake occurs because of the increase in metabolic demands when the ambient temperature is below the animal's thermal neutral zone. However, in extreme cold, intake does not increase at the same rate as metabolism causing a shortage of energy. Extra energy should be added during such adverse conditions to compensate for heat loss.

The thermal neutral zone of dairy cattle is about 40 to 80°F. However, this zone varies among the animals. The thermal neutral zone shifts down for lower producing animals while it shifts up for higher producing animals allowing them to better tolerate cold weather (18). Temperatures below or above the thermal neutral range alter intake and metabolic activity.

A rise in ambient temperature above the thermal neutral zone decreases milk production due to heat stress. Maintenance requirements of lactating dairy cows increase about 30 percent when ambient temperatures are raised from 80 to 104°F for 6 hours a day. Under these conditions, DMI decreases to about 55 percent of what is eaten in the thermal neutral zone. Depressed milk production results from the depressed intake. Water consumption of cattle increases up to 95°F, but further temperature increases decrease water consumption due to inactivity and low intake. The effect of

temperature can be exacerbated by high humidity (29). Humidity has little effect on heat stress until temperatures exceed 75°F.

Alleviating heat stress is crucial for keeping feed intake and production declines to a minimum. Plenty of water is the most economical way to maintain cow comfort. Shade also offers relief during hot periods. Natural shade, such as trees, or a constructed shade both reduce heat radiation. The barn climate can be controlled by ensuring ample ventilation. Large fans placed above the cows at 30 to 40 foot intervals and at the feed bunk increase air movement throughout the barn (4).

Water sprinkling systems are another method of reducing heat stress. Misters delivering 5 gallons of water per hour with a pressure of 20 pounds per square inch can be installed at the feed bunk or holding area. Misters should not be installed over bedded areas. Insufficient air movement with misters will actually raise the humidity decreasing cow comfort (4, 57).

Altering the feeding strategy can help in heat stress situations where feed intake declines. Lowering forages in the diet during summer reduces the body temperature in Holsteins by .5°F (18).

Management of the feedbunk is important for optimizing intake, especially during summer months. The surface of the bunk should be clean and smooth. Leftover feed should be removed to prevent spoilage. Removal of other debris is crucial since ingestion of it may cause digestive problems. Bunks lined with ceramic tile prolong the smooth condition of the bunk surface. Protection of the concrete from silages or other feeds which may etch the surface allowing aggregate or splinters to be exposed with tile or epoxy coatings may increase feed intake (9).

Feeding method - TMR vs individual ingredient

Feed delivery systems should be chosen to meet individual needs of the producer. Considerations when choosing a feeding system should include housing facilities, equipment necessities, herd size, labor availability and cost. Feeding can be effectively accomplished by either a TMR or by individual ingredient feeding.

A TMR ensures the desired proportions of feedstuffs in the ration with all ingredients being dispersed uniformly throughout the mix. Individual concentrate feeders on the other hand, offer the opportunity to control and monitor concentrate intake of individual cows. While individual feeding may be more precise for meeting individual cow needs, the system is more labor intensive, requires frequent equipment calibrations, and allows cows to select the proportions of forage or concentrates compared to TMR's. Maltz et al. (39) found neither TMR or computer concentrate feeders to be superior in five months of intake measurements (Table 6). A comparison of feeding systems of the top 50 DHIA herds in Minnesota in 1990 found no differences in milk production or composition associated with feeding TMR or individual ingredients (Table 7) (37).

Table 6. DMI per cow calculated over 5 months for cows fed a TMR or individual concentrates.

| | TMR | Individual concentrates |
|--------------------|-------|-------------------------|
| DMI (lb) | 43.4 | 45.0 |
| Concentrate:Forage | 67.33 | 65.35 |

Reference (39)

Table 7. Production summary of herds by feeding system.

| Feeding system | No. herds | Cows/ herd | DHIA rolling herd averages (12/31/90) | | |
|-------------------------------|-----------|------------|---------------------------------------|---------|-------------|
| | | | Milk (lb/cow) | Fat (%) | Protein (%) |
| TMR | 16 | 59 | 24,131 | 3.67 | 3.13 |
| Grain and forage fed separate | | | | | |
| Hand fed | 21 | 54 | 23,535 | 3.84 | 3.16 |
| Computer fed | 13 | 84 | 24,598 | 3.67 | 3.13 |

Reference (37)

Feeding frequency

Manipulations of feeding frequency and feeding sequence may result in higher production and fewer health problems. Because of diurnal patterns in rumen metabolites, increased frequency of feeding allows for more constant metabolite levels. This is mostly limited to increasing from once or twice daily feedings to three or more. Higher milk fat concentration also has been associated with increased feeding frequency (56). Additional benefits vary with individual situations. For instance, fluctuations in diurnal patterns of metabolites likely need to be adversely affecting microbial growth and fermentation before a benefit will be seen.

Additional reasons supporting increased feeding frequency exist. Insufficient bunk space for cows increases the rate of consumption, reduces eating time per day, and results in a longer period at the end of the feeding cycle when bunks are empty. Increasing feeding frequency may be helpful in this situation. Prevention of feed spoilage in the bunk may be accomplished by feeding more often.

Sequence of feeding

Sequence of feedstuffs may provide advantages. Offering cows that have been without feed for over six hours highly fermentable carbohydrates or proteins causes a rapid drop in rumen pH and an increase in ammonia. If forage is offered one to two hours later, appetite will be depressed due to acidotic conditions in the rumen, and digestion will be reduced due to the low pH (56). Feeding forage in the morning prior to other feedstuffs allows for the formation of a fiber mat in the rumen and also provides buffering capacity. This buffering is from both the forage and the salivation that is associated with feed consumption. Forage of medium to long chop length should be used to

prolong eating, increase salivation and reduce particle passage to increase the net fiber digestion (52).

Access to feed

Access to feed must be considered in feeding situations. Changing the length of daily feeding times influences metabolic and behavioral adaptation in animals. Cows having access to feed during the entire day consume feed in a number of meals and rest between the feeding periods. Restriction of feed curtails the number of meals consumed per day causing a reduction of intake. Cows having access to feed for 24 hours consumed 6% more DM than cows who had access to feed for only 8 hours. Feeding durations are especially important in periods of early lactation (40, 41).

SUMMARY

DMI is the foundation on which productive and profitable dairy rations are built. Several factors (cow, ration and environment) singly or interactively control DMI. Nutritionists need to know DMI's of cattle and cannot rely solely on predictive equations when formulating rations. Knowing what factors affect DMI and either capitalizing on them or correcting their negative influence will result in efficient and profitable milk production on dairy farms.

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