Measure dry matter routinely on the farm and make rations more consistent
A food dehydrator can make it simple[1]

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There are actually four rations for each group of cows being fed on a farm. There is the one that was formulated, the one the feeder was given to mix, the one the feeder actually fed, and the one the cows ate. Woe to the nutritionist or dairy farmer who assumes they are always one and the same. We have all seen situations in which a group of cows will change milk production several pounds in a day or two (we seem to notice the drops in production more than the increases!) without a change in the formulated ration. Worse, cows will suffer acidosis and go off-feed or drop in milk fat test without a change in the formulated ration. Most likely, these changes in cow health and performance occur because of a change in the ration that was actually fed. But don't blame the feeder, there may be a simple reason why the ration actually fed can change quickly from one day to the next. It may be a simple change in the dry matter (DM) content of feeds.

We formulate rations on a DM basis because cows require a specified amount of dry nutrients each day to meet their requirements for production and health. However, even dry feeds are not absolutely dry, and moist, fermented feeds can contain a large proportion of water that dilutes the dry nutrients in the feed. But the person mixing and feeding the ration cannot measure the dry weights of feeds, but must weight them as-is, moisture included. Thus, if we want to feed 50 lb of dry nutrients per cow and the feed contains 50% DM, we have to give the cow 100 lb of as-is (or as-fed) feed to provide the 50 lb of dry nutrients. The other 50 lb of as-is feed is water. It is all very simple, except that the DM of feeds does not stay constant from day to day.

Dry matter concentration can change in the silo, especially in tower silos, when we move to forage that was cut at different times of the day or from different fields or cuttings. Yet how many of us send a sample to the laboratory from one location in the silo and use the DM reported for weeks or months even though we are feeding from a completely different location in the silo? Does it matter that the ration given to the feeder for mixing is not adjusted for changes in DM? It can, especially if the formulated ration was designed to be at the upper or lower limits of fiber concentration.

For example, if 3333 lb of alfalfa silage containing 45% DM and 38% NDF on a DM basis is mixed with 5635 lbs of corn silage and concentrates that contain 62.1% DM and 23.7% NDF on a DM basis, the ration will provide 5000 lb of total DM that contains 28% NDF and 1500 lb of DM from alfalfa silage. Let's assume the alfalfa silage changed from 45 to 35% DM and we did not adjust the mixing ration. Now when we load 3333 lb of silage we are only feeding 1167 lb of DM from alfalfa silage instead of 1500 lb, and our mixed ration contains only 4667 lb of DM and 27.3% NDF. Not only have we have shorted them 333 lb of DM, but we dropped the NDF and the effective NDF of the ration, which could throw the cows off-feed. The cows will respond accordingly.

Typically, changes in DM within the silo occur over several days because filling and emptying the silo blends the silages between fields and cuttings. Thus, we observe a gradual change in cow production and health that generates those calls that nutritionist hate to receive, “My cows are down in milk over the last 5 days, something must be wrong with the ration.” Not only is it difficult to get the cows back up in production after such a nutritional shock, but also it is frustrating to make changes in the formulation only to discover that the mixing ration was at fault. Problems caused by gradual changes in DM could be easily solved by routinely measuring forage DM (once or twice weekly), and adjusting the mixing ration. In research trials at the U. S. Dairy Forage Research Center, we typically take a sample every day of each forage and make a weekly composite of the seven daily samples. These weekly composites typically have a range of 5 to 6% DM for silages harvested as a single lot. To obtain data that would be typical of many dairy farms, we sampled the silages being fed to the non-research herd every 3 to 4 days for several months (Figure 1). The range within lots of silage varied from 3 to 8% DM and there were 6 to 10% DM differences between lots of both alfalfa and corn silages (Figure 1). Dan Undersander, University of Wisconsin Extension, observed that 33% of the forage DM were more than 5%-units from the average on two dairies in Wisconsin and New York.

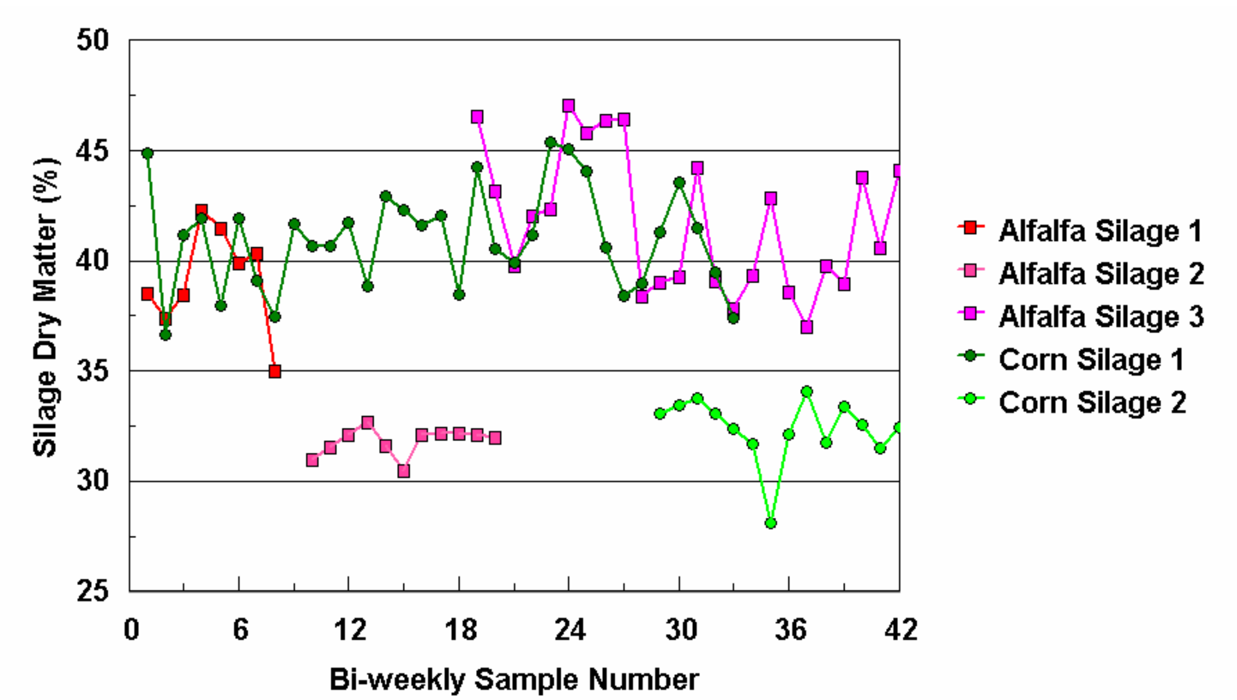

Figure 1. Variation in dry matter (determined by drying in a convection oven at 131 °F for 24 hours) of silages fed at the U. S. Dairy Forage Research Center over several months.

Although changes in forage DM can be gradual, rain and snow can result in abrupt changes in forage DM of 5 to 15% DM in exposed bunker silos, especially if there is loose silage on the floor of the silo. Note the drop in DM of both alfalfa and corn silages on sample numbers 6 to 8 and 19 to 21, which were probably related to rain or snow events (Figure 1). These changes in

DM can cause acute cases of acidosis or off-feed symptoms when high-energy rations that are borderline in fiber are fed because they always result in less forage DM being given to the cows. The 100 to 300 lbs of rain or snow in each loader bucket of silage adds weight that short-changes the cows on fiber, total nutrients and feed intake. Within a period of three days, the cows are fed a diet that is borderline in fiber, to one that is even lower in fiber with restricted intake, back to one that is borderline in fiber, but which is eaten quickly by hungry cows. It is a recipe for a nutritional disaster, which typically affects the highest producing group in the herd to the greatest extent. Cows seem to handle high-energy diets and low ruminal pH without problems if feed intake and minimal fiber concentrations are consistent. However, just one event that upsets intake when low fiber diets are fed can result in a cascade of ruminal responses that stress cows and lose production. Adjusting for these acute changes in silage DM requires a quick method that can determine DM immediately before feeding.

Dry matter in feeds is a simple concept and is one that can have a large nutritional impact on the ration that is actually fed. Ken collected TMR from high and low producing herds and observed that 25% of the TMR actually fed were significantly different in DM compared to the formulated ration. Variation in feed DM was the most important variable affecting TMR nutrient composition and in over 50% of the rations actual fiber content was less than that formulated.

It seems evident that we should measure DM routinely and use this information to guarantee that our cows are offered the same amounts and proportions of dry nutrients in their ration every day. It sounds easy, just dry ration ingredients in an oven, determine the DM in each, and reformulate the ration to adjust for differences in DM. However, measuring moisture is not as easy as it sounds. Some water is on the surface of particles and is easy to evaporate, other water is inside of particles and must migrate to the surface to be evaporated, and some water is tightly bound to molecules in the feed. Thus, it takes time for moisture to migrate and evaporate from feeds. We can speed the process by increasing the temperature and air-flow, but risk losing other components in feeds and causing chemical changes, if the temperature is too high.

Measuring DM using an oven is complicated because more is going on than just the evaporation of water. In fermented feeds, like silages or wet distiller's or brewer's grains, there are significant amounts of short chain fatty acids that are volatile. In fact, we often describe acetic, propionic, and butyric acids as volatile fatty acids (VFA). In addition, there are other components in feeds like residual alcohols and protein degradation products that are volatile (we can often smell them even at room temperatures). Even carbohydrates can lose weight when dried at temperatures that are too high. When you brown or char a sample during drying, you probably have lost matter that is not water.

The gold standard for measuring DM, or more correctly moisture, in feeds is the Karl Fischer method. This method uses a chemical reaction between water and an indicator reagent to measure moisture. The feed and reagent have to be homogenized together to extract and react all the water in the feed with the indicator reagent. The Karl Fischer method uses relatively small sample amounts, requires specialized equipment and technical skill, and is labor intensive. It is not used routinely to measure DM for these reasons, even in analytical laboratories.

Determining DM by drying in a convection oven is a more simple process that also generates a dried sample that can be ground and used for additional analyses. However, each combination of time and temperature in the oven will generate a different estimate of DM and some combinations will damage the sample. This is why laboratories have to standardize an oven-drying method to obtain repeatable DM results. We can determine the optimal time for drying by re-weighing the sample as it dries and observing the time at which the dry weight does not change. However, the optimal temperature of oven drying is less easily determined. Drying at low temperatures is slow, but drying at high temperatures can lose matter that is not moisture. Because both water and other volatile compounds can evaporate during drying the optimal temperature to use is a compromise. Drying at 55 °C (131 °F) volatilizes some non-water components in feed but also leaves some residual water. These two errors seem to compensate for one another. Drying at 55 °C for 24 hours closely matches the DM determined by measuring true water loss and provides a good reference value for evaluating other methods for DM determination.

On the farm, a Koster[2] tester can be used to dry one sample at a time in about 5-10 min, but requires individual attention and weighing multiple times to be done correctly. Similarly, a microwave oven can be used to rapidly dry samples, but it takes experience and skill to dry the sample without charring and also requires individual attention. Most farms feed more than one moist feed. It would be ideal if there was a method that could dry multiple samples, would be somewhat automated, and could be worked into the routine flow of daily feeding activity. Food dehydrators are designed to dry moist foods at relatively low temperatures, they are readily available, and have the capacity to dry multiple samples. We tested an food dehydrator with nine shelves and the variable temperature control set at the maximum (155 °F) to determine if a method could be developed that can be used routinely on the farm. By removing every other shelf, this unit can dry four samples simultaneously.

Forages are very heterogeneous, and if test samples are small there can be large variation between them, which makes DM measurement of the forage imprecise. To ensure that a single sample of forages would be representative for DM determination, we selected a 200-gram test sample amount. Initial experiments demonstrated that the surface area of the pan affected the rate at which samples would dry. Drying rate was considerably slower when there was more than 1.3 to 1.4 grams of moist sample per square inch of pan area. Thus, a 10X15, 11X14 or 12X13 inch pan would be acceptable for a 200 g test sample. We used cookie or baking pans because they are inexpensive, durable, and easy to obtain.

If DM is determined routinely on forages that are consistent or changing slowly, it is reasonable to develop a method that could be done in 24 h. Forages could be sampled in the morning and put in the dehydrator and weighed the following day. After selecting the test sample amount and pan size, we evaluated the effect of drying time in the food dehydrator. We evaluated the food dehydrator method using 24 silages (including 8 alfalfa silages and 11 corn silages) that ranged from 22.2 to 54.2% DM and four concentrates (including high moisture corn, distiller’s grain and brewer’s grains) that ranged from 24.5 to 73.4 % DM.

Much to our surprise, four samples could be dried relatively quickly in the dehydrator. After 4 hours in the dehydrator, average DM values were typically within 99% (slightly lower for wetter samples) of those from our reference oven method. Drying in the dehydrator for 6 to 8 hours equaled our reference method DM and drying for 24 hours resulted in DM that were slightly lower than the reference values. The standard deviation among replicated samples was higher for shorter drying times, but were similar to the reference method when drying time exceeded 6 hours (Table 1). It appears that the dehydrator can dry replicated 200-g test samples within 1% DM of one another, which is similar to the reference laboratory method.

Table 1. Change in dry matter determination and its standard deviation with drying time in a food dehydrator (155 °F) for three forages each dried on all four shelves on two different days.

Drying time	Dry Matter	Standard deviation[a]
2 hours	45.7	±1.80
4 hours	35.8	±1.41
6 hours	34.8	±1.16
8 hours	34.5	±1.04
24 hours	34.3	±1.03
24 hours, Reference Method[b]	34.6	±0.99

[a]Standard deviation is the + and – spread in the average value that would include 2/3 of the replicates.
[b]Reference method dry matter determined in a forced-air draft convection oven at 131 °F.

It appeared that alfalfa silages dried more quickly than corn silages, but they also differed in DM (40.1 and 34.6%, respectively). We classified the silages into several groups based on DM and observed that alfalfa silage had only a slightly faster drying rate than corn silage when the moisture content of the silages were similar (Figure 2). Most of the difference in drying rate is related to the moisture content of the silage. As expected, feeds with higher moisture dried at a slower rate. However, we were surprised how rapidly the dehydrator could dry forages in the first 4 hours at a low temperature that would minimize evaporation of non-moisture matter and not char the sample without supervision. We suspect that this efficient drying is due to the combination of shallow test sample depth and high flow rate of heated air in the dehydrator. It is obvious that some volatile fatty acids and alcohols are evaporated by the dehydrator method, but their loss is probably compensated by the incomplete removal of all water at 155 °F, similar to the laboratory reference method for DM.

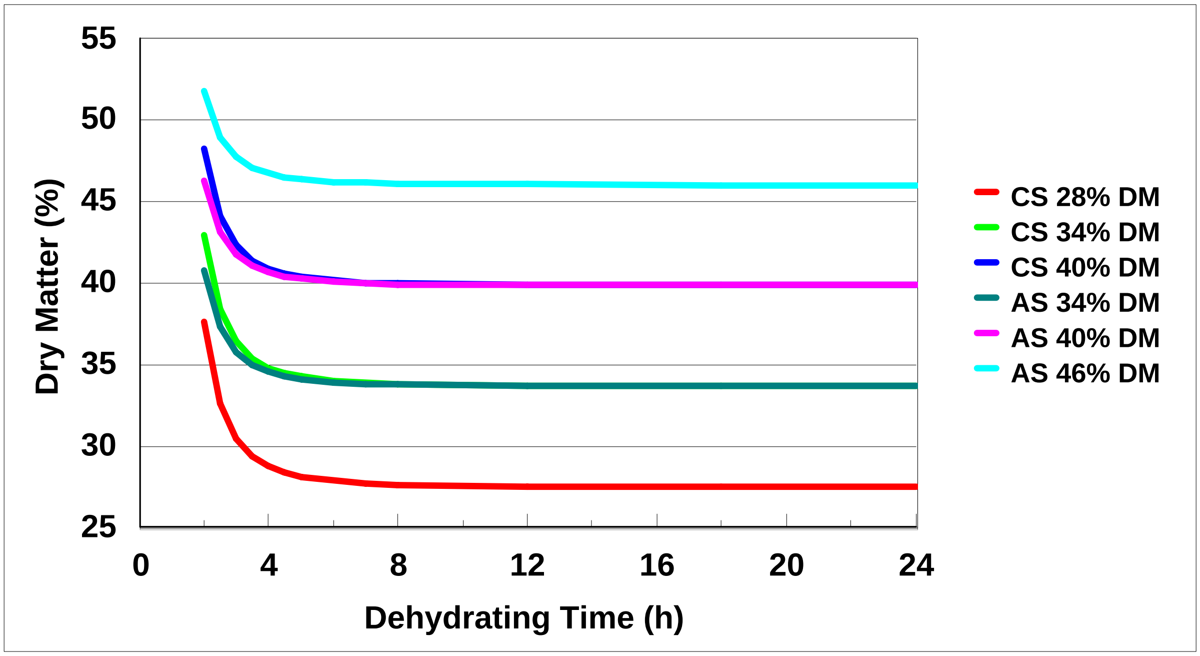

Figure 2. Effect of drying time on dry matter determination of alfalfa and corn silages of different dry matter concentrations using a food dehydrator at 155 °F.

There are times when a rapid determination of DM is needed, such as when the nutritionist want to check them during a farm visit or the feeder needs to adjust the mixing ration for moisture added by rain or snow. Although it appears that samples cannot dry completely in 2 hours, it was possible to develop an equation that can be used to estimate the 24-hour DM with from 2-hour DM measurement with acceptable accuracy: 24h DM = -17.4 + 1.21 X (2h DM). This equation is only valid for the specific dehydrator and method we used. Although using the equation is not as accurate as drying for 6 to 8 hours (variation that is about 2.5 times that of the reference method), it is acceptable for quickly checking DM.

We tested the food dehydrator method to ensure that it could handle four very wet samples and observed that they dried at similar rates compared to when they were dried as single sample with three other materials in the dehydrator. We also evaluated the effect of shelf location. We observed that the average DM for all drying times that was determined on the bottom and top shelves (36.7 and 36.6%, respectively) were slightly higher than DM on the middle shelves (35.9 and 36.2%). Because the bottom and top shelves had higher DM it indicates that samples on them did not dry as quickly. Most of this difference in DM was related to short drying times and by 24h there was less than 0.5% DM difference among shelves. The variation in DM among shelves is small relative to the variation among replicated test samples and should be of little concern. However, most efficient drying of samples can be obtained by putting the samples with most moisture on the middle shelves.

Materials and costs:

Excalibur Food dehydrator Model 2900 or 3900 (without timer) or Model 3926T (with a 26 hour timer)[2]	$250.

Four 10X15X1 inch cookie baking pans	$ 12
Electronic scale, accurate to 0.1 g (postal scales from office supply stores will work)	$ 40

Procedure:

1. Collect a representative sample of all moist feeds (a total of about 2 gallons collected from 10 locations).
2. Turn on the dehydrator to preheat it and leave the front open.
3. Place a labeled pan on the scale and record the pan weight (P_wt) to the nearest 0.1 g.
4. Tare the pan to 0.0 and add 200-205 g of test sample for the first feed.
5. Remove the pan + sample from the scale, spread it evenly over the surface of the pan and record the weight (S_wt) to the nearest 0.1 g. If any sample is dislodged from the pan when spreading the sample, it is not weighed.
6. Place one of the fine mesh screens that come with the dehydrator on the back portion of the pan (closest to the fan) to minimize loss of dried sample by air flow. Load the pan in the dehydrator.
7. Repeat steps 2 through 6 for each additional feed.
8. After all pans are loaded, replace the front cover of the dehydrator. It will not close completely when 15-inch pans are used but this is OK.
9. If your dehydrator has a timer, it can be set to the appropriate time for drying. If you dry for 2 hours to obtain a rapid estimate of DM, it is recommended that you reload the samples and dry them for an additional 2 to 6 hours to confirm the DM determination.
10. After the samples have dried, remove and weigh each pan + dried sample and record the final weight (F_wt) to the nearest 0.1g.
11. Calculate DM: % DM = 100 X (F_wt – P_wt) / S_wt. If DM was determined after 2 hours of drying, estimate DM using the equation: % DM 24h = -17.4 + 1.21 X (% DM 2h).
12. Adjust rations for any DM changes.

The most important step in determining DM is to obtain a representative sample. When sampling a bunker silo or feed pit or bay it is recommended to obtain 10 handfuls of feed from different locations where the feed will be loaded. For silage or high moisture corn that is stored in tower silos, start the unloader and obtain 10 handfuls of material. Thoroughly mix the sample and take a representative 200 g test sample for DM determination. Even with the best of sampling, there is still variation between daily samples of forage. We recommend smoothing the variation among samples using a rolling average that is calculated by averaging the latest DM with the previous rolling average that was calculated. This weighs the last DM more heavily in determining the DM that is used to adjust mixing rations, but minimizes changes in rations due to random sample variation. The exception to using a rolling average occurs when the DM of a feed changes by more than 6% DM, especially if it is related to external moisture from a rain or snow event. In this case, we recommend using the actual DM that was determined and then revert back to the rolling average when the feed with external moisture is gone.

Regardless of how DM is determined, the information is a waste of effort if it is not used to adjust the mixing ration. Dairy farmers with commercial feeding software can simply enter the updated DM values and the software will adjust the mix and the total amount to be fed to each pen. If you do not have feeding software, a simple spreadsheet can be used by the feeder to adjust the wet weigh of feeds that should be included in a batch. At the top of the spreadsheet list the DM and wet weights of feeds that were fed yesterday and those to be fed today with the updated DM. These calculations can be used to determine the total batch weight and amounts to be fed to different pens if the batch is split. Below these calculations, list the range in DM expected for each wet feed in a row and in the first column list a range of amounts of total ration DM that is needed for batches of various sizes. In the second column calculate the amount of feed DM needed for each batch size using the DM proportion determined in the formulated ration. Then for each column of differing DM percentage for the wet feed, calculate the amount of wet feed weight needed to obtain the DM amounts required for each batch size. After these matrices of wet weights have been calculated, all the feeder has to do is move across a given row to find the amount of each wet feed to mix in a batch when DM changes. The size of the batch can be adjusted by going up and down in a column for each feed.

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[1]The technical support of Alistair Carr in conducting this research is greatly appreciated.

[2]Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U. S. Department of Agriculture over others not mentioned.