Management Strategies For TMR Feeding Systems

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During the last 3 decades, average herd size of U.S. dairy farms has increased. Over the same period of time, production per cow and level of concentrates fed per day have also increased. In 1969, A.H. Rakes suggested these changes were increasing the need for specialization and automation of the feeding system, and as a result of these changes, new feeding systems have been developed. Coppock and coauthors, in 1981, reviewed the ongoing shift from feeding individual ingredients in multiple locations to feeding complete rations. The reasons for these changes were the same as those discussed by Rakes. As dairy farm managers adopt, adapt, and manage total mixed rations, there are several key points that can influence the success of the feeding system in meeting the goals of the nutrition management program. The focus of this paper is the evaluation of critical decisions or control points in successfully managing total mixed ration (TMR) feeding systems.

Grouping Decisions

Grouping decision is the first decision in managing the TMR system. Simply put, which cows are assigned to which groups and what will these cows be fed? Some fixed factors such as lot size, stalls per lot, and size of milking parlor/holding pen will influence feeding group size. But how cows should be assigned to lots is an important management consideration.

Nutritional requirements, age, body condition, reproductive status, and health, have been and are used successfully on commercial farms to assign cows to groups (McCullough). Grouping by age for example, allows producers to limit social diversity and range of dominance within a group. Open (non-pregnant) cows in a single group can improve efficiency of reproductive management (ie., estrus detection program focused on fewer groups). Some herds use separate groups to manage sick cows. By managing this group separately, managers reduce exposure of healthy cows to disease and allow cows treated with antibiotics to be milked last or in a separate parlor. This management practice improves residue avoidance programs. However, the overwhelming conclusion of research in this area indicates grouping by nutritional requirements is the best basis for grouping cows into feeding groups.

The basis of any diet formulation is the accurate prediction of dry matter intake (DMI). Kertz and others summarized results of feeding trials conducted over a six year period. These researchers reported dry matter intake was better estimated if days in milk was included in the prediction equation. In addition, prediction of dry matter intake was most accurate if intake was predicted for each week from calving to 42 days in milk. After 42 days postpartum, predicted dry matter intake was improved if calculated for weeks 6 to 8, 9 to 13, and 14 to 20 of lactation. Another important observation was the difference in feed intake of first lactation cows compared to later lactation animals. These results define the importance of measuring and monitoring dry matter intake across groups. Therefore, TMR systems should be based on ration mixers equipped with

Table 1: The economic benefits of grouping strategies as influenced by level of milk production.

Two Group Scenario

Grouping Strategy (lbs/cow/year)	Level of Production per Cow 17,600	19,800	22,000
	($ per cow per year)		
Nutrient Concentration	1,144	1,301	1,531
Nutr. Conc./NDF intake	1,144	1,304	1,538
Days in Milk	1,137	1,289	1,519
DHIA Test Day Milk	1,100	1,249	1,477
Test Day FCM	1,126	1,279	1,507

Three Group Scenario

Grouping Strategy (lbs/cow/year)	Level of Production per Cow 17,600	19,800	22,000
	($ per cow per year)		
Nutrient Concentration	1,164	1,333	1,570
Nutr. Conc./NDF intake	1,166	1,338	1,579
Days in Milk	1,166	1,310	1,542
DHIA Test Day Milk	1,107	1,275	1,494
Test Day FCM	1,133	1,295	1,524

(Adapted from Williams and Oltenocu; J. Dairy Sci. 75:155 (1992).

accurate scale. Accurate dry matter intake measurement should then be used to formulate group diets. This is critical in determining what nutrient density is necessary given the DMI. But, which cows go in which group?

Grouping Strategies

Several strategies have been proposed for production grouping of dairy cows. In a series of studies conducted at Virginia Tech, McGilliard and others evaluated different methods to group cows. Grouping criteria evaluated included CP percentage and Mcal net energy per lb expected dry matter intake (cluster) versus test day milk, fat corrected milk, (FCM) and FCM per unit metabolic body weight (defined as dairy merit). Over 100,000 test day records from 80 Virginia DHIA Holstein herds were used to allocate individual cows to groups. Cows were grouped into two groups per herd each month. Clustering cows grouped 25, 22, and 15% of cows in different groups compared to test day, FCM and dairy merit grouping strategies. Nutrient clustering decreased the variation within groups compared to other criteria evaluated. Schucker and others (1988) conducted a field study to investigate nutrient requirement grouping of dairy cows on commercial farms. Nutrient clustering of cows into feeding groups was found to be more accurate than test day milk production only.

Williams and Oltenacu, using a dairy herd production computer model, evaluated economics of grouping criteria. Several criteria for grouping were compared for a theoretical 100-cow herd with three levels of potential milk production per lactation (305 d; 17,600, 19,800, and 22,200 lb). These investigators reported required energy and crude protein per lb of predicted dry matter intake or per lb of estimated neutral detergent intake capacity supported highest milk production and highest income over feed cost per cow. (See Table 1).

Another decision that must be made is the grouping and movement of cows to and from feeding groups. Spahr and colleagues evaluated a grouping strategy program based on 3.5% FCM production as a percentage of body weight between 42 and 56 days postpartum. This method was most sensitive in identifying cows with low potential milk production. The authors reported difficulty in distinguishing between cows with medium or high potential. Results were improved by grouping primiparous cows separately from older cows. Potential problems with allocating cows to production group may be caused by early postpartum health problems (metabolic or mastitis) that would lower estimated potential. Body weight is also an important variable that would need to be included.

Table 2. Comparison of milk production and lead factors for cows by percent of cows in each group.

% Cows per Group	High (Milk/LF)	Middle (Milk/LF)	Low (Milk/LF)
100:0	45.3/1.3	..../....	..../....
50:50	56.3/1.17	..../....	34.1/1.22
33:33:33	61.4/1.14	44.7/1.08	30.6/1.21
25:50:25	64.2/1.12	44.7/1.13	28.2/1.20
50:25:25	56.8/1.17	40.0/1.07	28.2/1.20

(Adapted from Stallings and McGilliard; J. Dairy Sci. 67:902 (1984)

Lead Factors

Another critical point is movement of cows to different groups and how close the diets compare between groups. Spahr and others noted moving cows from high to medium TMR tended to reduce milk production but not FCM when grouping cows based on lactation potential. These results point out the importance of properly balancing TMR for the group being fed. Stallings and McGilliard evaluated methods of estimating lead factors for the formulation of TMRs for production groups. Their study indicated that as the group became more similar in milk production (less variation within the production group), the lead factor required was reduced. The results indicate that feed costs can be potentially reduced due to less overfeeding of low producers in the group. In addition, higher producing cows might better realize production potential. (See Table 2).

One-group TMR feeding has been used by dairy farm managers. Howard has described advantages and disadvantages of one group TMR. However, while one group TMR may have merits for small to *average size dairy operations, large operations can achieve obvious economic benefits by production grouping the herd. Advantages of grouping dairy cattle include:*

1). More accurate ration formulation based on production,

2). With increased accuracy of ration formulation, production efficiency and profitability can be improved,

3). Special groups of cows can be better managed. For example, first lactation cows can be placed in groups with reduced competition by older, more dominant cows for feedbunk space.

4). Forages may be allocated and matched to production group based on quality of forage and level of production potential.

Feed Management

When discussing feed quality, forage quality is usually the topic discussed for dairy cattle diets. It is important, however, that all feeds be closely monitored for changes in nutrient composition. For TMR management, the discussion is better focused on factors that influence accuracy of the diet being mixed and delivered. One factor often overlooked but a major influencer of TMR management is dry matter content of ensiled forages. Workers at Penn State reported that increased uncertainty in forage DM affected the accuracy of protein and NDF of the TMR mix. Linn recommended ensiled and/or wet feeds (i.e., wet brewers grains) be monitored weekly to prevent large fluctuations in diets presented to cows in the bunk. Rainfall can also influence DM of ensiled forages being fed and the accuracy of diet mixing. Equal attention should be placed on monitoring DM of the TMR diet being offered in the bunk. Monitoring DM and amounts fed per group can be used to monitor dry matter intake (DMI) of groups. Dry matter intake is a critical component of the feeding systems management. Remember, if you don't measure it, you can't manage it.

In addition to the influence of DM of wet feeds on nutrient content of the mixed ration, dry matter of the total diet might influence DMI. Lahr and coworkers reported diets less than 50% dry matter may reduce feed intake by cows. However, Robinson and colleagues reported no differences in DMI of diets ranging from 35-65% DM. These studies differed in how diet DM was manipulated. Lahr's study relied on replacement of alfalfa silage with alfalfa hay. In contrast, Robinson's experiment used concentrates and silages soaked in water. The optimal dry matter content of the TMR is the level that optimizes DMI by the herd. Close monitoring of dry matter is important in monitory DMI by groups.

To measure DM, an on farm method that provides results accurately measured and easily attained. Oetzel et al. compared four methods of evaluating DM of feeds. The microwave proved most accurate but requires the most time and careful monitoring. The Koster Moisture Tester tended to over estimate DM of feeds but was comparable to microwaving. An electronic moisture tester was also evaluated and found to be comparable to the DM measurements made using the (time) and Koster Microwave oven (smelly house with unhappy spouse). While no system of measuring dry matter content of ingredients and mixed rations is perfect, it is important for farm management to be active in managing this important variable.

Forage Fiber Source Considerations

One goal of the TMR system is to limit "selective intake" of individual dietary ingredients. In traditional feeding systems, cows were fed concentrates separately from forages with dry hay and ensiled forages fed in multiple locations. As a result, cows had freedom to select and consume an unbalanced and/or unhealthy diet. The management goal of the TMR is to blend all dietary ingredients into a single diet including the effective fiber source. Historically, long, dry hay is fed as a free-choice supplement. Beauchemin and Buchanan-Smith reported the inclusion of long dry hay in the TMR increased milk production over 3 lbs per cow per day. In addition, cows consuming hay had meals of longer duration, and increased chews/minute during meals. Cows consuming long hay also spent more time ruminating and chewing. Increased chewing time tended to improve rumen pH by reducing time pH was below 6.0. While not statistically significant, this shift in rumen pH reflects better natural buffering of

Table 3: Effects of diet and feeding sequence on production and digestive function of lactating dairy cows.[1]

	Diet[2]			Significance[3]	
Variable	C-S	H-C-S	C-S+H	Hay	M
DMI (lb/d)	36.1	36.6	37.1	.10	NS
CP (lb/d)	5.8	6.1	6.1	.01	NS
Milk (lb/d)	38.1	41.6	40.3	.01	NS
Milk efficiency					
Kg/milk/Mcal NE_1	.58	.63	.60	.01	NS
Meal duration					
(min)	15.4	18.2	18.0	.04	NS
Rumination					
Periods per day	12.4	14.3	14.4	.05	NS
Chews per period	1306	1316	1350	NS	NS
Min/d	274	318	328	.05	NS
Min/kg DM	16.7	19.3	19.5	.05	NS
Boli per d	297	364	380	.05	NS
pH					
<6.0 (min)	280	213	214	NS	NS
Extent of alfalfa silage disappearance (%)					
DM	68.9	73.7	70.3	.05	.05
NDF	44.6	51.7	47.5	.05	NS

1: Adapted from Beauchemin and Buchanan-Smith (1990).
2: C-S = concentrate fed followed by silage. H-C-S = hay fed prior to concentrate followed by silage. C-S+H = concentrate followed by blended silage + hay.
3: Significance: H = Hay; M = method.

the rumen. This result would be expected to reduce off-feed problems and health problems (ie., acidosis, laminitis). (See Table 3).

The incorporation and consumption of effective fiber benefits the cow by improving both production and health of the animal. Management considerations should include how the TMR mixer will handle long, dry hay; should hay be pre-processed to reduce particle size and improve mixing; is dry forage over-mixed which reduces dry hay to small, ineffective particle length. Linn pointed out that feeding 10 lbs of long, dry hay per cow per day supplies enough effective fiber to maintain normal, healthy rumen. When feeding processed forages (silage, processed hay, TMR mixer with hay processing ability), Linn recommended that 50% of ensiled forage particles by longer than .4 inches in length with 15% of the forage particles longer than 1.5 inches. It is important that forage particles consumed by the cows have adequate length to stimulate rumen contractions and rumination. Over mixing of good quality dry hay can reduce particle size and result in inadequate effective fiber intake. Forages must be evaluated after mixing and delivery to the feedbunk.

Animals not consuming adequate amounts of effective fiber are at increased risk of metabolic disorders such as ruminal acidosis, laminitis, inverted milk fat to milk protein ratio and displaced abomasum. The management goal is to have cows consume adequate effective fiber to maintain health and production.

Feed Access And Feeding System

Availability of feed can often be a limiting factor in maximizing DMI. Some nutritionists use the term "slick-bunk syndrome" to describe feeding situations where cows are simply underfed and lick the bunk clean giving it a "slick" appearance. In most controlled investigations, feed access is measured as the time cows have physical access to adequate amounts of feed. Freer et al. (1962) observed an interaction of forage quality, feed access, and DMI. These results indicate intake is influenced by forage quality and should be considered. This difference would be especially noticeable if cattle were grouped and fed different quality forages across groups.

More applicable to well managed farms, access to ad lib amounts of high quality feeds should be considered. Erdman et al. (1989) reported increasing feed access time from 8 h to 20 h per day increased feed intake from 51.7 lb/d to 54.3 lb/d in mid-lactation cows. Increased access did not change milk production and intake, as a % of body

Table 4: Interaction of access to feed and forage quality on DMI and chewing activity[1].

			------------time (min)------------		
feed	access (h)	DMI (lb)	eating	ruminating	resting
Hay	24	29.6	405	565	470
	4.5	25.3	261	534	645
	2.0	17.9	122	434	884
Straw	24	13.8	343	474	623
	4.5	11.2	251	392	797
	2.0	8.5	121	358	961

1: Adapted from Freer et al. (1962).

weight, was not changed. Cows with increased feed access time did have higher weight gains (8h/d, +.8 lb/d; 20h/d, +1.5 lb/d). In contrast, Martinsson and Burstedt (1990) measured intake and production responses of early lactation cows given different access to feed (8h to 24h). In this study, diet ingredients (hay, silage, and concentrates) were fed separately. Cows assigned 8h feed access time were fed 0600 to 0930 and 1230 to 1700h each day. Cows with restricted feed intakes in year 1 tended to have reduced feed intake (8h DMI = 30.4 lb/d vs 24h DMI = 32.6 lb/d). Intake differences due to feed access were greater during year 2 (8h DMI = 32.2 lb/d vs 2h DMI = 35.4). The large difference in DMI resulted in a 2.4 lb increase in milk production. These workers suggested feed access is important especially for early lactation cows.

Feed access and intake can also be influenced by competition for feed and feeding space (Albright, 1993). Friend and Polan (1974) reported cows spent almost 5 h/d at the feedbunk. The social rank of animals within the group influenced time spent at the bunk after feed was placed in the bunk. Therefore, more dominant animals had more opportunity to consume feed first after feeding. Subsequent research reports showed .7 ft per cow would allow adequate access and not depress intake (Friend et al., 1976). Most current recommendations establish feeding space per cow at 1.5 to 2 ft per head. These recommendations agree with results of feeding behavior research trials. A more recent report indicated that cows selected feeding positions in fenceline feeders based on dominance relationships (Manson and Appleby, 1990). Cows with the greatest differences in social dominance had average separation of 4.4 feeding positions (feed position = 2 ft per position). Albright (1993) reported cows fed total mixed rations in fenceline feeders ate longer than cows fed in bunks with access around the entire bunk. Feeding system design and layout can potentially impact intake by influencing feed access time via manipulation of animal to animal interactions.

Feed Palatability

One critical aspect that must be considered on the feed side of feedbunk managements palatability of the diet. For example, two reports from the University of Maryland described the effects of silage pH on feed intake. Shaver et al. (1984) predicted optimum silage organic matter intake would be achieved with a forage pH equal to 5.6, with an optimal range between pH 5 to 6. Erdman (1988) reported partial neutralization of corn silage (from pH = 3.64 to pH = 5.44) increased forage DMI 2.2 lb/d. Total DMI was also increased (2.9 lb/d). Corn silage pH was manipulated by the addition of sodium bicarbonate. Milk yield was not different, but milk fat % and 4% FCM yield were increased by buffering corn silage. Palatability of forage may also explain differences in intake of alfalfa hay and straw reported by Freer et al. (1962).

Concentrate palatability can also influence intake. Dustiness and texture of concentrate mix can depress intake of grain mixes. Feed additives have been found to depress grain intake. The recent development of cation:anion balancing and use of anionic salts can influence concentrate consumption. Oetzel and Barmore (1993) ranked anionic salt mixtures based on intake and reported $MgSO_4$ was consumed better than other anionic salts. Animal by-product feeds (animal proteins and fats) have been reported to decrease intake. In most cases, feed intake returned to normal following an adaptation period. Inclusion of new feeds (new silo, hay cutting, etc.) and feed additives in the diet should be *done gradually over an adaptation period. This strategy helps prevent potential off-feed problems and better maintains animal performance.*

Water Accessibility

Water consumption has also been found to influence DMI and milk production. Dado and Allen (1994) reported a highly significant correlation between water intake and milk yield (Pearson correlation coefficient r = .94). A significant relationship was also described between DMI and water intake (Pearson correlation coefficient r = .96). Drinking time required 10% of time spent eating (Table 5). While eating events required more time, cows had more drinking bouts (14.0, all lactations) than eating bouts (11.0, all lactations). These differences indicate the importance of animals access to water. Time spent drinking was not described relative to eating activities during the day. However, water supply should be convenient to feed to stimulate DMI. A general guide is to provide water within 50 ft of the feedbunk.

Feeding Management Considerations

Robinson (1989) described potential interactions between feeding strategies, feedstuff characteristics, and quality of animal management. Options and possibilities are unlimited for consideration of feeding systems and strategies within a given animal facility. Within a feeding system, many factors influence DMI. Diet formulation, mixing, and feeding to ensure normal rumen function is a high priority for achieving maximum intake and productivity. Control of diet ingredient intake is also a primary goal of the feeding management system. Feed access contributes to animal performance and success of the feeding program. Palatability of feed can stimulate or depress intake. Blending and use of feed ingredients with poor palatability should be done carefully to minimize off-feed problems. Maintaining fresh feed during periods of high eating activity (ie. after milking) stimulates larger meal sizes as a result of improved palatability. Water supply must also be fresh, clean and accessible to maintain intake and production. Feeding management strategies are dynamic to feeding system, diet, and farmstead layout (NRAES - 38, 1990). Manage all factors that influence DMI to achieve and maintain high intakes and animal performance.

Table 5: Milk production and feeding behavior statistics of lactating Holstein cows[1].

Item	Primiparous Mean	Multiparous Mean
Milk (lb/d)	63.1	82.5
DMI (lb/d)	44.0	54.6
Time eating (min/d)	284	314
Water intake (L)	63.2	89.5
Time drinking (min/d)	17.7	19.1

1: Adapted from Dado and Allen (1994).

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