Total Mixed Rations for Dairy Cows

Total mixed rations help dairy cows achieve maximum performance and are the most common method for feeding high producing, indoor-housed dairy cows in the world.

ARTICLES

Introduction

Feeding a total mixed ration (TMR) helps a dairy cow achieve maximum performance. Since its inception in the 1950s, it is now the most adopted method for feeding high producing, indoor-housed dairy cows in the world. This is accomplished by feeding a nutritionally balanced ration at all times, allowing cows to consume as close to their actual energy requirements as possible and maintaining the physical or roughage characteristics, which we now refer to as feed particle size, required for proper rumen function. Advantages and disadvantages of any feeding system, however, must be weighed before choosing a TMR.

Good feeding management practices must be followed to achieve maximum performance from cows. First, monitor forage and feed inventory on a regular basis and allocate to the appropriate animal group. Second, test forages and feeds several times throughout the year or when any noticeable change occurs. Lastly, update ration formulations based on milk production, milk fat and milk protein percent, current body weight and body condition scores, moisture changes in forages or high moisture feed ingredients, and prices of current feeds. Checking forage moisture on a frequent basis is critical to implementing a successful TMR system.

There are several strategies that can be used in TMR systems. Separate TMR can be developed for different animal groups. These can be formulated for fresh cows, early lactation cows, and mid- and late-lactation animals, as well as for far off and close-up dry cows. Such multi-group strategies are particularly helpful for meeting the needs of dry cows. One group TMR, on the other hand, can be used for lactating cows with or without top-dress feeding. Cows can be grouped based on actual or fat-corrected milk, days in milk, reproductive status, age, nutrient requirements, and health. Different farms have reasons for adopting different strategies for using TMR and these must be a decision of the farm manager based on many aspects of the operation as well as research and personal preference.

Advantages of a TMR Feeding System

Improved feeding efficiency often occurs with herds using a TMR. Each mouthful of feed that the cow consumes contains the proper amount of ingredients for a balanced ration, resulting in a more stable and ideal environment for the rumen microbes and providing adequate carbohydrates and nitrogen sources that vary in their ability and rate of rumen breakdown. This in turn can lead to production of higher levels of microbial protein by the rumen microbes throughout the entire 24-hour day. A 4% increase in feed utilization can be expected when using a TMR compared to a conventional ration of forage and grain fed separately, twice daily. In addition, the ability to use feeds with various rates of breakdown is enhanced, often enabling even better nutrient utilization. Farmers can also utilize a greater variety of byproduct feeds with a TMR, thereby allowing for possible ration cost savings. The incidence of digestive and metabolic problems often decreases when a TMR is fed, and milk production has been shown to be as much as 5% higher with a TMR compared to conventional rations as a result of these benefits.

A TMR provides greater accuracy in formulation and feeding if managed properly. Using feed scales both on mixing equipment in a feed area allows the quantity of each ingredient fed to be closely controlled. When a TMR is mixed properly, a cow cannot consume significantly more or less of a forage or concentrate than planned in the ration formulation. Parlor and selective feeding can be discontinued or limited to token amounts to facilitate cow movement, unless specific milking systems such as robotic milking systems are being used. The TMR system is well adapted to mechanization with a mixer wagon or a stationary mixer with conveyors or mobile feeders. Mixing equipment must be properly maintained and load cells and scales must be kept in accurate working order. Mixers can be purchased that handle the addition of long hay, however these are seldom recommended. Many of the TMR mixers that chop long forage also break down other feed and silage particles while they are reducing the long hay particle size. The result is often that the entire TMR has reduced particle size as a result of attempting to add a few pounds of long dry hay to the mix. It is most always recommended to chop long forage as a separate commodity before adding it to the TMR mixer and mix for a limited amount of time as recommended by the manufacturer. This generally is no more than 4 to 5 minutes--just long enough to achieve a good mixture.

Commodity ingredients can be fed quite effectively in a TMR diet. Both unique and common types of commodities are often less expensive due to bulk handling and direct purchasing. However, quality control must be maintained when purchasing commodity feeds. This often entails additional feed analysis, but additional costs of transportation and handling required by a commercial feed manufacturer are avoided. The quantity of commodity feeds purchased depends on rate of spoilage, level of use, and available storage space. Purchasing large quantities may not be economical due to increased inventory costs. Total feed losses for commodity feeds, including what occurs during storage and handling, can range from 3% for a dry grain product to 15% for a high-moisture product such as wet brewers grain. Purchasing should be based on quality and nutrients needed for the ration, not solely on price. Additionally, a greater variety of ingredients allow more flexibility in formulating the ration for various production groups.

One of the major advantages of blending all the feeds together in a TMR is that it can mask the flavor of less palatable feeds. Feeds such as urea, limestone, fats, and some by-pass protein sources may be less palatable. However, through blending, they can be added to TMR in reasonable amounts with little to no reduction in feed consumption.

Disadvantages of a TMR Feeding System

Mixing or blending devices needed for the ration require small to moderate expenditures for equipment and maintenance. Further, it is important to follow the manufacturer's recommendations for mixing. Over mixing can cause serious problems due to grinding and pulverizing the feed. Under mixing can result in less effective feed utilization by the cows.

Accurate weighing with calibrated scales, which also may involve additional cost and maintenance, is essential. Care must be taken in formulating and mixing the ration. If the diet is not balanced correctly or mixed properly, the cow ultimately will suffer reduced performance. While this is true of any feeding system, it is under the control of the person feeding the herd. Remember with a true TMR, cows have no other option for a diet and depend solely on the ration for a balanced diet to achieve production and health.

In some cases, existing buildings, feed alleys, and mangers may make a TMR system nearly impossible to use. Some housing and feeding facilities may just not be well suited for a TMR system. Further, it may not be economical for all herds, particularly small herds or those using pasture feeding over an extended period of time, to implement a TMR system due to the increased cost of the feeding system per animal-day it is utilized.

Feeding Management on TMR Systems

Forages should be chopped properly before ensiling. Most forage particles in silage and haylage should range from 3/8 to 3/4 inch in length. Forage particles that are very fine, or grain that is too coarse or whole, should be avoided in the ration. Cows generally sort against long particles due to their less palatable nature and sort for finer particles in the ration. This behavior can lead to metabolic problems such as subacute ruminal acidosis (SARA). Cows consuming the finer particles of the ration are reducing their particle size consumption and, in effect, their NDF intake. These sorted diets contain more fermentable carbohydrates and less effective fiber than the formulated ration. Effectively a sorted TMR is not a balanced TMR, and much of the time, effort, and expense involved in making the TMR is lost when it is sorted by the cow.

It is imperative to develop rations based on current forage analysis reports. Current recommendations are to take the average of at least two separate and independent forage analyses from the same lab before building a TMR. Make ration adjustments when a change in forage is observed; again, this should be based on more than one sample and forage analysis. The dry matter of ensiled material should also be checked frequently. A change in dry matter can alter the TMR drastically, and these changes usually are more long term and progressive. Accuracy of the scales and mixing system is critical to a TMR system, and a regular maintenance schedule should be planned and executed.

Determining the actual dry matter intake of cows often helps to indicate problems with forage quality and dry matter content. Cows should be within 5% of the expected dry matter intake. If actual dry matter intake exceeds 5% of the expected, that ration should be reformulated. Extremely low intakes may indicate that forage quality and/or dry matter contents have changed and may be a limiting factor to intake.

The number of animal groups to have in a TMR system is determined by the existing herd size and layout of the barns and loafing areas. An ideal TMR system for an entire farm could have seven main groups: high, medium, and low production lactating cows, far-off and close-up dry cows, and prebreeding and postbreeding heifers. In addition, many herds separate a first-lactation cow group from older cows for all or part of the first lactation. On many farms this group is critical, especially if other cow groups are overcrowded. First lactation cows most often respond well if they are undercrowded in terms of feed bunk and resting space per animal. Depending on farm size, having this many separate groups may be unrealistic, yet larger farms may have multiple groups of each.

When working with a one- or two-group TMR system, there is less flexibility to formulate rations to meet specific needs. For instance, the lower-producing cows receive the same forage as the higher-producing cows, which may not allow for optimal use of various forages. In a three-group system, low-group cows can usually be fed cheaper forage to reduce costs. Using a one-group TMR system usually results in higher feed costs because more expensive ingredients such as undegradable protein sources, fats, and certain feed additives are fed to cows in later stages of lactation. These cows should be fed a ration with higher levels of forage than a one-group TMR would provide. Lower-producing cows may become over conditioned in a one-group TMR system. Many of the problems of the one-group system can be avoided by using two groups, especially if one of them is fed according to above average group production. Obviously cow movement and changing social orders within pens is another factor to be considered when deciding the best number of groups for a farm operation. There is no one perfect answer for all systems and some farms will vary the number of TMR groups from year to year to best match other situations and priorities on the farm. The larger the farm, the easier it is to have the larger number of groupings or ration changes throughout the lactation cycle.

Dry cows, in particular, are often recommended to be divided into two groups, far-off and close-up. Using a two-group TMR system for dry cows can minimize the level of metabolic and nutritional disorders observed at calving and in the postpartum period. The close-up group should be cows two or three weeks from calving, or if it is being balanced for anions and cations, three to four weeks.

To ensure proper ration formulation for growth and development, a two-group TMR system is necessary for heifers with the inclusion of one prebreeding and one postbreeding heifer group. Young heifers lack the capacity to consume very high forage diets while maintaining proper growth. It is necessary for prebreeding heifers to have an energy- and protein-dense diet.

There are other points to consider when feeding a TMR. First, the ration should be available to the cows 22 to 24 hours daily. To promote maximum feed intake it is often recommended that refusals for the fresh group remain around 2 to 4%, 1 to 3% for high groups, and 0.5 to 3% for late-lactation groups. In general, feed refusal should not exceed 3 to 4%. Feed refusals can be fed to older heifers, steers, or other beef cattle. Refusals should never be fed to prefresh or fresh cows. First-calf heifers should be placed into a higher group than their production level to compensate for growth that they will have in the first lactation. Placing first-lactation heifers in a group separate from older cows reduces competition and gives younger cows improved access to bunk and stall space. Second, if hay or grain is fed separate from the TMR, it should be limited to two to five pounds per head per day. Supplemental grain feeding to high producers may be necessary in one-group TMR systems. However, the amounts to feed will depend on the level of concentrate that is being fed in the TMR. When large quantities of feedstuffs are fed separately from the TMR, the TMR loses many of the advantages it has over conventionally fed rations. Therefore, if possible keep all or nearly all of the ingredients in the TMR to maximize performance and profit.

General Approach to Formulating TMR

The key to formulating TMR is to optimize dry matter intake. Total dry matter intakes should be consistent with production and breed (see Table 1). Intakes may be depressed when ensiled materials undergo abnormal fermentation. Forage dry matter should consist of good- to excellent-quality forages, especially for high-producing animals. Palatability of forages, the presence of certain weeds, and water quality can affect intake. Dry matter intakes may be elevated when forage is chopped too finely or excessive concentrate dry matter is present. Dry matter intake during the first two weeks post calving may average 2% of body weight.

Table 1. Expected daily intakes of total dry matter by dairy cattle.

Milk production, 4% FCM (lbs/day)	Dry matter intake (% of body weight) Large breeds	Dry matter intake (% of body weight) Small breeds
100	4.30	5.80
90	4.10	5.40
80	3.80	5.00
75	3.65	4.80
70	3.50	4.50
65	3.40	4.25
60	3.25	4.00
55	3.13	3.85
50	3.00	3.70
45	2.85	3.50
40	2.70	3.30

Milk production, 4% FCM (lbs/day)	Dry matter intake (% of body weight) Large breeds	Dry matter intake (% of body weight) Small breeds
35	2.60	3.10
30	2.50	2.90
20	2.10	2.50

The ration differences between groups should be minimal, otherwise cows will decrease milk yield significantly when they are moved to a different group. Limit differences in concentrate dry matter proportions to not over 10 to 15% between groups. The level of concentrate dry matter and protein depends to a certain extent on the production level and the type of forage used (see Table 2).

Table 2. Guide to ration composition for high-producing cows.[a]

	Stage of Lactation Early[b]	Stage of Lactation Mid[c]	Stage of Lactation Late
Crude protein, %DM	17 to 18	16 to 17	15 to 16
Soluble protein, %CP	30 to 34	32 to 36	32 to 38
Degradable protein, %CP	62 to 66	62 to 66	62 to 66
Undegradable protein, %CP[d]	34 to 38	34 to 38	34 to 38
NE_L, Mcal/lb DM[e]	0.76 to 0.80	0.72 to 0.76	0.68 to 0.72
Forage NDF, %DM	21 to 24	25 to 26	27 to 28
Total NDF, %DM	28 to 32	33 to 35	36 to 38
NFC, %DM	32 to 38	32 to 38	32 to 38
Fat, maximum, %DM[f]	5 to 7	4 to 6	4 to 5
Calcium, %DM[g]	0.81 to 0.91	0.77 to 0.87	0.70 to 0.80
Phosphorous, %DM[g]	0.40 to 0.42	0.40 to 0.42	0.40 to 0.42
Magnesium, %DM[g]	0.28 to 0.37	0.25 to 0.34	0.22 to 0.28
Potassium, %DM[h]	1.00 to 1.50	1.00 to 1.50	1.00 to 1.50
Sulfur, %DM	0.23 to 0.24	0.21 to 0.23	0.20 to 0.21
Salt, %DM or	0.45 to 0.50	0.45 to 0.50	0.45 to 0.50
Sodium, %DM	0.20 to 0.25	0.20 to 0.25	0.20 to 0.25
Chlorine, %DM	0.25 to 0.30	0.25 to 0.30	0.25 to 0.30
Manganese, ppm	44	44	44
Copper, ppm[i]	11 to 25	11 to 25	11 to 25
Zinc, ppm	70 to 80	70 to 80	70 to 80

	Stage of Lactation Early[b]	Stage of Lactation Mid[c]	Stage of Lactation Late
Iron, ppm	100	100	100
Added selenium, ppm	0.3	0.3	0.3
Added cobalt, ppm	0.2	0.2	0.2
Added iodine, ppm	0.5	0.5	0.5
Total vitamin A, IU/lb DM	4,500	4,500	4,500
Added vitamin D, IU/lb DM			
Minimum	750	750	750
Maximum	1,100	1,100	1,100
Total vitamin E, IU/lb DM	30	30	30
Approximate concentrate, %DM[j]	55 to 60	45 to 50	35 to 40
Approximate DMI, %BW	4.0+	3.5+	3.0+

[a]Refers to milk production equivalent to a DHI rolling herd average of 24,000 lb of 4% fat-corrected milk or higher.
[b]Refers to cows in approximately the first 15 weeks of lactation. If cows fresh less than 4 weeks are kept in a separate group or fed individually, or founder is encountered in first-calf heifers, use the following modified specifications: CP 19%, UIP 38%, NE_L 0.76%, forage NDF 24%, fat 3 to 5%, the higher levels of minerals indicated and approximately 50% concentrate dry matter. DMI during the first month may range from 2.2% BW at calving to 2.8% BW at 14 days and 3.3% at 30 days.
[c]Follow guidelines for mid lactation animals if a one-group TMR is being fed.
[d]Use more than one high protein supplement to meet undegradable protein needs (UIP). Often lysine and sometimes methionine are the most limiting essential amino acids. On a largely corn-based ration as silage, grain or corn by-products; part of the UIP should be furnished by animal or fish protein, soybean protein or cottonseed protein to provide more lysine. Limit use of brewers, distillers, corn gluten meal, and feather meal in high corn diets.
[e]NE_L needs are dependent upon production level, body condition scores, and deviations in dry matter intake.
[f]Fat at over 5% should be furnished by rumen-inert or by-pass fats.
[g]Use these minerals at the higher level indicated when fat content exceeds 4.0%.
[h]Use the higher potassium level during periods of hot, humid weather.
[i]Use the higher copper levels when low serum copper occurs on rations containing usual levels of 10 to 12 ppm. Induced copper deficiency may result from excessive intake of iron, manganese, molybdenum, and sulfur.
[j]When feeding total mixed rations avoid differences between rations that exceed 10 to 15% for milking groups to avoid excessive drops in production when moving to a lower group.

Moving cows through groups in multi-group systems may control body condition in herds fed a TMR. In single-group TMR systems, the percentage of concentrate dry matter may be altered; thin cows could receive supplemental feed and over-conditioned cows could be somewhat limited in amounts of the ration fed. In general, it is important to follow sound nutrition practices with respect to crude protein, energy, neutral detergent fiber, nonfiber carbohydrates, fat, macro and micro minerals, and vitamins for the respective levels of production. Monitoring intakes of the TMR is beneficial so that animals do not over- or under-consume.

Dry cows, in particular, may need at least five pounds of long-stem hay along with a TMR to provide sufficient "effective fiber." Dry cows placed on a close-up TMR should be kept on the ration until the day they freshen. This applies to both regular and anionic close-up rations (see Table 3). Dry cows that are not grouped and offered one TMR may be fed limited amounts of the milk cow TMR two or three weeks prior to freshening. However, restrictions must be set to ensure that there is adequate forage dry matter intake and that the nutrient densities of protein, minerals, and vitamins do not exceed recommendations for close-up dry cows.

Table 3. Guide to ration composition for dry cows.

	Far-off	Close-up, regular[a,b]	Close-up, anionic[a,c]
Crude protein, %DM	12 to 13	13.5 to 14.5	13.5 to 14.5
Soluble protein, %CP	30 to 38	30 to 38	30 to 38
Degradable protein, %CP	-	-	-
Undegradable protein, %CP	-	-	-
NE_L, Mcal/lb DM	0.60 to 0.64	0.62 to 0.66	0.63 to 0.67
Forage NDF, %DM	27, min	27, min	27, min
Total NDF, %DM	36, min	36, min	36, min
NFC, %DM	26, min	26, min	28, min
Fat, maximum, %DM	-	-	-
Calcium, %DM	0.45 to 0.55	0.45 to 0.55	1.40 to 1.60
Phosphorous, %DM	0.30 to 0.32	0.30 to 0.32	0.32 to 0.35
Magnesium, %DM	0.24 to 0.28	0.28 to 0.32	0.28 to 0.32
Potassium, %DM	0.80 to 1.00	0.80 to 1.00	0.80 to 1.10
Sulfur, %DM[d]	0.16 to 0.17	0.17 to 0.19	0.35 to 0.40
Salt, %DM or	0.25 to 0.30	0.25 to 0.30	0.25 to 0.30
Sodium, %DM	0.10 to 0.12	0.10 to 0.12	0.10 to 0.12
Chlorine, %DM	0.20 to 0.24	0.20 to 0.24	0.70 to 0.80
Manganese, ppm	44	44	44
Copper, ppm[e]	11 to 25	11 to 25	11 to 25

[a]The last three to four weeks prior to expected calving.
[b]Regular or cationic (alkaline) diet.
[c]Anionic or acidic diet with a cation-anion balance of -100 to -150 milliequivalents per kilogram (mEq/kg). This is based on the simple equation of: mEq/kg = mEq (Na+K) - mEq (Cl+S). Factors to convert from nutrient % to mEq/kg of diet are Na: 435, K: 256, Cl: 282, and S: 624. *Example*: Calculate the cation-anion balance of a ration with Na at 0.15%, K at 1.10%, Cl at 0.80%, and S at 0.40% (all values are on a dry matter basis). mEq/kg = [(0.15 x 435) + (1.10 x 256)] - [(0.80 x 282) + (0.40 x 624)] = (65.3 + 281.6) - (225.6 + 249.6) = 346.9 - 475.2 = -128.3
[d]Sulfur level of 0.45% in the close-up anionic diet may be tolerated for short periods of time (three to four weeks).
[e]Use the higher or intermediate levels when an induced copper problem exists due to high iron, manganese, molybdenum, or sulfur intakes.

	Far-off	Close-up, regular[a,b]	Close-up, anionic[a,c]
Zinc, ppm	70 to 80	70 to 80	70 to 80
Iron, ppm	100	100	100
Added selenium, ppm	0.3	0.3	0.3
Added cobalt, ppm	0.2	0.2	0.2
Added iodine, ppm	0.5	0.5	0.5
Total vitamin A, IU/lb DM	3,500	3,500	3,500
Added vitamin D, IU/lb DM			
Minimum	750	750	750
Maximum	1,100	1,100	1,100
Total vitamin E, IU/lb DM	35	35	35
Approximate concentrate, %DM	12 to 15	22 to 25	22 to 25
Approximate DMI, %BW	2.0	1.8	1.8

[a]The last three to four weeks prior to expected calving.
[b]Regular or cationic (alkaline) diet.
[c]Anionic or acidic diet with a cation-anion balance of -100 to -150 milliequivalents per kilogram (mEq/kg). This is based on the simple equation of: mEq/kg = mEq (Na+K) - mEq (Cl+S). Factors to convert from nutrient % to mEq/kg of diet are Na: 435, K: 256, Cl: 282, and S: 624. *Example*: Calculate the cation-anion balance of a ration with Na at 0.15%, K at 1.10%, Cl at 0.80%, and S at 0.40% (all values are on a dry matter basis). mEq/kg = [(0.15 x 435) + (1.10 x 256)] - [(0.80 x 282) + (0.40 x 624)] = (65.3 + 281.6) - (225.6 + 249.6) = 346.9 - 475.2 = -128.3
[d]Sulfur level of 0.45% in the close-up anionic diet may be tolerated for short periods of time (three to four weeks).
[e]Use the higher or intermediate levels when an induced copper problem exists due to high iron, manganese, molybdenum, or sulfur intakes.

Nutrient specifications for heifer TMR are in Table 4. Total dry matter intakes are regulated by the bulk of the ration and its energy density. If corn silage is fed heavily in a heifer TMR, intakes may have to be controlled and more closely monitored to avoid over conditioning.

Table 4. Guide to ration composition (on a dry matter basis) for dairy replacement heifers.

	0 to 6 Mo.	7 to 11 Mo.	12 to 24 Mo.
Crude protein, %DM	16	13	12
Soluble protein, %CP	25 to 30	30 to 35	30 to 38
Degradable protein, %CP	45 to 55	33 to 37	25 to 30
Undegradable protein, %CP	45 to 55	63 to 67	66 to 72
NE_M, Mcal/lb DM	0.77	0.72	0.65

[a]Use higher or intermediate copper levels when an induced copper problem exists due to high iron, manganese, molybdenum, or sulfur intake.

	0 to 6 Mo.	7 to 11 Mo.	12 to 24 Mo.
NE_G, Mcal/lb	0.49	0.44	0.38
TDN, %DM	69	66	63
Total NDF, min., %	25	30	35
Calcium, %DM	0.60	0.48	0.45
Phosphorous, %DM	0.40	0.32	0.30
Magnesium, %DM	0.22	0.22	0.22
Potassium, %DM	0.80	0.80	0.80
Sulfur, %DM	0.21	0.17	0.16
Salt, %DM or	0.25 to 0.30	0.25 to 0.30	0.25 to 0.30
Sodium, %DM	0.10 to 0.12	0.10 to 0.12	0.10 to 0.12
Chlorine, %DM	0.20 to 0.24	0.20 to 0.24	0.20 to 0.24
Manganese, ppm	44	44	44
Copper, ppm[a]	11 to 25	11 to 25	11 to 25
Zinc, ppm	70 to 80	70 to 80	70 to 80
Iron, ppm	100	100	100
Added selenium, ppm	0.3	0.3	0.3
Added cobalt, ppm	0.2	0.2	0.2
Added iodine, ppm	0.5	0.5	0.5
Total vitamin A, μ/lb DM	2,500	2,500	2,500
Added vitamin D, μ/lb DM	400	400	400
Total vitamin E, μ/lb DM	35	35	35
Approximate concentrate, %DM	60 to 65	20 to 25	10 to 15
Approximate DMI, %BW	2.6	2.2	1.7
[a]Use higher or intermediate copper levels when an induced copper problem exists due to high iron, manganese, molybdenum, or sulfur intake.			

The benefits of using a TMR far outweigh the disadvantages, but each farm has different goals and facilities that may or may not adapt well. Each case should be analyzed to find the most profitable alternative. A carefully designed and well thought-out system will pay off in the long run.

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