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**NUTRITION FOR  
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## Measuring Dry Matter Using a Food Dehydrator

**Adapted from:** “Measure dry matter routinely on the farm and make rations more consistent - A food dehydrator can make it simple.” by David R. Mertens, Ken Bolton and Matt Jorgensen (USDA-ARS, U.S. Dairy Forage Research Center, Madison, WI and Univ. of Wisconsin Cooperative Extension, Jefferson and Neillsville, WI.

### Materials needed and their costs:

Excalibur Food Dehydrator Model 2900 or 3900 (without timer) or Model 3926T (with a 26 hour timer) (see attached for Model 2900 information from an example vendor)	\$190 to \$250
Four 10 inch x 15 inch x 1 inch cookie baking pans	\$12
Electronic scale, 400 g capacity and 0.1 g readability an example is the Ohaus Scout Pro Portable Electronic Balance, Model SC401E, 400 g capacity x 0.1 g readability (see attached for ordering information from Nasco)	\$150

### Procedure:

1. Collect a representative sample of all moist feeds (a total of about 2 gallons collected from 10 locations). Spread the sample over a smooth, flat surface and evenly mix. Divide the mixed sample into four quarters. Be sure to completely separate each of the quarters. Discard two of the quarters, re-mix the feed, and quarter the sample again. Select about 200 grams of feed for the dry matter analysis – this should be about one of the four remaining quarters.
2. Set the temperature of the dehydrator at the maximum (about 155°F). 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. Add about 200-205 g of the first feed to the pan. It is not critical to add exactly this much feed – just get fairly close to this amount.
5. Remove the pan + sample from the scale, and spread the feed evenly over the surface of the pan. Put the pan + sample back on the scale and record the total initial weight (I\_wt) to the nearest 0.1 g.
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. Dry the samples for about 6 to 8 hours (typically overnight). It does not hurt to leave the samples in the dehydrator for as long as 24 hours.

If you want a rapid estimate of dry matter, you can dry the sample for exactly 2 hours and then use the equation below to estimate the dry matter from this partially dried sample. After estimating the dry matter at 2 hours, reload the sample(s) and dry them for an additional 4 to 6 hours to confirm the estimated 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 using this formula:  
$$\% \text{ DM} = 100 \times (F\_wt - P\_wt) / (I\_wt - P\_wt)$$

If DM was determined after 2 hours of drying, estimate DM using the equation:

$$\% \text{ DM} = -17.4 + 1.21 \times (\% \text{ DM } 2\text{h})$$
12. Adjust rations for any DM changes.

### **Comments from the developers of this protocol:**

We tested a 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 10 x 15, 11 x 14 or 12 x 13 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.

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.

There are times when a rapid determination of DM is needed, such as when the nutritionist wants 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:  $\text{DM} = -17.4 + 1.21 \times (2\text{h DM})$ . 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. Samples on the bottom and top shelves 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.

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.

*Note: 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 or the University of Wisconsin-Madison over other products not mentioned.*

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Description

Features & Specifications

Excalibur Model ED-2900 9-tray Food Dehydrator (Excaliber)

The ED2900 is a 9-Tray Family Sized Economy Model

Drying food is fun! The Excalibur Dehydrator allows you to dry anything evenly and efficiently. The unit can dry all vegetables, meats, and more! Make fruit leathers and home-made jerky - FRESH! The Excalibur has a trademarked horizontal-airflow drying system which dries foods perfectly evenly on all the trays.

Dehydrating is a great way to add a new way of consuming foods without damaging valuable nutrients which may be lost during high heat cooking! Dried foods are a great treat to snack on because they hold almost all of their nutritional value and flavor.

This unit differs from other dehydrators because of its unique horizontal drying system in the rear of the unit. This provides a sure way to provide an even dehydration process as the warm air removes moisture and is pushed out the front of the machine. There is also no need to rotate trays because of the horizontal drying.

Features:

- Thermostat adjusts from 85 - 145 degrees
- 15 Square Feet of drying space
- 15" X 15" Trays
- 1.25" between each shelf
- Trays can be removed to expand the drying chamber
- Removable doors and trays
- Each tray is supported on its own 'shelf' making it easy to slide in and out
- Made of FDA Approved polycarbonate plastic
- Plexiglas door
- Trays are dishwasher safe!



- Includes instruction manual with over 50 recipes!

Specifications:

Model	ED-2900
Weight	23 lbs.
Dimensions	Depth 19" Width: 17" Height: 13"
Voltage	120 V / AC / 60Hz
Power	600 W
Thermostat	Yes
Number of Trays	9
Amount of Drying Space	15 SQ FT.
Clearance between shelves	1.25"
Fan Size	7"
Built of	Thick polycarbonate plastic
Warranty	1 Year
Non-stick sheets	<u>Available</u>

Any reference to the Excalibur company name remains the right of Excalibur/Killer Baits Inc. We make no claims that we are the manufacturer or have any signed agreements with Excalibur

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# Ohio Dairy Veterinarians Meeting

Pre-Conference Workshop, January 7, 2010

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## Nutrition Troubleshooting Toolbox

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### Evaluating Diet Formulation

It is very difficult for non-nutritionists to evaluate diet formulation (i.e., the paper ration) - and for good reasons. First, the complexity of diet formulation has increased considerably over the last decade. Many commercially-available ration formulation programs (Cornell or Penn Models, CPM Dairy, Amino Cow, 2001 Dairy NRC) model nutrient uptakes based on level of intake, individual feed ingredient digestibility, estimated amino acid composition, and physiological state of the cow. It difficult to understand these models unless you are well-trained in nutrition and have experience running them.

While diet formulation has become more complex, the variation in diet formulations (especially for lactating cows) has decreased. The decrease in the number of herds has also decreased the number of nutritionists needed in the field. As a result, only the most competent have remained in business, and in general they do a very good job formulating diets. There is also more agreement amongst nutritionists as to what nutrient requirements should be for lactating cows, so the lactation diets I now see in the field are quite similar.

*Lactation Diet Formulations.* Recent trends in lactation diets are toward higher carbohydrate diets. These diets are relatively high in both NDF and NFC. They also contain more forage (albeit higher digestibility forage) than diets in the past. Nutritionists are making room for more carbohydrate in their diets by decreasing the amount of crude protein (about 16.5% crude protein is all that is needed, provided amino acid balance is good) and decreasing the amount of supplemental fat (diets with 6.0 to 6.5% fat are uncommon now – 4.5 to 5.0% is more the norm). These relationships are illustrated in Figure 1 (top of the next page). I encourage you to be supportive of nutritionists who are moving in the direction of higher carbohydrate, higher forage diets.

<u>'Old' Diet</u>		<u>High NDF Diet</u>		<u>'High Carb' Diet</u>	
CP	18.5%	CP	18.5%	CP	16.5%
EE	6.0%	EE	6.0%	EE	4.5%
NDF	29.0%	NDF	32.0%	NDF	33.0%
Ash	9.0%	Ash	9.0%	Ash	8.0%
<u>NFC</u>	<u>37.5%</u>	<u>NFC</u>	<u>34.5%</u>	<u>NFC</u>	<u>38.0%</u>
Total	100.0%	Total	100.0%	Total	100.0%

Total CHO 66.5%    Total CHO 67.5%    Total CHO 71.0%

**Figure 1.** Total composition of traditional (“old”) lactation diets, high NDF diets, and high carbohydrate diets. The high carbohydrate diet is preferred.

*Dry Cow Diet Formulations.* In contrast to lactating diets, formulations used for dry cow diets are quite variable from one nutritionist to the next. This is expected, given that the science behind dry cow feeding is equally variable and in fact is quite confusing. Some studies demonstrate benefits for higher energy, higher intake dry cow diets, but other studies show the exact opposite. Some studies suggest that cows should be grouped into two or more groups, others suggest that only the far-off diet is important, etc., etc.

I have seen all kinds of dry cow formulations seemingly “work” on dairies. And I have seen formulations that “work” on one farm fail miserably on another farm. My conclusion (at least for now) is that diet formulation for dry cows is not nearly as important as sufficient access to bunk space, minimizing pen moves near calving, allowing high dry matter intakes, delivering feed very consistently, and feeding only high quality ingredients.

The one approach to dry cow diets that most often fails is adding excessive straw (or coarse dry hay) to a pre-fresh diet for a group of cows that already has low dry matter intake (<24 lbs/cow/day if a mixed parity pre-fresh pen, or <26 lbs/cow/day if only 2+ lactation cows in the pre-fresh pen). In these situations, adding extra straw or hay depresses dry matter intake even further and may trigger a disastrous increase in fatty liver, ketosis, and DA. In contrast, herds with good intakes in the pre-fresh pens may benefit from lower energy density and increased bulk from the added straw.

Supplementation with anionic salts (i.e., low DCAD diets) are a good means of reducing both subclinical and clinical milk fever. However, anions should be supplemented only when feeding management is excellent, feed ingredient quality is good, dry matter intakes in the pre-fresh cows are already high (>26 lbs/cow/day for mixed parity pens, or >28 lbs/cow/day for pens with only 2+ lactation cows), and the producer regularly monitors urinary pH. Forage DCAD (especially K and Cl) are highly variable, and it is virtually impossible to sample the forages frequently enough to keep up with changes in K and Cl. So, it is essential to use a biological test (in this case, urinary pH) to monitor the feeding rate of the source(s) of supplemental anions. The details of this test are discussed elsewhere in these notes. Herds that feed supplemental anions but do not regularly check urinary pH will unavoidably run into problems with either

over-acidification (which decreases pre-fresh dry matter intake and increases the risk for fatty liver, ketosis, and DA) or under-acidification (which increases the risk for milk fever and DA).

## Evaluating Individual Feed Ingredients

Sometimes nutritionists overlook the importance of evaluation of individual feed ingredients – especially the more subjective aspects such as preservation, palatability, particle length, and sortability. I find it very helpful to see all the feeds on the farm and at a minimum do a visual appraisal of each. I am particularly interested in their smell of fermented feeds - but don't do too much sniffing if the feed is moldy and/or you have allergy problems! I am sometimes surprised to find butyric acid smell in a silage that no one else has yet noticed. Butyric acid intake is a strong risk factor for ketosis - this is described in detail in another section of these proceedings. It is easier to appreciate the butyric acid smell if the feed is at room temperature and in a clean place. Sometimes other odors on the farm mask the butyric smell.

Silages containing butyric acid have an elevated pH – definitely over 4.8 and usually in the 5.2 to 6.0 range. So, a check of the silage pH can be helpful (add 1 tablespoon to 50 ml distiller water, mix, and check the pH on a meter). To confirm and quantify the amount of butyric acid in a silage, have the nutritionist send a sample to a lab for a silage organic acid analysis (often termed VFA analysis – an unfortunate misnomer, since lactic acid is not volatile). These tests cost about \$20 each and are well worth it if there is any concern at all about the quality of a fermentation. Appendix I provides details about the silage fermentation process and the interpretation of organic acid test results.

The dry matter content of ensiled feeds is the major determinant of the quality of the fermentation. Table 1 lists recommended dry matters for different feeds and different silo types.

**Table 1.** Recommended dry matter and moisture content at harvest for different feeds and silo types.

Feed ingredient	Silo type	Recommendation for :	
		Dry matter, %	Moisture, %
Corn silage	Oxygen-limiting*	40 – 45	55 – 60
	Vertical (open top)	30 – 35	65 – 70
	Horizontal (bunker)	28 – 33	67 – 72
Hay silage (alfalfa or grass haylage)	Oxygen-limiting*	50 – 55	45 – 50
	Vertical (open top)	35 – 45	55 – 65
	Horizontal (bunker)	35 – 40	55 - 60
High moisture corn	Oxygen-limiting*	75 – 80	20 – 25
	Vertical (open top)	65 – 70	30 – 35
	Horizontal (bunker)	65 – 70	30 – 35

\* Oxygen-limiting silos include Harvestore or similar upright silos and silage bags.

There isn't anything you can do to alter feed dry matter content once it is harvested and ensiled. Someone needs to be alert to check dry matter at the time the feed is harvested. This probably won't be your job, but you can help make sure that it is getting done on the farm. Some farms routinely harvest forages that are either too wet or too dry, and they almost always pay the price for these mistakes. John Deere manufacturers an on-board NIR moisture tester that can be installed on the discharge chute of its choppers. This unit costs \$30,000, but making big mistakes in the dry matter content of ensiled feeds usually cost a lot more. Make sure your producers get the message that ensiled feeds must be harvested at the correct dry matter – at almost any cost.

It is important to accurately know the dry matter content of a feed ingredient during feedout so that the correct amount of dry matter from that ingredient can be added to the mixer. You can help dairy producers make sure this job gets done. The frequency of dry matter testing needed depends on the type of feed and the structure it is stored in. In general, corn silage and high moisture corn have fairly consistent dry matter content. However, hay crop silages can have quite variable dry matter content at harvest. These variations are particularly important if the hay crop silage is stored in a bag or narrow vertical silo (especially if top-unloading). The problem is that dry matter content can vary from load to load of chopped forage, and silage in these structures is unloaded in a manner that feed from one load to the next is not mixed. In these cases, daily dry matter monitoring may be necessary. Hay crop silages stored in bunker silos have more consistent dry matter content at feedout because feed from many different loads is fed out simultaneously. Weekly monitoring of dry matter content of the haylage coming out of a bunker silo may be sufficient. Checking forage dry matter only when feed refusals change noticeably or when the feed is visibly different is better than no testing at all. However, proactive monitoring of forage dry matter content is much better. Details on forage dry matter determinations are given in Appendix II to V.

Particle length of forages and the particle size of grains are also important. Someone else will probably be responsible for this task – you need to encourage the farm to make sure that it gets done. Details about evaluating forage particle length using the Penn State shaker box are found in Appendix VI, and details about determining grain particle size (using a set of particle size screens) are given in Appendix VII. You can do informal evaluation of feed ingredient particle length or size by simply looking at a few handfuls of the feed on a clean, flat surface (e.g., the back of a clipboard) and then separating the coarse from the fine particles. Don't forget to also look at the particle length of dry, chopped hays if these are a part of the diet. Coarse, long hay particles (greater than about 2 inches in length) are easily sorted away by the cows. In contrast, cows will sort toward soft, leafy hay and eat it first – even if not chopped at all. In either case, chopping the hay about 1 to 2 inches long before adding it to the mixer will prevent most sorting.

A simple visual appraisal of custom concentrate, protein, or mineral mixes can be invaluable. Take a handful or two of the feed (in this case, the mix) and separate into its different components on a flat surface. Sometimes you can catch inadvertent errors in feed mixes simply by spotting the wrong

ingredients or obviously incorrect proportions of ingredients in the mix. Samples can then be submitted for wet chemistry analysis or feed microscopy for confirmation of the problem.

### **Evaluating Accuracy of Mixing the TMR**

I find it useful to start my evaluation of TMR mixing accuracy by following the mixer as new feed is delivered and then visually inspecting the feed. Does the mix appear the same from the start to the finish of unloading? Is there more long hay in a certain part of the mix? Are there large chunks of hay that are not mixed with other ingredients? Are there more whole cottonseeds in any part of the mix? Do the whole cottonseeds appear brown and matted (an indication of over-mixing), or are they still fluffy and white? Does the corn silage or haylage in the mix appear mashed and pulverized, or are the long forage particles still intact?

The best time to sample the TMR for analysis is at the time it is first fed. So, while I am following the mixer and inspecting the mix, I usually collect a representative sample for later analysis. It is important that this sample be as representative as possible of the entire TMR batch. Collect about 12 handfuls of feed from the start to the end of unloading the mixer. Put the feed into a 5-gallon bucket as you go – it should be full when you are done. Collect the handfuls by scooping upwards; otherwise, finer particles could be selectively lost by grabbing the sample and drawing it away from the bunk. Some suggest using pre-positioned trays in the feed bunk to collect the samples; however, the depth of feed typically placed in feed bunks makes this impractical.

After collecting the 12 or more handfuls, dump them out of the bucket onto a flat surface (preferably a smooth, clean table) and mix them gently. Then separate the feed into quarters. Discard two of the quarters (decide randomly which quarters to discard), then re-mix the remaining feed and repeat the quartering and discarding procedure. Discard different quarters each time you do the mixing. Continue mixing, quartering, and discarding until you have reduced the sample to the size you need. For particle length analysis in the Penn State shaker box you need 6 cups of feed per sample. For submission of the TMR to a laboratory for nutrient analysis you need about 1/2 pound (one pint) of feed.

*TMR Bunk Sample Particle Length.* Particle length is usually the most important single test for a TMR mix. The protocol for testing is the same as for individual forages – see details in Appendix VI. TMR bunk samples should contain about 7 to 12% long particles (top screen), and have more particles on the middle screen than the bottom screen plus pan. There can be many exceptions to this rule. High fiber diets fed very consistently with adequate bunk space may be fine at 4 to 7% long particles. Wet by-product feeds can artificially elevate the proportion of feed on the bottom screen and pan. Long particles over 2 inches in length may be sortable and actually contribute little or nothing to effective fiber in the rumen.

*TMR Sorting Analysis.* It can be particularly helpful to compare particle length of the TMR at feeding to the TMR refusals from the same pen (usually the previous day's refusals). Ideally the appearance and

particle of both samples should be identical. In reality, modest increases in long particles in the refusals (up to 5 percentage points) appear to be acceptable. For example, if a TMR is offered at 7% long particles, it would be acceptable for the refusals to be up to 12% long particles. I consider a 5 to 10% increase in long particles in the refusal to be a moderate sorting problem. More than a 10% increase in long particles would be a severe problem.

It would be ideal (but very time-consuming) to evaluate particle length of the TMR in the bunk throughout the feeding period. This would clearly reveal when the sorting is occurring during the day. However, for most troubleshooting exercises it is sufficient to compare the feed offered to the feed refused at the end of the day. Sometimes a third sampling in the middle of the day can be added to the evaluation without much difficulty.

Excessive TMR sorting is usually caused by overly long forage particles (especially dry hay or straw), often in combination with TMR that is too dry (>50% dry matter). Most sorting problems can be solved by processing the dry hay or straw finer (<2 inches) before adding it to the mixer, feeding more frequently during the day, adding extra water or a wet by-product feed to the TMR (goal of 40 to 45% TMR dry matter), adding liquid molasses to the TMR, or a combination of these. Realize that adding water or molasses to TMR mixes increases heating problems in the bunk in the summer. However, this can be a good thing if it causes the dairy producer to feed more frequently in the summer months.

*TMR Bunk Sample Nutrient Analysis.* A wet chemistry analysis of a carefully collected TMR bunk sample can be a useful adjunct to calculated estimates of what the cows are actually eating. Recognize that bunk sampling and nutrient testing is not a perfect representation of what the cows are eating. However, it can sometimes provide very useful information that could not be determined any other way.

TMR bunk samples should be submitted for wet chemistry analyses only – near-infrared reflectance spectroscopy (NIRS) analyses of TMR bunk samples is very difficult because of the near impossibility of creating a valid calibration set for a sample containing different feed ingredients in different proportions. I typically request wet chemistry analyses for dry matter, ether extract (crude fat), crude protein, bound protein, soluble protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, ash, calcium, phosphorus, magnesium, potassium, sodium, chloride, sulfur, copper, iron, manganese, and zinc. The non-fiber carbohydrate (NFC) content of the TMR can then be calculated by subtracting the ether extract, crude protein, neutral detergent fiber, and ash from 100% of the dry matter. The net energy for lactation (NEL) content of the TMR can be estimated from the ether extract, crude protein, NDF, lignin, and ash values using the OARDC (Ohio) equations. Do not use NEL values for TMR mixes calculated from the ADF value alone – these NEL estimates are valid only for individual feed ingredients and cannot be applied to TMR bunk samples. Expect a TMR bunk analysis for this array of nutrients to cost about \$40 to \$80 and to take three to five days.

It is important that the laboratory not try to further sub-sample whatever TMR bunk sample you have already carefully sub-sampled. TMR samples may separate considerably during shipping and handling,

especially if they are relatively dry. Therefore, it is best to submit only a relatively small quantity of feed (about 1/2 lb or one pint of sample) and to then request that the lab dry and grind the entire sample submitted. I put this request on each bag of TMR sample that I submit for analysis. Most laboratories are glad to comply with this request, as long as you submit only a small amount of feed.

Laboratory results for TMR bunk samples should be interpreted broadly, not strictly. There are numerous causes of variation between the expected and actual TMR bunk sample analysis, including poorly representative bunk samples, undetected changes in feed ingredient analyses (especially forages), undetected inconsistencies in adding feed ingredients to the mixer wagon, and laboratory error in the wet chemistry analyses. Some of these indicate an on-farm problem that requires intervention, but others are inherent errors in TMR bunk sampling. Determining which errors might be involved can be difficult. I consider the expected and laboratory results to be acceptably close if they are within about  $\pm 5\%$  of each other (on a total nutrient basis). For instance, if the expected calcium content of a TMR was 1.00%, then any lab result between .95% and 1.05% would be considered acceptable.

Laboratory analysis of TMR bunk samples almost always results in slightly higher ADF and NDF values than estimated. I have come to expect about a 5 to 10% total over-estimation in ADF or NDF results from TMR bunk samples. For example, if the actual ADF content of a TMR was 19%, then the lab result would be likely be about 20.0 to 20.9%. Or if the actual NDF content of the TMR was 28%, then the lab result would likely be about 29.4 to 30.8%. The source of this bias is uncertain, but may involve the inclusion of some of the fat added to the TMR being retained in the ADF and NDF fractions during laboratory testing. The slight over-estimation of the NDF value lowers the NEL value calculated by the Ohio equation by about 2 to 3% of the total NEL value. So, a TMR sample with an expected NEL of .78 Mcal/lb would likely have an NEL value of .757 to .764 calculated by the lab.

The greatest value in TMR bunk samples is to identify gross errors in feed analysis, mixing, or delivery. For example, omitting the salt from a custom protein mix would result in a TMR bunk sample with unexpectedly low sodium and chloride content. Omitting the trace mineral/vitamin premix from the ration would result in unexpectedly low copper, iron, manganese, and zinc results. Feeding excessive dry matter from alfalfa haylage because the haylage became drier than the nutritionist's last analysis would result in elevated dry matter, crude protein, soluble protein, ADF, and NDF values in the bunk samples.

When there are substantial discrepancies in expected vs. lab analysis results in TMR bunk samples, I find it useful to summarize the ration data, including the nutrient requirements, the ration formulated by the nutritionist (the "second" ration), the dry matters of the feed ingredients, the expected ration, and the lab analysis results all on one sheet of paper. I tabulate this information using a spreadsheet (see an example in Appendix VIII).

## Evaluating Consistency of Feed Delivery

It is difficult to evaluate the consistency of feed delivery on a farm, but a few questions will sometimes provide very revealing information. If the farm uses a feed mixing monitoring program (Feed Watch, etc.), then you can evaluate not only the accuracy of feed ingredient delivery, but also the consistency of the time of day that feed is delivered to each pen.

The feeding schedule on a dairy needs to be fanatically consistent, and particularly in respect to the synchrony of feeding and milking times. The first feeding of the day should coincide with the cows returning from the parlor after their first milking. This will be the biggest meal of the day for most cows. It is crucial that this be done consistently. Cows apparently learn to carefully regulate their meal patterns (meal frequency and meal size) in order to self-regulate their ruminal pH. But if the feeding schedule is erratic, they will never accomplish this self-regulation. It seems particularly dangerous if cows receive their TMR later than usual – hungry cows may over-eat when feed is finally offered. Problems with an inconsistent feeding schedule are magnified by shortages in bunk space, a shortage in free stalls (cows may be more concerned about securing a place to lie down rather than eating to regulate their ruminal pH), or inadequate availability of water immediately after milking.

## Evaluating Frequency of Feed Delivery

It is common to offer TMR once daily to most groups of cows. Many herds increase to twice daily feeding in the summer, which is an excellent decision. I prefer twice daily feeding year-round, but recognize that this usually requires extra labor. Frequent pushing up feed during the day may stimulate some additional dry matter intake, but does not appear to reduce the potential for sorting when TMR is offered infrequently. Increased feeding frequency is particularly important if the TMR is already prone to be sortable (dry TMR, excessive amount of coarse particles).

## Evaluating the Amount of Feed Offered

Each day the dairy producer makes a decision as to how much feed to offer each group of cows on the farm. The goal is to keep cows from getting hungry and over-eating on a sporadic basis, and yet not waste too much feed on the farm. The ability of the farm to utilize TMR refusals often decides how much refusal they will target.

This decision to make “feed calls” at the start of each day should be based on the appearance of the bunk at the end of the previous feeding day. A typical goal is about a 5% daily feed refusal. More feed refusal (about 10%) is needed for pens with very dynamic populations (i.e., the transition cows in the pre- and post-fresh pens). Mid and late lactation pens can be fed to much lower feed refusal (2% or less) because pen populations are more stable. Some herds consistently run zero daily feed refusals without difficulty. However, this requires exceptionally consistent feeding management. The cows can self-regulate intakes and ruminal pH if the bunks are empty the same time each day, and if new feed is offered at the same

time each day. Most dairies cannot manage their feed calls this well and need to target  $\geq 5\%$  daily refusals.

It is very helpful if the producer records the feed offered and feed refused for each pen each day. The refusals do not have to be weighed daily; an estimation of the amount refused is usually sufficient.

The amount of feed offered to each pen each day should be an adjustment of the total batch. The producer should not lock most the ingredients and then “float” just one ingredient (usually a forage). Severe ration imbalances can occur if only one ingredient in the mix is floated. Producers should monitor forage dry matter regularly and have the confidence to adjust the entire TMR mix recipe up or down each day.

## Appendix I - Silage Fermentation Analyses

*Silage Fermentation Process.* Proper silage fermentation starts with forage harvested at the proper dry matter content. This silage should then be chopped to the proper particle length. Finer chopping tends to improve packing and silage fermentation products, but conversely increases the risk for ruminal acidosis. So, proper chop length represents a compromise between maximal silo packing and optimal rumen health.

Once silage has been harvested at the proper dry matter content and chopped to the correct particle length, it must be packed as quickly and tightly as possible in the silo. The goal during silo filling is exclusion of as much air as possible so that the silage goes through only a short aerobic stage of fermentation. This stage of fermentation ends when aerobic bacteria consume the oxygen in the silage. Heat is a major end product of aerobic fermentation, so it is desirable to limit it as much as possible. With good silage, this phase only lasts a few days and the silage does not become excessively hot.

The aerobic phase of silage fermentation will be extended if the silage is too dry when chopped, loosely packed in the silo, or if the top layer of the silo is exposed to excessive oxygen because of slow filling. Any of these problems leads to excessive loss of silage dry matter as soluble carbohydrates are converted to heat and lost. Additionally, excessive heating may damage silage proteins by irreversibly binding them to fiber and making them indigestible. Heat-damaged proteins can be measured as bound protein (also termed ADF-CP, ADF-N, ADIN, unavailable protein, or Maillard protein).

Once the oxygen in the silage is consumed, fermentation moves into the anaerobic phase. Anaerobic bacteria initially convert soluble carbohydrates in the silage into acetic acid. As the pH of the silage drops from the accumulation of acetic acid, lactic-acid producing bacteria dominate. These bacteria produce lactic acid until the pH of the silage drops below about 4 or 5. At that point, all bacteria in the silage die and the silage becomes a stable, preserved mass. The anaerobic phase of silage fermentation takes about 1 to 3 weeks, depending on the availability of soluble carbohydrates in the ensiled material and the ambient temperature (fermentation proceeds slower during cooler weather). Anaerobic fermentation does not produce heat or cause loss of silage dry matter.

Silage proteins are partially degraded to ammonia and other forms of non-protein nitrogen during aerobic and anaerobic fermentation. Excessive protein degradation is undesirable and reduces the nutritional value of the forage. The lower the dry matter of the ensiled material, the more extensive the protein degradation. Proper forage dry matter at ensiling is a compromise between rapid oxygen exclusion and risk of improper silage fermentation at very low dry matters. Wetter forages have advantages of more rapid oxygen exclusion and rapid acid production, but they suffer from extensive protein degradation. Wetter forages may also favor fermentation by clostridial species of bacteria, which produce very undesirable fermentation end products such as butyric acid and toxic protein amines. Clostridial fermentation does not lower silage pH below 5.0 and thus is not self-limiting. Butyric acid concentrations in silages fermented by clostridial bacteria continue to rise during storage as long as the silage pH stays above about 5.0.

When the silage is fed out of the silo, it is re-exposed to oxygen and undergoes a secondary aerobic fermentation. Heat is produced during this phase, plus spoilage bacteria, yeasts, and molds may grow as silage pH rises. Silages with a lower final pH and higher total acid content are less vulnerable to secondary fermentation problems than are poorly fermented silages with higher final pH's and lower total acid content. Acetic acid is more effective in inhibiting secondary fermentation than is lactic acid; however, high acetic acid content may inhibit feed intake and is not desirable. Well-fermented silages typically contain about twice as much lactic acid as acetic acid.

*Silage Fermentation Analysis.* Silage pH can be determined on the farm. Add about 1 tablespoon of silage in about 50 ml distilled or deionized water and mix well. Then determine pH using a pH meter (Cardy Twin pH Meter, (Spectrum Technologies, Plainfield, IL, 800-248-8873 or <http://www.specmeters.com>). or pH paper strips (Whatman Lab, pH indicator paper range 4 to 6, type CS, 800/942-9626). Laboratories can perform a full organic acid analysis that typically includes silage dry matter, pH, crude protein, lactic acid, acetic acid, propionic acid, butyric acid, iso-butyric acid, total acids, ethanol, and ammonia. A hypothetical example of a report from a silage fermentation analysis is listed on the next page.

## S A M P L E F E R M E N T A T I O N A N A L Y S I S

Test Item	Value	Unit	Normal Range (alf. silage)
Dry Matter	30.3	% DM	35 - 45
Crude Protein	22.6	% DM	18 - 22
Bound Protein	1.0	% DM	.3 - 2.2
Bound Protein	4.4	% CP	2 - 10
Ammonia (CP equivalent)	5.0	% DM	1 - 2.5
Ammonia (CP equivalent)	22.2	% CP	7 - 15
pH	5.43		4.2 - 4.8
Lactic acid	1.7	% DM	2 - 4
Acetic acid	4.63	% DM	1 - 2
Propionic acid	0.59	% DM	0 - .25
Iso-butyric acid	0.22	% DM	<.01
Butyric acid	2.24	% DM	<.01
Total fermentation acids	9.38	% DM	3 - 6
Lactic acid/total acids	18.12	% acids	> 50
Ethanol	0.0	% DM	<.01

Results of this analysis show a typical pattern of an overly wet alfalfa silage that has gone through a mixed fermentation pattern that includes clostridial bacteria. The end result is a silage that is high in ammonia, high in pH, low in lactic acid, and high in butyric and acetic acids. This silage has not reached a terminal pH, and the clostridial bacteria present will continue to convert lactic acid to butyric acid.

Expected values from silage fermentation analysis for alfalfa silage, grass silage, corn silage, and high moisture shelled corn are presented in the table on the next page.

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**Normal Values for Ensiled Feed Fermentation Analyses**


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<b>Test Item</b>	<b>Alfalfa or Grass Silage</b>	<b>Corn Silage</b>	<b>Hi Moist. Sh. Corn</b>
Dry matter, %	35 – 45	30 – 35	65 – 75
Crude protein, % DM	18 – 22	7 – 9	8 – 10
Bound protein, % CP	2 – 10	2 – 8	2 – 8
Ammonia (CP equiv), % DM	1.0 – 2.5	.2 – 1.0	---
Ammonia (CP equiv), % CP	7 – 15	5 – 10	---
pH	4.2 – 4.8	3.5 – 3.8	4.2 – 4.8
Lactic acid, % DM	2 – 4	3 – 6	---
Acetic acid, % DM	1 – 2	1 – 3	---
Propionic acid, % DM	0 - .25	0 - .25	---
Iso-butyric acid, % DM	<.01	<.01	<.01
Butyric acid, % DM	<.01	<.01	<.01
Total acids, % DM	3 – 6	4 – 9	---
Lactic acid, % total acids	>50	>60	---
Ethanol, % DM	<.01	<.01	<.01

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## Appendix II – Forage Dry Matter Overview

### A. Subjective Evaluation of Forage DM:

- <50% DM      Just forms a ball when sample is firmly squeezed in your hand
- <45% DM      Forage begins to stick to your hand when squeezed
- <35% DM      Alfalfa and grass forages begin to stink (butyric acid, etc.)
- <30% DM      Can squeeze water from the sample; alfalfa and grass forages definitely stink at this low a DM
- <25% DM      Fresh, unwilted forage (pasture, green chop, immature corn silage)

### B. Forage Dry Matter Variation

1. Forage dries during the day as harvest continues
2. Not all harvesting is done on the same day
3. Individual loads of silage stay in fairly even layers in vertical silos and are unloaded as individual loads
4. Moisture does not migrate appreciably in silos (compression at the bottom of a silo may cause it to "run" from the bottom, but the moisture itself has not migrated)
5. Examples of forage dry matter variations in single crop forage within silos - see Table 1 (next page)

### C. Effect of Forage Dry Matter Variations

1. Not as critical in component-fed herds
  - a. group feedbunks or in-barn feeding of forages tends to be done by volume rather than by weight
  - b. variations in forage intake are observed separate from concentrate intake; adjustments can be made and monitored fairly easily
2. Very critical in TMR-fed herds
  - a. forage is added to mixer by scale weight only (i.e., as-fed basis), but the diet formulation assumes a DM amount

- b. forage:concentrate ratio and nutrients can therefore deviate as forage dry matter varies
- c. example of effect of changing forage dry matter on TMR composition - see Table 2 (next page)

<b>TABLE 1. Forage dry matter content over time from single crops stored in upright stave silos.</b>		
Crop		
Week	1st Cut Alfalfa Haylage	Corn Silage
———— % forage DM ————		
1	55	35
2	59	36
3	59	34
4	50	34
5	49	37
6	46	37
7	44	38
8	44	34
9	44	33
10	48	34
11	49	33
12	49	33
13	45	33
14	41	32
15	48	32
16	55	32
17	62	33
18	61	33
19	56	35

**TABLE 2. Changes in energy, protein, and fiber as forage dry matter changes (without compensation) in a TMR feeding system.**

Nutrient	Actual DM Values (formulated at 50% DM)				
	40%	45%	50%	55%	60%
NEL, Mcal/lb	.80	.79	.78	.77	.77
Crude protein, %	18.9	18.9	18.9	18.8	18.8
ADF, %	18.1	18.7	19.4	19.9	20.4
NDF, %	29.8	30.4	31.1	31.6	32.2
FNDF, %	18.9	19.9	21.0	21.9	22.8
NFC, %	37.5	36.8	36.2	35.7	35.2

#### D. Conclusions:

1. as forage becomes wetter (lower DM), fiber content of the diet decreases and risk of ruminal acidosis greatly increases
2. as forage becomes drier (higher DM), energy content of the diet falls, resulting in poor milk production and/or body condition loss; excessive intake of total NDF may also result in decreased total dry matter intakes
3. protein content of the diet is not substantially affected by changes in alfalfa haylage dry matter because alfalfa protein content is similar to the final diet protein content

#### E. Recommendations:

1. TMR-fed should check the DM content of alfalfa haylage at least once a week (some herds do it daily). Haylage DM should also be checked whenever it obviously changes. Corn silage and high moisture shelled corn DM content can be checked less frequently (monthly, and/or whenever there is a visible change).
2. Use an on-farm test appropriate for on-farm conditions.

## Appendix III – Forage Dry Matter Determination Using a Microwave Oven

### A. Overview of Microwave Oven Method

1. Requires drying known quantity of sample (weighed) in microwave oven until completely dry, then weighing again and then calculating dry matter content
2. Will work for virtually any feed ingredient
3. Cannot just turn oven on and leave sample in until dry - the sample will burn first under the intense microwave heat! Instead, sample must be heated in increments until completely dried (no more decrease in scale weight after 2 or 3 successive periods of heating in the microwave). It takes about 20 minutes to run an alfalfa haylage sample and 45 minutes to run a corn silage sample; constant attention to the oven is required the whole time.
4. Most accurate and versatile method; however, it requires the most operator skill and patience.
5. After operator diligence and time, scale accuracy is the next most limiting factor. It is best to select a scale that is accurate to .1 g and has a capacity of 400 grams or more. The same scale can be used for forage particle length and grain particle size determinations. Example scales are:

Ohaus Scout Pro Portable Electronic Balance (Model SC401E, 400 g capacity x 0.1 g readability); about \$125 from Nasco.

Ohaus Triple Beam Metric Scale Balance scale (Model 750-S, 500 g capacity x 0.1 g readability); about \$110 from Nasco.

### B. Procedure for Microwave Oven Dry Matter Determination

#### Items required:

1. Microwave oven, preferably with a turntable (600 watt oven is best; newer 900 watt and 1200 watt ovens may burn the sample!)
2. Microwaveable containers: 1 for water and several for feed ingredients (paper plates work well for feeds)
3. Scale or balance, as described above
4. Calculator

#### Procedure:

1. Weigh empty paper plate(s) and record weight.

2. Fill plate(s) with representative sample of feed(s), weigh, and record weight. A paper plate (double thickness works best) can conveniently hold 100 grams of wet feed.
3. Fill one container with approximately 200 ml water (to help prevent burning) and set in microwave oven along with feed container(s). For the first several sequences you can do several samples at once to make this procedure a little less time-consuming.
4. Start by setting the oven for 2 minutes at High, then 1.5 minutes at Medium High. This will rapidly bring down the moisture level of the sample(s). **WARNING:** High moisture shelled corn and the corn kernels in corn silage may begin popping if oven is set at High for more than 2 minutes. Also, some of the drier forages may be ignited. In either case, you will have to start over, since material has been lost (popped corn fragments) or altered (forages to ash). Allowing the samples to cool between sequences will also help you to avoid these problems.
5. The next sequence is generally 2.0 minutes at Medium High, then 1.5 minutes at Medium. However, there is no set protocol and you may wish to lower either the time or the setting if you are working with a particularly dry ingredient, such as core samples from baled hay.
6. At this point you can continue drying either high moisture shelled corn or corn silage for 1.0 minutes at Medium High and haylages for 1.0 minutes at Medium, then work back from those settings.
7. When you think that you might be nearing the end-point, weigh the sample between drying sequences. Repeat this process until the weight of the sample decreases by no more than .1 gram cumulative in three 30-second Medium sequences.
8. Percent dry matter is calculated as follows:

$$\frac{(\text{wt. container with dried ingredient}) - (\text{wt. empty container})}{(\text{wt. container with wet ingredient}) - (\text{wt. empty container})} \times 100 = \%DM$$

**Notes:**

1. Allowing for cooling off periods between drying sequences, grass haylage takes from 15-20 minutes to dry, alfalfa haylage from 20-30 minutes, and corn silage and high moisture shelled corn anywhere up to 1 hour. Accurate results cannot be obtained by hurrying through the process.
2. This description is based on a 600 watt microwave oven: High = 100% power; Medium High = 70% power; Medium = 50% power. Your technique will obviously vary with different output power (check the owner's manual).
3. Set up your equipment in a well ventilated area. Besides releasing a strong odor, the escaping gases can also cause eye irritation/allergies.

## Appendix IV – Forage Dry Matter Determination Using a Koster Tester

### A. Overview of Koster Tester Method

1. Uses forced hot air blown through the feed sample
2. Takes from 45 minutes to 2 hours to dry a sample (less for haylages, more for corn)
3. Accuracy is lower than for microwave; however, it is simpler to operate
4. Scale accuracy appears to be a problem for the scale provided with the Koster tester. The procedure might be more accurate if an accurate scale (similar to that recommended above for the forage particle length procedure) was used instead of using the provided dial scale.
5. Cannot be used with extremely wet feeds (water drips through the screen on the bottom of the sample container)

### Procedure for a Koster Tester Dry Matter Determination

#### Items required:

1. Koster Tester
2. Scale with about a 400 g capacity and 0.1 g readability (as described earlier in Appendix III)
3. Timer (optional)
4. Calculator

#### Procedure:

1. Weigh empty top feed basket and record weight.
2. Fill the basket with about 200 grams of wet feed and record total weight.
3. Turn the Koster Tester on and let it run for about the following times:

alfalfa or grass silages	25 minutes
corn silage	30 minutes
high-moisture grains	85 minutes
4. Weigh the sample on the scales, then dry for 5 more minutes and weigh again.

5. Record a final weight when the dry weight of the feed drops <1.0 grams after 5 minutes of additional drying.
6. Percent dry matter is calculated as follows:

$$\frac{(\text{wt. container with dried ingredient}) - (\text{wt. empty basket})}{(\text{wt. container with wet ingredient}) - (\text{wt. empty basket})} \times 100 = \%DM$$

## Appendix V – Forage Dry Matter Determination Using an Electronic Tester

### A. Overview of Electronic Moisture Testers

1. Measure electrical conductivity through the sample, which is fairly well correlated to dry matter content.
2. Results are virtually instantaneous; just look up "log" reading on a chart to get %DM
3. Very accurate for haylage and high moisture shelled corn. Less accurate for corn silage, very wet alfalfa haylage, or for forages with unusual chop lengths (i.e., too fine or too coarse)
4. Cannot sample ground corn or any type of ear corn; only unground shelled corn will work
5. Cannot sample some types of forages; cannot sample any mixture of feeds
6. Can be custom calibrated (by the farmer, with a little help in deriving the proper equations) for virtually any feed ingredient
5. Requires the least operator skill and time; is the most likely test to actually be done on the farm

### B. Procedure for a Electronic Tester Dry Matter Determination

#### Items required:

1. Farmex 1210 Silage Tester
2. Plastic sample bags, grain tray, and feed thermometer (all provided with the tester)
3. A warm place to conduct the test. While the tester does provide a temperature compensation for cold feed samples, we have found that it is more accurate to conduct the test in a warm place with a warm feed sample.

#### Procedure:

1. Unwind the pressure knob on the tester (counter-clockwise) until the pressure plate is completely raised.
2. For forages – fill a plastic bag full of forage, compressing the material in the bag with your fingers. Uniformly pack then seal the bag. Flatten the bag evenly – it should be about 1/2” thick when done.
3. For whole kernel grains – fill the grain tray level full with grain.

4. Place the plastic bag or grain tray in the test chamber. Make sure the sample is evenly spaced between the two electrodes on the bottom of the chamber.
5. Apply pressure to the sample by turning the control knob clockwise. Carefully count the number of turns as you tighten. Continue tightening until the yellow indicator band in the center of the knob appears and its lower edge is level with the knob face.

The number of turns required to expose the yellow band MUST be between 4 and 5 1/2 turns for forage samples. Either add or remove sample from the bag in order to achieve the desired number of turns of the pressure knob. The number of turns for grain samples in the grain tray is not critical.

6. Once the correct pressure has been reached, wait 20 to 25 seconds. During this time, press the "BATTERY" button to make sure that the battery is still properly charged. This is indicated by a battery reading of >75.0 (7.5 volts). Replace the battery if the reading is less than 75.0.
7. Press the "SAMPLE" button and record the log reading from the digital display.
8. Unwind the pressure knob and remove the sample bag or grain tray.
9. Check the temperature of the sample using the thermometer supplied with the tester.
10. Find the temperature correction factor for the feed being tested from the log chart. Apply the temperature correction to the log reading before looking up the dry matter (or moisture) content of the feed.
11. Look up the dry matter reading of forages where the corrected log and number of turns of the pressure knob intersect. For samples in the grain tray, the number of turns of the pressure knob is not used; simply look up the moisture from the corrected log reading.

**Appendix VI – Forage Particle Length Determination Using the Penn State Shaker Box****Equipment needed:**

Penn State shaker box; about \$250 from Nasco, Agricultural Sciences Catalog (Nasco calls it the S3-Sieve Forage Particle Separator) 800/558-9595, [www.enasco.com](http://www.enasco.com)

“Gram” scale with accuracy of 0.1 grams, capacity of 400 grams or more. The same scale can be used for the dry matter and grain particle size determinations. Scales I have used :

Ohaus Scout Pro Portable Electronic Balance (Model SC401E, 400 g capacity x 0.1 g readability); about \$125 from Nasco.

Ohaus Triple Beam Metric Scale Balance scale (Model 750-S, 500 g capacity x 0.1 g readability); about \$110 from Nasco.

Form to record and calculate results (see attached)

**Procedure:**

1. **Carefully** sample the feed – make sure that the sample you are shaking down is representative of the entire lot of feed.
2. Measure 6 cups of the forage to be tested. The measuring tray that can be purchased with the box contains 6 cups. ***The most common error in this procedure is using too much forage!***
3. Place the 6-cup sample on the top screen of the shaker box.
4. Shake the box a total of 40 times – 5 shakes, then rotate 90 degrees, 5 shakes again, etc. until you have rotated around the box twice (8 times 5 shakes). Stroke length should be 7 inches back and forth. Each full shake (back and forth) should take about one second. Shake forcefully enough that the feed sample travels across the top of the first screen. Hold the box as flat as possible when shaking. For wet haylage samples, smaller particles may adhere to long particles on the top screen. If this happens, gently separate the material on the top screen and shake the sample again. Do not include clumps of haylage on the top screen as long particles – either break them up by hand or discard them.
5. Weigh the amount of feed present on each of the 2 screens and on the bottom tray. Calculate the % coarse particles (% particles on the top screen). Also compare the amount of material on the middle screen to the amount of feed on the bottom tray – they should be about equal for properly chopped feeds. All of these calculations are done on an as-fed basis – it is not necessary to correct the amounts for % dry matter.

6. Mean particle length can be calculated based on these results, but the calculations are difficult and not particularly useful.
7. For complete details about using the Penn State box, see <http://www.das.psu.edu/dairynutrition/forages/particle/>

**Forage Particle Length Determinations**

(Penn State Forage Particle Separator)

Farm Name: \_\_\_\_\_

Date: \_\_\_\_\_

Evaluate duplicate samples for each feed; record the average in the right-hand column.

Weight of weighing tray:  (tare scale to zero with tray on or subtract tray from each weight)

Sample <input type="text"/> Amt.      % Top <input type="text"/> <input type="text"/> Middle 1 <input type="text"/> <input type="text"/> Middle 2 <input type="text"/> <input type="text"/> Bottom <input type="text"/> <input type="text"/> Total <input type="text"/> <input type="text"/>	Sample <input type="text"/> Amt.      % Top <input type="text"/> <input type="text"/> Middle 1 <input type="text"/> <input type="text"/> Middle 2 <input type="text"/> <input type="text"/> Bottom <input type="text"/> <input type="text"/> Total <input type="text"/> <input type="text"/>	Average <input type="text"/> Amt.      % Top <input type="text"/> <input type="text"/> Middle 1 <input type="text"/> <input type="text"/> Middle 2 <input type="text"/> <input type="text"/> Bottom <input type="text"/> <input type="text"/> Total <input type="text"/> <input type="text"/>
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## Appendix VII - Grain Particle Size Length Determination on Screens

### Equipment needed:

Metal sieves for separating grains (USA Standard Testing Sieve; ASTM E-11 Specification).

I use the 8-inch diameter, brass screens from Fisher Scientific (800/766-7000, [www3.fishersci.com](http://www3.fishersci.com)). These were the cheapest type of metal sieves that they sell - about \$250 USD for the set. An alternate source is Seedburo Equipment Corp., Chicago, IL (312/738-3700, [www.seedburo.com](http://www.seedburo.com)). You need the following size screens in the sieves:

#4 (1/4 inch)

#8 (1/8 inch)

#16 (1/16 inch)

#30 (1/30 inch)

Pan

Note: screens and pan must be the same size and type in order to properly stack together

Plastic tray to collect and weigh separated grain particles (same tray as used for the forage particle length determinations)

Gram scale to weigh corn on the different screens and pan (same scale as for forage particle length)

Measuring cup for 1-cup measurement

Form to record and calculate results (see attached)

### Procedure:

1. Carefully sample the grain – make sure that the sample you are separating is representative of the entire lot of grain.
2. Measure 1 cup of the grain.
3. Stack the screens and pan, with the coarsest screen on top and the pan on the bottom.
4. Pour the 1-cup sample onto the top screen.
5. Shake and tap the screens until the amount of grain remaining on the top (#4) screen is constant. We are not worried about long particles tipping up and sliding through the screen, so over-

- shaking is not possible. Once the top screen is finished, take it off, set it aside, and shake/tap the remaining screens until the amount of grain on the next screen (#8) is consistent. Set this screen aside, and shake/tap until the next screen (#16) is done. Repeat this until all of the screens are finished.
6. Weigh the amount of grain present on each of the 4 screens and on the bottom pan. Calculate the % particles on each screen and on the pan. All of these calculations are done on an as-fed basis – it is not necessary to correct the amounts for % dry matter.
  6. Compare your results to those listed on the table on the next page. The recommended particle size distribution depends on the moisture of the grain being tested. Interpret the results loosely - no grain sample will fit the ideal distribution perfectly. We are looking for major errors in grain processing with this test. It is not intended to “fine tune” a dairy’s grain processing methods.

#### Interpretation of Grain Screening Results:

Feed Ingredient:	Percent on Top of Screen:				
	#4	#8	#16	#30	Pan
HMSC, <70% dry matter	65	20	<5	<5	<5
HMSC, 70 to 73% dry matter	29	50	20	<5	<5
HMSC, 74 to 77% dry matter	10	25	30	25	10
HMSC, >77% dry matter	0	0	30	50	20
Dry shelled corn	0	0	30	50	20

**Grain Screening Results**

USA Standard Testing Sieve; ASTM E-11 Specification

Farm Name: \_\_\_\_\_

Date: \_\_\_\_\_

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Appendix VIII – Example Ration Worksheet, with TMR Bunk Sample Analysis

<b>Herd Ration Worksheet</b>										
<b>Example Herd</b>	<i>Pre-Fresh TMR - Pens 7 and 8</i>									
<b>Feed Ingredients:</b>	<b>Formulated Ration:</b>				<b>Our Estimated Ration:</b>					
	Date: 2/19/06				Date: 2/20/06					
	As-Fed	DM	DM	% of Ration	As-Fed	DM	DM	% of Ration		
	(lbs)	(%)	(lbs)	(DM basis)	(lbs)	(%)	(lbs)	(DM basis)		
Corn Silage (pile)	19.00	41.5	7.89	32.5%	16.58	39.1	6.48	30.7%	42.0%	of forage DM
Wheat Straw (bales)	7.50	90.0	6.75	27.8%	6.54	89.0	5.82	27.5%	37.7%	of forage DM
Western Hay (bales)	4.00	88.0	3.52	14.5%	3.49	90.0	3.14	14.9%	20.3%	of forage DM
Hi Moist Sh Corn (HVST)	2.75	82.2	2.26	9.3%	2.40	81.6	1.96	9.3%		
Soybean Meal, 47%	2.25	90.2	2.03	8.4%	1.96	89.0	1.74	8.2%		
Prefresh Mix	2.00	91.5	1.83	7.5%	2.09	95.4	1.99	9.4%		
Water	10.00	0.0	0.00	0.0%	8.73	0.0	0.00	0.0%		
<b>Totals:</b>	<b>47.50</b>		<b>24.28</b>	<b>100.0%</b>	<b>41.78</b>		<b>21.14</b>	<b>100.0%</b>	<b>73.1%</b>	<b>forage</b>
<b>Nutrient Analysis (DM Basis)</b>	<b>Amount Req'd:</b>			<b>Formulated Ration:</b>				<b>Estimated Ration:</b>		<b>Lab Analysis, Bunk Sample:</b>
Dry matter, %	>40			51.1				50.6		51.7
NEL, Mcal/lb	.70 - .72			0.62				0.64		0.52
Ether extract, %	<4.5			2.4				2.5		2.2
Crude protein, %	12 - 14.5			14.5				15.4		9.8
RUP, % of CP	>32			---				41.2		---
Soluble P, % of CP	25 - 40			23.5				24.7		33.3
ADF, %	>21			27.6				27.7		42.0
NDF, %	32 - 40			43.6				42.0		62.7
Lignin, %	---			---				6.0		7.5
NFC*, %	35 - 40			29.6				28.7		15.8
Ash**, %	---			9.8				11.4		9.5
Calcium, %	>0.50			1.47				1.64		0.82
Chlorine, %	>0.20			0.70				0.57		0.56
Magnesium, %	>0.35			0.46				0.59		0.32
Phosphorus, %	.30 - .40			0.40				0.45		0.29
Potassium, %	>0.65			1.30				1.28		1.33
Sodium, %	>0.10			0.12				0.16		0.15
Sulfur, %	>0.20			0.33				0.39		0.24
DCAD, meq/kg	---			-19				-7		98
Cobalt, ppm	>0.10			2.05				2.60		---
Copper, ppm	>15			43				45		36
Iodine, ppm	>0.70			---				1.50		---
Iron, ppm	>50			---				257		394
Manganese, ppm	>50			131				143		113
Suppl. Se, ppm	0.30			0.49				0.60		---
Zinc, ppm	>60			132				159		113
Suppl. Vit A, KIU/lb	>2.20			9.37				10.90		---
Suppl. Vit D, KIU/lb	>1.00			1.44				0.70		---
Suppl. Vit E, IU/lb	15 - 40			95.1				121.0		---
*for estimated ration, NFC = 100 - (CP + EE + NDF + Ash)										
**for formulated ration, Ash = 100 - (CP + EE + NDF + NFC)										

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# Ohio Dairy Veterinarians Meeting

Pre-Conference Workshop, January 7, 2010

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## Nutrition Troubleshooting Toolbox

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### Evaluating Diet Formulation

It is very difficult for non-nutritionists to evaluate diet formulation (i.e., the paper ration) - and for good reasons. First, the complexity of diet formulation has increased considerably over the last decade. Many commercially-available ration formulation programs (Cornell or Penn Models, CPM Dairy, Amino Cow, 2001 Dairy NRC) model nutrient uptakes based on level of intake, individual feed ingredient digestibility, estimated amino acid composition, and physiological state of the cow. It difficult to understand these models unless you are well-trained in nutrition and have experience running them.

While diet formulation has become more complex, the variation in diet formulations (especially for lactating cows) has decreased. The decrease in the number of herds has also decreased the number of nutritionists needed in the field. As a result, only the most competent have remained in business, and in general they do a very good job formulating diets. There is also more agreement amongst nutritionists as to what nutrient requirements should be for lactating cows, so the lactation diets I now see in the field are quite similar.

*Lactation Diet Formulations.* Recent trends in lactation diets are toward higher carbohydrate diets. These diets are relatively high in both NDF and NFC. They also contain more forage (albeit higher digestibility forage) than diets in the past. Nutritionists are making room for more carbohydrate in their diets by decreasing the amount of crude protein (about 16.5% crude protein is all that is needed, provided amino acid balance is good) and decreasing the amount of supplemental fat (diets with 6.0 to 6.5% fat are uncommon now – 4.5 to 5.0% is more the norm). These relationships are illustrated in Figure 1 (top of the next page). I encourage you to be supportive of nutritionists who are moving in the direction of higher carbohydrate, higher forage diets.

<u>'Old' Diet</u>		<u>High NDF Diet</u>		<u>'High Carb' Diet</u>	
CP	18.5%	CP	18.5%	CP	16.5%
EE	6.0%	EE	6.0%	EE	4.5%
NDF	29.0%	NDF	32.0%	NDF	33.0%
Ash	9.0%	Ash	9.0%	Ash	8.0%
<u>NFC</u>	<u>37.5%</u>	<u>NFC</u>	<u>34.5%</u>	<u>NFC</u>	<u>38.0%</u>
Total	100.0%	Total	100.0%	Total	100.0%

Total CHO 66.5%    Total CHO 67.5%    Total CHO 71.0%

**Figure 1.** Total composition of traditional (“old”) lactation diets, high NDF diets, and high carbohydrate diets. The high carbohydrate diet is preferred.

*Dry Cow Diet Formulations.* In contrast to lactating diets, formulations used for dry cow diets are quite variable from one nutritionist to the next. This is expected, given that the science behind dry cow feeding is equally variable and in fact is quite confusing. Some studies demonstrate benefits for higher energy, higher intake dry cow diets, but other studies show the exact opposite. Some studies suggest that cows should be grouped into two or more groups, others suggest that only the far-off diet is important, etc., etc.

I have seen all kinds of dry cow formulations seemingly “work” on dairies. And I have seen formulations that “work” on one farm fail miserably on another farm. My conclusion (at least for now) is that diet formulation for dry cows is not nearly as important as sufficient access to bunk space, minimizing pen moves near calving, allowing high dry matter intakes, delivering feed very consistently, and feeding only high quality ingredients.

The one approach to dry cow diets that most often fails is adding excessive straw (or coarse dry hay) to a pre-fresh diet for a group of cows that already has low dry matter intake (<24 lbs/cow/day if a mixed parity pre-fresh pen, or <26 lbs/cow/day if only 2+ lactation cows in the pre-fresh pen). In these situations, adding extra straw or hay depresses dry matter intake even further and may trigger a disastrous increase in fatty liver, ketosis, and DA. In contrast, herds with good intakes in the pre-fresh pens may benefit from lower energy density and increased bulk from the added straw.

Supplementation with anionic salts (i.e., low DCAD diets) are a good means of reducing both subclinical and clinical milk fever. However, anions should be supplemented only when feeding management is excellent, feed ingredient quality is good, dry matter intakes in the pre-fresh cows are already high (>26 lbs/cow/day for mixed parity pens, or >28 lbs/cow/day for pens with only 2+ lactation cows), and the producer regularly monitors urinary pH. Forage DCAD (especially K and Cl) are highly variable, and it is virtually impossible to sample the forages frequently enough to keep up with changes in K and Cl. So, it is essential to use a biological test (in this case, urinary pH) to monitor the feeding rate of the source(s) of supplemental anions. The details of this test are discussed elsewhere in these notes. Herds that feed supplemental anions but do not regularly check urinary pH will unavoidably run into problems with either

over-acidification (which decreases pre-fresh dry matter intake and increases the risk for fatty liver, ketosis, and DA) or under-acidification (which increases the risk for milk fever and DA).

## Evaluating Individual Feed Ingredients

Sometimes nutritionists overlook the importance of evaluation of individual feed ingredients – especially the more subjective aspects such as preservation, palatability, particle length, and sortability. I find it very helpful to see all the feeds on the farm and at a minimum do a visual appraisal of each. I am particularly interested in their smell of fermented feeds - but don't do too much sniffing if the feed is moldy and/or you have allergy problems! I am sometimes surprised to find butyric acid smell in a silage that no one else has yet noticed. Butyric acid intake is a strong risk factor for ketosis - this is described in detail in another section of these proceedings. It is easier to appreciate the butyric acid smell if the feed is at room temperature and in a clean place. Sometimes other odors on the farm mask the butyric smell.

Silages containing butyric acid have an elevated pH – definitely over 4.8 and usually in the 5.2 to 6.0 range. So, a check of the silage pH can be helpful (add 1 tablespoon to 50 ml distiller water, mix, and check the pH on a meter). To confirm and quantify the amount of butyric acid in a silage, have the nutritionist send a sample to a lab for a silage organic acid analysis (often termed VFA analysis – an unfortunate misnomer, since lactic acid is not volatile). These tests cost about \$20 each and are well worth it if there is any concern at all about the quality of a fermentation. Appendix I provides details about the silage fermentation process and the interpretation of organic acid test results.

The dry matter content of ensiled feeds is the major determinant of the quality of the fermentation. Table 1 lists recommended dry matters for different feeds and different silo types.

**Table 1.** Recommended dry matter and moisture content at harvest for different feeds and silo types.

Feed ingredient	Silo type	Recommendation for :	
		Dry matter, %	Moisture, %
Corn silage	Oxygen-limiting*	40 – 45	55 – 60
	Vertical (open top)	30 – 35	65 – 70
	Horizontal (bunker)	28 – 33	67 – 72
Hay silage (alfalfa or grass haylage)	Oxygen-limiting*	50 – 55	45 – 50
	Vertical (open top)	35 – 45	55 – 65
	Horizontal (bunker)	35 – 40	55 - 60
High moisture corn	Oxygen-limiting*	75 – 80	20 – 25
	Vertical (open top)	65 – 70	30 – 35
	Horizontal (bunker)	65 – 70	30 – 35

\* Oxygen-limiting silos include Harvestore or similar upright silos and silage bags.

There isn't anything you can do to alter feed dry matter content once it is harvested and ensiled. Someone needs to be alert to check dry matter at the time the feed is harvested. This probably won't be your job, but you can help make sure that it is getting done on the farm. Some farms routinely harvest forages that are either too wet or too dry, and they almost always pay the price for these mistakes. John Deere manufacturers an on-board NIR moisture tester that can be installed on the discharge chute of its choppers. This unit costs \$30,000, but making big mistakes in the dry matter content of ensiled feeds usually cost a lot more. Make sure your producers get the message that ensiled feeds must be harvested at the correct dry matter – at almost any cost.

It is important to accurately know the dry matter content of a feed ingredient during feedout so that the correct amount of dry matter from that ingredient can be added to the mixer. You can help dairy producers make sure this job gets done. The frequency of dry matter testing needed depends on the type of feed and the structure it is stored in. In general, corn silage and high moisture corn have fairly consistent dry matter content. However, hay crop silages can have quite variable dry matter content at harvest. These variations are particularly important if the hay crop silage is stored in a bag or narrow vertical silo (especially if top-unloading). The problem is that dry matter content can vary from load to load of chopped forage, and silage in these structures is unloaded in a manner that feed from one load to the next is not mixed. In these cases, daily dry matter monitoring may be necessary. Hay crop silages stored in bunker silos have more consistent dry matter content at feedout because feed from many different loads is fed out simultaneously. Weekly monitoring of dry matter content of the haylage coming out of a bunker silo may be sufficient. Checking forage dry matter only when feed refusals change noticeably or when the feed is visibly different is better than no testing at all. However, proactive monitoring of forage dry matter content is much better. Details on forage dry matter determinations are given in Appendix II to V.

Particle length of forages and the particle size of grains are also important. Someone else will probably be responsible for this task – you need to encourage the farm to make sure that it gets done. Details about evaluating forage particle length using the Penn State shaker box are found in Appendix VI, and details about determining grain particle size (using a set of particle size screens) are given in Appendix VII. You can do informal evaluation of feed ingredient particle length or size by simply looking at a few handfuls of the feed on a clean, flat surface (e.g., the back of a clipboard) and then separating the coarse from the fine particles. Don't forget to also look at the particle length of dry, chopped hays if these are a part of the diet. Coarse, long hay particles (greater than about 2 inches in length) are easily sorted away by the cows. In contrast, cows will sort toward soft, leafy hay and eat it first – even if not chopped at all. In either case, chopping the hay about 1 to 2 inches long before adding it to the mixer will prevent most sorting.

A simple visual appraisal of custom concentrate, protein, or mineral mixes can be invaluable. Take a handful or two of the feed (in this case, the mix) and separate into its different components on a flat surface. Sometimes you can catch inadvertent errors in feed mixes simply by spotting the wrong

ingredients or obviously incorrect proportions of ingredients in the mix. Samples can then be submitted for wet chemistry analysis or feed microscopy for confirmation of the problem.

### **Evaluating Accuracy of Mixing the TMR**

I find it useful to start my evaluation of TMR mixing accuracy by following the mixer as new feed is delivered and then visually inspecting the feed. Does the mix appear the same from the start to the finish of unloading? Is there more long hay in a certain part of the mix? Are there large chunks of hay that are not mixed with other ingredients? Are there more whole cottonseeds in any part of the mix? Do the whole cottonseeds appear brown and matted (an indication of over-mixing), or are they still fluffy and white? Does the corn silage or haylage in the mix appear mashed and pulverized, or are the long forage particles still intact?

The best time to sample the TMR for analysis is at the time it is first fed. So, while I am following the mixer and inspecting the mix, I usually collect a representative sample for later analysis. It is important that this sample be as representative as possible of the entire TMR batch. Collect about 12 handfuls of feed from the start to the end of unloading the mixer. Put the feed into a 5-gallon bucket as you go – it should be full when you are done. Collect the handfuls by scooping upwards; otherwise, finer particles could be selectively lost by grabbing the sample and drawing it away from the bunk. Some suggest using pre-positioned trays in the feed bunk to collect the samples; however, the depth of feed typically placed in feed bunks makes this impractical.

After collecting the 12 or more handfuls, dump them out of the bucket onto a flat surface (preferably a smooth, clean table) and mix them gently. Then separate the feed into quarters. Discard two of the quarters (decide randomly which quarters to discard), then re-mix the remaining feed and repeat the quartering and discarding procedure. Discard different quarters each time you do the mixing. Continue mixing, quartering, and discarding until you have reduced the sample to the size you need. For particle length analysis in the Penn State shaker box you need 6 cups of feed per sample. For submission of the TMR to a laboratory for nutrient analysis you need about 1/2 pound (one pint) of feed.

*TMR Bunk Sample Particle Length.* Particle length is usually the most important single test for a TMR mix. The protocol for testing is the same as for individual forages – see details in Appendix VI. TMR bunk samples should contain about 7 to 12% long particles (top screen), and have more particles on the middle screen than the bottom screen plus pan. There can be many exceptions to this rule. High fiber diets fed very consistently with adequate bunk space may be fine at 4 to 7% long particles. Wet by-product feeds can artificially elevate the proportion of feed on the bottom screen and pan. Long particles over 2 inches in length may be sortable and actually contribute little or nothing to effective fiber in the rumen.

*TMR Sorting Analysis.* It can be particularly helpful to compare particle length of the TMR at feeding to the TMR refusals from the same pen (usually the previous day's refusals). Ideally the appearance and

particle of both samples should be identical. In reality, modest increases in long particles in the refusals (up to 5 percentage points) appear to be acceptable. For example, if a TMR is offered at 7% long particles, it would be acceptable for the refusals to be up to 12% long particles. I consider a 5 to 10% increase in long particles in the refusal to be a moderate sorting problem. More than a 10% increase in long particles would be a severe problem.

It would be ideal (but very time-consuming) to evaluate particle length of the TMR in the bunk throughout the feeding period. This would clearly reveal when the sorting is occurring during the day. However, for most troubleshooting exercises it is sufficient to compare the feed offered to the feed refused at the end of the day. Sometimes a third sampling in the middle of the day can be added to the evaluation without much difficulty.

Excessive TMR sorting is usually caused by overly long forage particles (especially dry hay or straw), often in combination with TMR that is too dry (>50% dry matter). Most sorting problems can be solved by processing the dry hay or straw finer (<2 inches) before adding it to the mixer, feeding more frequently during the day, adding extra water or a wet by-product feed to the TMR (goal of 40 to 45% TMR dry matter), adding liquid molasses to the TMR, or a combination of these. Realize that adding water or molasses to TMR mixes increases heating problems in the bunk in the summer. However, this can be a good thing if it causes the dairy producer to feed more frequently in the summer months.

*TMR Bunk Sample Nutrient Analysis.* A wet chemistry analysis of a carefully collected TMR bunk sample can be a useful adjunct to calculated estimates of what the cows are actually eating. Recognize that bunk sampling and nutrient testing is not a perfect representation of what the cows are eating. However, it can sometimes provide very useful information that could not be determined any other way.

TMR bunk samples should be submitted for wet chemistry analyses only – near-infrared reflectance spectroscopy (NIRS) analyses of TMR bunk samples is very difficult because of the near impossibility of creating a valid calibration set for a sample containing different feed ingredients in different proportions. I typically request wet chemistry analyses for dry matter, ether extract (crude fat), crude protein, bound protein, soluble protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, ash, calcium, phosphorus, magnesium, potassium, sodium, chloride, sulfur, copper, iron, manganese, and zinc. The non-fiber carbohydrate (NFC) content of the TMR can then be calculated by subtracting the ether extract, crude protein, neutral detergent fiber, and ash from 100% of the dry matter. The net energy for lactation (NEL) content of the TMR can be estimated from the ether extract, crude protein, NDF, lignin, and ash values using the OARDC (Ohio) equations. Do not use NEL values for TMR mixes calculated from the ADF value alone – these NEL estimates are valid only for individual feed ingredients and cannot be applied to TMR bunk samples. Expect a TMR bunk analysis for this array of nutrients to cost about \$40 to \$80 and to take three to five days.

It is important that the laboratory not try to further sub-sample whatever TMR bunk sample you have already carefully sub-sampled. TMR samples may separate considerably during shipping and handling,

especially if they are relatively dry. Therefore, it is best to submit only a relatively small quantity of feed (about 1/2 lb or one pint of sample) and to then request that the lab dry and grind the entire sample submitted. I put this request on each bag of TMR sample that I submit for analysis. Most laboratories are glad to comply with this request, as long as you submit only a small amount of feed.

Laboratory results for TMR bunk samples should be interpreted broadly, not strictly. There are numerous causes of variation between the expected and actual TMR bunk sample analysis, including poorly representative bunk samples, undetected changes in feed ingredient analyses (especially forages), undetected inconsistencies in adding feed ingredients to the mixer wagon, and laboratory error in the wet chemistry analyses. Some of these indicate an on-farm problem that requires intervention, but others are inherent errors in TMR bunk sampling. Determining which errors might be involved can be difficult. I consider the expected and laboratory results to be acceptably close if they are within about  $\pm 5\%$  of each other (on a total nutrient basis). For instance, if the expected calcium content of a TMR was 1.00%, then any lab result between .95% and 1.05% would be considered acceptable.

Laboratory analysis of TMR bunk samples almost always results in slightly higher ADF and NDF values than estimated. I have come to expect about a 5 to 10% total over-estimation in ADF or NDF results from TMR bunk samples. For example, if the actual ADF content of a TMR was 19%, then the lab result would be likely be about 20.0 to 20.9%. Or if the actual NDF content of the TMR was 28%, then the lab result would likely be about 29.4 to 30.8%. The source of this bias is uncertain, but may involve the inclusion of some of the fat added to the TMR being retained in the ADF and NDF fractions during laboratory testing. The slight over-estimation of the NDF value lowers the NEL value calculated by the Ohio equation by about 2 to 3% of the total NEL value. So, a TMR sample with an expected NEL of .78 Mcal/lb would likely have an NEL value of .757 to .764 calculated by the lab.

The greatest value in TMR bunk samples is to identify gross errors in feed analysis, mixing, or delivery. For example, omitting the salt from a custom protein mix would result in a TMR bunk sample with unexpectedly low sodium and chloride content. Omitting the trace mineral/vitamin premix from the ration would result in unexpectedly low copper, iron, manganese, and zinc results. Feeding excessive dry matter from alfalfa haylage because the haylage became drier than the nutritionist's last analysis would result in elevated dry matter, crude protein, soluble protein, ADF, and NDF values in the bunk samples.

When there are substantial discrepancies in expected vs. lab analysis results in TMR bunk samples, I find it useful to summarize the ration data, including the nutrient requirements, the ration formulated by the nutritionist (the "second" ration), the dry matters of the feed ingredients, the expected ration, and the lab analysis results all on one sheet of paper. I tabulate this information using a spreadsheet (see an example in Appendix VIII).

## Evaluating Consistency of Feed Delivery

It is difficult to evaluate the consistency of feed delivery on a farm, but a few questions will sometimes provide very revealing information. If the farm uses a feed mixing monitoring program (Feed Watch, etc.), then you can evaluate not only the accuracy of feed ingredient delivery, but also the consistency of the time of day that feed is delivered to each pen.

The feeding schedule on a dairy needs to be fanatically consistent, and particularly in respect to the synchrony of feeding and milking times. The first feeding of the day should coincide with the cows returning from the parlor after their first milking. This will be the biggest meal of the day for most cows. It is crucial that this be done consistently. Cows apparently learn to carefully regulate their meal patterns (meal frequency and meal size) in order to self-regulate their ruminal pH. But if the feeding schedule is erratic, they will never accomplish this self-regulation. It seems particularly dangerous if cows receive their TMR later than usual – hungry cows may over-eat when feed is finally offered. Problems with an inconsistent feeding schedule are magnified by shortages in bunk space, a shortage in free stalls (cows may be more concerned about securing a place to lie down rather than eating to regulate their ruminal pH), or inadequate availability of water immediately after milking.

## Evaluating Frequency of Feed Delivery

It is common to offer TMR once daily to most groups of cows. Many herds increase to twice daily feeding in the summer, which is an excellent decision. I prefer twice daily feeding year-round, but recognize that this usually requires extra labor. Frequent pushing up feed during the day may stimulate some additional dry matter intake, but does not appear to reduce the potential for sorting when TMR is offered infrequently. Increased feeding frequency is particularly important if the TMR is already prone to be sortable (dry TMR, excessive amount of coarse particles).

## Evaluating the Amount of Feed Offered

Each day the dairy producer makes a decision as to how much feed to offer each group of cows on the farm. The goal is to keep cows from getting hungry and over-eating on a sporadic basis, and yet not waste too much feed on the farm. The ability of the farm to utilize TMR refusals often decides how much refusal they will target.

This decision to make “feed calls” at the start of each day should be based on the appearance of the bunk at the end of the previous feeding day. A typical goal is about a 5% daily feed refusal. More feed refusal (about 10%) is needed for pens with very dynamic populations (i.e., the transition cows in the pre- and post-fresh pens). Mid and late lactation pens can be fed to much lower feed refusal (2% or less) because pen populations are more stable. Some herds consistently run zero daily feed refusals without difficulty. However, this requires exceptionally consistent feeding management. The cows can self-regulate intakes and ruminal pH if the bunks are empty the same time each day, and if new feed is offered at the same

time each day. Most dairies cannot manage their feed calls this well and need to target  $\geq 5\%$  daily refusals.

It is very helpful if the producer records the feed offered and feed refused for each pen each day. The refusals do not have to be weighed daily; an estimation of the amount refused is usually sufficient.

The amount of feed offered to each pen each day should be an adjustment of the total batch. The producer should not lock most the ingredients and then “float” just one ingredient (usually a forage). Severe ration imbalances can occur if only one ingredient in the mix is floated. Producers should monitor forage dry matter regularly and have the confidence to adjust the entire TMR mix recipe up or down each day.

## Appendix I - Silage Fermentation Analyses

*Silage Fermentation Process.* Proper silage fermentation starts with forage harvested at the proper dry matter content. This silage should then be chopped to the proper particle length. Finer chopping tends to improve packing and silage fermentation products, but conversely increases the risk for ruminal acidosis. So, proper chop length represents a compromise between maximal silo packing and optimal rumen health.

Once silage has been harvested at the proper dry matter content and chopped to the correct particle length, it must be packed as quickly and tightly as possible in the silo. The goal during silo filling is exclusion of as much air as possible so that the silage goes through only a short aerobic stage of fermentation. This stage of fermentation ends when aerobic bacteria consume the oxygen in the silage. Heat is a major end product of aerobic fermentation, so it is desirable to limit it as much as possible. With good silage, this phase only lasts a few days and the silage does not become excessively hot.

The aerobic phase of silage fermentation will be extended if the silage is too dry when chopped, loosely packed in the silo, or if the top layer of the silo is exposed to excessive oxygen because of slow filling. Any of these problems leads to excessive loss of silage dry matter as soluble carbohydrates are converted to heat and lost. Additionally, excessive heating may damage silage proteins by irreversibly binding them to fiber and making them indigestible. Heat-damaged proteins can be measured as bound protein (also termed ADF-CP, ADF-N, ADIN, unavailable protein, or Maillard protein).

Once the oxygen in the silage is consumed, fermentation moves into the anaerobic phase. Anaerobic bacteria initially convert soluble carbohydrates in the silage into acetic acid. As the pH of the silage drops from the accumulation of acetic acid, lactic-acid producing bacteria dominate. These bacteria produce lactic acid until the pH of the silage drops below about 4 or 5. At that point, all bacteria in the silage die and the silage becomes a stable, preserved mass. The anaerobic phase of silage fermentation takes about 1 to 3 weeks, depending on the availability of soluble carbohydrates in the ensiled material and the ambient temperature (fermentation proceeds slower during cooler weather). Anaerobic fermentation does not produce heat or cause loss of silage dry matter.

Silage proteins are partially degraded to ammonia and other forms of non-protein nitrogen during aerobic and anaerobic fermentation. Excessive protein degradation is undesirable and reduces the nutritional value of the forage. The lower the dry matter of the ensiled material, the more extensive the protein degradation. Proper forage dry matter at ensiling is a compromise between rapid oxygen exclusion and risk of improper silage fermentation at very low dry matters. Wetter forages have advantages of more rapid oxygen exclusion and rapid acid production, but they suffer from extensive protein degradation. Wetter forages may also favor fermentation by clostridial species of bacteria, which produce very undesirable fermentation end products such as butyric acid and toxic protein amines. Clostridial fermentation does not lower silage pH below 5.0 and thus is not self-limiting. Butyric acid concentrations in silages fermented by clostridial bacteria continue to rise during storage as long as the silage pH stays above about 5.0.

When the silage is fed out of the silo, it is re-exposed to oxygen and undergoes a secondary aerobic fermentation. Heat is produced during this phase, plus spoilage bacteria, yeasts, and molds may grow as silage pH rises. Silages with a lower final pH and higher total acid content are less vulnerable to secondary fermentation problems than are poorly fermented silages with higher final pH's and lower total acid content. Acetic acid is more effective in inhibiting secondary fermentation than is lactic acid; however, high acetic acid content may inhibit feed intake and is not desirable. Well-fermented silages typically contain about twice as much lactic acid as acetic acid.

*Silage Fermentation Analysis.* Silage pH can be determined on the farm. Add about 1 tablespoon of silage in about 50 ml distilled or deionized water and mix well. Then determine pH using a pH meter (Cardy Twin pH Meter, (Spectrum Technologies, Plainfield, IL, 800-248-8873 or <http://www.specmeters.com>). or pH paper strips (Whatman Lab, pH indicator paper range 4 to 6, type CS, 800/942-9626). Laboratories can perform a full organic acid analysis that typically includes silage dry matter, pH, crude protein, lactic acid, acetic acid, propionic acid, butyric acid, iso-butyric acid, total acids, ethanol, and ammonia. A hypothetical example of a report from a silage fermentation analysis is listed on the next page.

## S A M P L E F E R M E N T A T I O N A N A L Y S I S

Test Item	Value	Unit	Normal Range (alf. silage)
Dry Matter	30.3	% DM	35 - 45
Crude Protein	22.6	% DM	18 - 22
Bound Protein	1.0	% DM	.3 - 2.2
Bound Protein	4.4	% CP	2 - 10
Ammonia (CP equivalent)	5.0	% DM	1 - 2.5
Ammonia (CP equivalent)	22.2	% CP	7 - 15
pH	5.43		4.2 - 4.8
Lactic acid	1.7	% DM	2 - 4
Acetic acid	4.63	% DM	1 - 2
Propionic acid	0.59	% DM	0 - .25
Iso-butyric acid	0.22	% DM	<.01
Butyric acid	2.24	% DM	<.01
Total fermentation acids	9.38	% DM	3 - 6
Lactic acid/total acids	18.12	% acids	> 50
Ethanol	0.0	% DM	<.01

Results of this analysis show a typical pattern of an overly wet alfalfa silage that has gone through a mixed fermentation pattern that includes clostridial bacteria. The end result is a silage that is high in ammonia, high in pH, low in lactic acid, and high in butyric and acetic acids. This silage has not reached a terminal pH, and the clostridial bacteria present will continue to convert lactic acid to butyric acid.

Expected values from silage fermentation analysis for alfalfa silage, grass silage, corn silage, and high moisture shelled corn are presented in the table on the next page.

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**Normal Values for Ensiled Feed Fermentation Analyses**


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<b>Test Item</b>	<b>Alfalfa or Grass Silage</b>	<b>Corn Silage</b>	<b>Hi Moist. Sh. Corn</b>
Dry matter, %	35 – 45	30 – 35	65 – 75
Crude protein, % DM	18 – 22	7 – 9	8 – 10
Bound protein, % CP	2 – 10	2 – 8	2 – 8
Ammonia (CP equiv), % DM	1.0 – 2.5	.2 – 1.0	---
Ammonia (CP equiv), % CP	7 – 15	5 – 10	---
pH	4.2 – 4.8	3.5 – 3.8	4.2 – 4.8
Lactic acid, % DM	2 – 4	3 – 6	---
Acetic acid, % DM	1 – 2	1 – 3	---
Propionic acid, % DM	0 - .25	0 - .25	---
Iso-butyric acid, % DM	<.01	<.01	<.01
Butyric acid, % DM	<.01	<.01	<.01
Total acids, % DM	3 – 6	4 – 9	---
Lactic acid, % total acids	>50	>60	---
Ethanol, % DM	<.01	<.01	<.01

---

## Appendix II – Forage Dry Matter Overview

### A. Subjective Evaluation of Forage DM:

<50% DM	Just forms a ball when sample is firmly squeezed in your hand
<45% DM	Forage begins to stick to your hand when squeezed
<35% DM	Alfalfa and grass forages begin to stink (butyric acid, etc.)
<30% DM	Can squeeze water from the sample; alfalfa and grass forages definitely stink at this low a DM
<25% DM	Fresh, unwilted forage (pasture, green chop, immature corn silage)

### B. Forage Dry Matter Variation

1. Forage dries during the day as harvest continues
2. Not all harvesting is done on the same day
3. Individual loads of silage stay in fairly even layers in vertical silos and are unloaded as individual loads
4. Moisture does not migrate appreciably in silos (compression at the bottom of a silo may cause it to "run" from the bottom, but the moisture itself has not migrated)
5. Examples of forage dry matter variations in single crop forage within silos - see Table 1 (next page)

### C. Effect of Forage Dry Matter Variations

1. Not as critical in component-fed herds
  - a. group feedbunks or in-barn feeding of forages tends to be done by volume rather than by weight
  - b. variations in forage intake are observed separate from concentrate intake; adjustments can be made and monitored fairly easily
2. Very critical in TMR-fed herds
  - a. forage is added to mixer by scale weight only (i.e., as-fed basis), but the diet formulation assumes a DM amount

- b. forage:concentrate ratio and nutrients can therefore deviate as forage dry matter varies
- c. example of effect of changing forage dry matter on TMR composition - see Table 2 (next page)

<b>TABLE 1. Forage dry matter content over time from single crops stored in upright stave silos.</b>		
Crop		
Week	1st Cut Alfalfa Haylage	Corn Silage
————— % forage DM —————		
1	55	35
2	59	36
3	59	34
4	50	34
5	49	37
6	46	37
7	44	38
8	44	34
9	44	33
10	48	34
11	49	33
12	49	33
13	45	33
14	41	32
15	48	32
16	55	32
17	62	33
18	61	33
19	56	35

**TABLE 2. Changes in energy, protein, and fiber as forage dry matter changes (without compensation) in a TMR feeding system.**

Nutrient	Actual DM Values (formulated at 50% DM)				
	40%	45%	50%	55%	60%
NEL, Mcal/lb	.80	.79	.78	.77	.77
Crude protein, %	18.9	18.9	18.9	18.8	18.8
ADF, %	18.1	18.7	19.4	19.9	20.4
NDF, %	29.8	30.4	31.1	31.6	32.2
FNDF, %	18.9	19.9	21.0	21.9	22.8
NFC, %	37.5	36.8	36.2	35.7	35.2

#### D. Conclusions:

1. as forage becomes wetter (lower DM), fiber content of the diet decreases and risk of ruminal acidosis greatly increases
2. as forage becomes drier (higher DM), energy content of the diet falls, resulting in poor milk production and/or body condition loss; excessive intake of total NDF may also result in decreased total dry matter intakes
3. protein content of the diet is not substantially affected by changes in alfalfa haylage dry matter because alfalfa protein content is similar to the final diet protein content

#### E. Recommendations:

1. TMR-fed should check the DM content of alfalfa haylage at least once a week (some herds do it daily). Haylage DM should also be checked whenever it obviously changes. Corn silage and high moisture shelled corn DM content can be checked less frequently (monthly, and/or whenever there is a visible change).
2. Use an on-farm test appropriate for on-farm conditions.

## Appendix III – Forage Dry Matter Determination Using a Microwave Oven

### A. Overview of Microwave Oven Method

1. Requires drying known quantity of sample (weighed) in microwave oven until completely dry, then weighing again and then calculating dry matter content
2. Will work for virtually any feed ingredient
3. Cannot just turn oven on and leave sample in until dry - the sample will burn first under the intense microwave heat! Instead, sample must be heated in increments until completely dried (no more decrease in scale weight after 2 or 3 successive periods of heating in the microwave). It takes about 20 minutes to run an alfalfa haylage sample and 45 minutes to run a corn silage sample; constant attention to the oven is required the whole time.
4. Most accurate and versatile method; however, it requires the most operator skill and patience.
5. After operator diligence and time, scale accuracy is the next most limiting factor. It is best to select a scale that is accurate to .1 g and has a capacity of 400 grams or more. The same scale can be used for forage particle length and grain particle size determinations. Example scales are:

Ohaus Scout Pro Portable Electronic Balance (Model SC401E, 400 g capacity x 0.1 g readability); about \$125 from Nasco.

Ohaus Triple Beam Metric Scale Balance scale (Model 750-S, 500 g capacity x 0.1 g readability); about \$110 from Nasco.

### B. Procedure for Microwave Oven Dry Matter Determination

#### Items required:

1. Microwave oven, preferably with a turntable (600 watt oven is best; newer 900 watt and 1200 watt ovens may burn the sample!)
2. Microwaveable containers: 1 for water and several for feed ingredients (paper plates work well for feeds)
3. Scale or balance, as described above
4. Calculator

#### Procedure:

1. Weigh empty paper plate(s) and record weight.

2. Fill plate(s) with representative sample of feed(s), weigh, and record weight. A paper plate (double thickness works best) can conveniently hold 100 grams of wet feed.
3. Fill one container with approximately 200 ml water (to help prevent burning) and set in microwave oven along with feed container(s). For the first several sequences you can do several samples at once to make this procedure a little less time-consuming.
4. Start by setting the oven for 2 minutes at High, then 1.5 minutes at Medium High. This will rapidly bring down the moisture level of the sample(s). **WARNING:** High moisture shelled corn and the corn kernels in corn silage may begin popping if oven is set at High for more than 2 minutes. Also, some of the drier forages may be ignited. In either case, you will have to start over, since material has been lost (popped corn fragments) or altered (forages to ash). Allowing the samples to cool between sequences will also help you to avoid these problems.
5. The next sequence is generally 2.0 minutes at Medium High, then 1.5 minutes at Medium. However, there is no set protocol and you may wish to lower either the time or the setting if you are working with a particularly dry ingredient, such as core samples from baled hay.
6. At this point you can continue drying either high moisture shelled corn or corn silage for 1.0 minutes at Medium High and haylages for 1.0 minutes at Medium, then work back from those settings.
7. When you think that you might be nearing the end-point, weigh the sample between drying sequences. Repeat this process until the weight of the sample decreases by no more than .1 gram cumulative in three 30-second Medium sequences.
8. Percent dry matter is calculated as follows:

$$\frac{(\text{wt. container with dried ingredient}) - (\text{wt. empty container})}{(\text{wt. container with wet ingredient}) - (\text{wt. empty container})} \times 100 = \%DM$$

**Notes:**

1. Allowing for cooling off periods between drying sequences, grass haylage takes from 15-20 minutes to dry, alfalfa haylage from 20-30 minutes, and corn silage and high moisture shelled corn anywhere up to 1 hour. Accurate results cannot be obtained by hurrying through the process.
2. This description is based on a 600 watt microwave oven: High = 100% power; Medium High = 70% power; Medium = 50% power. Your technique will obviously vary with different output power (check the owner's manual).
3. Set up your equipment in a well ventilated area. Besides releasing a strong odor, the escaping gases can also cause eye irritation/allergies.

## Appendix IV – Forage Dry Matter Determination Using a Koster Tester

### A. Overview of Koster Tester Method

1. Uses forced hot air blown through the feed sample
2. Takes from 45 minutes to 2 hours to dry a sample (less for haylages, more for corn)
3. Accuracy is lower than for microwave; however, it is simpler to operate
4. Scale accuracy appears to be a problem for the scale provided with the Koster tester. The procedure might be more accurate if an accurate scale (similar to that recommended above for the forage particle length procedure) was used instead of using the provided dial scale.
5. Cannot be used with extremely wet feeds (water drips through the screen on the bottom of the sample container)

### Procedure for a Koster Tester Dry Matter Determination

#### Items required:

1. Koster Tester
2. Scale with about a 400 g capacity and 0.1 g readability (as described earlier in Appendix III)
3. Timer (optional)
4. Calculator

#### Procedure:

1. Weigh empty top feed basket and record weight.
2. Fill the basket with about 200 grams of wet feed and record total weight.
3. Turn the Koster Tester on and let it run for about the following times:

alfalfa or grass silages	25 minutes
corn silage	30 minutes
high-moisture grains	85 minutes
4. Weigh the sample on the scales, then dry for 5 more minutes and weigh again.

5. Record a final weight when the dry weight of the feed drops <1.0 grams after 5 minutes of additional drying.
6. Percent dry matter is calculated as follows:

$$\frac{(\text{wt. container with dried ingredient}) - (\text{wt. empty basket})}{(\text{wt. container with wet ingredient}) - (\text{wt. empty basket})} \times 100 = \%DM$$

## Appendix V – Forage Dry Matter Determination Using an Electronic Tester

### A. Overview of Electronic Moisture Testers

1. Measure electrical conductivity through the sample, which is fairly well correlated to dry matter content.
2. Results are virtually instantaneous; just look up "log" reading on a chart to get %DM
3. Very accurate for haylage and high moisture shelled corn. Less accurate for corn silage, very wet alfalfa haylage, or for forages with unusual chop lengths (i.e., too fine or too coarse)
4. Cannot sample ground corn or any type of ear corn; only unground shelled corn will work
5. Cannot sample some types of forages; cannot sample any mixture of feeds
6. Can be custom calibrated (by the farmer, with a little help in deriving the proper equations) for virtually any feed ingredient
5. Requires the least operator skill and time; is the most likely test to actually be done on the farm

### B. Procedure for a Electronic Tester Dry Matter Determination

#### Items required:

1. Farmex 1210 Silage Tester
2. Plastic sample bags, grain tray, and feed thermometer (all provided with the tester)
3. A warm place to conduct the test. While the tester does provide a temperature compensation for cold feed samples, we have found that it is more accurate to conduct the test in a warm place with a warm feed sample.

#### Procedure:

1. Unwind the pressure knob on the tester (counter-clockwise) until the pressure plate is completely raised.
2. For forages – fill a plastic bag full of forage, compressing the material in the bag with your fingers. Uniformly pack then seal the bag. Flatten the bag evenly – it should be about 1/2” thick when done.
3. For whole kernel grains – fill the grain tray level full with grain.

4. Place the plastic bag or grain tray in the test chamber. Make sure the sample is evenly spaced between the two electrodes on the bottom of the chamber.
5. Apply pressure to the sample by turning the control knob clockwise. Carefully count the number of turns as you tighten. Continue tightening until the yellow indicator band in the center of the knob appears and its lower edge is level with the knob face.

The number of turns required to expose the yellow band **MUST** be between 4 and 5 1/2 turns for forage samples. Either add or remove sample from the bag in order to achieve the desired number of turns of the pressure knob. The number of turns for grain samples in the grain tray is not critical.

6. Once the correct pressure has been reached, wait 20 to 25 seconds. During this time, press the “BATTERY” button to make sure that the battery is still properly charged. This is indicated by a battery reading of >75.0 (7.5 volts). Replace the battery if the reading is less than 75.0.
7. Press the “SAMPLE” button and record the log reading from the digital display.
8. Unwind the pressure knob and remove the sample bag or grain tray.
9. Check the temperature of the sample using the thermometer supplied with the tester.
10. Find the temperature correction factor for the feed being tested from the log chart. Apply the temperature correction to the log reading before looking up the dry matter (or moisture) content of the feed.
11. Look up the dry matter reading of forages where the corrected log and number of turns of the pressure knob intersect. For samples in the grain tray, the number of turns of the pressure knob is not used; simply look up the moisture from the corrected log reading.

**Appendix VI – Forage Particle Length Determination Using the Penn State Shaker Box****Equipment needed:**

Penn State shaker box; about \$250 from Nasco, Agricultural Sciences Catalog (Nasco calls it the S3-Sieve Forage Particle Separator) 800/558-9595, [www.enasco.com](http://www.enasco.com)

“Gram” scale with accuracy of 0.1 grams, capacity of 400 grams or more. The same scale can be used for the dry matter and grain particle size determinations. Scales I have used :

Ohaus Scout Pro Portable Electronic Balance (Model SC401E, 400 g capacity x 0.1 g readability); about \$125 from Nasco.

Ohaus Triple Beam Metric Scale Balance scale (Model 750-S, 500 g capacity x 0.1 g readability); about \$110 from Nasco.

Form to record and calculate results (see attached)

**Procedure:**

1. **Carefully** sample the feed – make sure that the sample you are shaking down is representative of the entire lot of feed.
2. Measure 6 cups of the forage to be tested. The measuring tray that can be purchased with the box contains 6 cups. ***The most common error in this procedure is using too much forage!***
3. Place the 6-cup sample on the top screen of the shaker box.
4. Shake the box a total of 40 times – 5 shakes, then rotate 90 degrees, 5 shakes again, etc. until you have rotated around the box twice (8 times 5 shakes). Stroke length should be 7 inches back and forth. Each full shake (back and forth) should take about one second. Shake forcefully enough that the feed sample travels across the top of the first screen. Hold the box as flat as possible when shaking. For wet haylage samples, smaller particles may adhere to long particles on the top screen. If this happens, gently separate the material on the top screen and shake the sample again. Do not include clumps of haylage on the top screen as long particles – either break them up by hand or discard them.
5. Weigh the amount of feed present on each of the 2 screens and on the bottom tray. Calculate the % coarse particles (% particles on the top screen). Also compare the amount of material on the middle screen to the amount of feed on the bottom tray – they should be about equal for properly chopped feeds. All of these calculations are done on an as-fed basis – it is not necessary to correct the amounts for % dry matter.

6. Mean particle length can be calculated based on these results, but the calculations are difficult and not particularly useful.
7. For complete details about using the Penn State box, see <http://www.das.psu.edu/dairynutrition/forages/particle/>

**Forage Particle Length Determinations**

(Penn State Forage Particle Separator)

Farm Name: \_\_\_\_\_

Date: \_\_\_\_\_

Evaluate duplicate samples for each feed; record the average in the right-hand column.

Weight of weighing tray:  (tare scale to zero with tray on or subtract tray from each weight)

Sample <input type="text"/> Amt.      % Top <input type="text"/> <input type="text"/> Middle 1 <input type="text"/> <input type="text"/> Middle 2 <input type="text"/> <input type="text"/> Bottom <input type="text"/> <input type="text"/> Total <input type="text"/> <input type="text"/>	Sample <input type="text"/> Amt.      % Top <input type="text"/> <input type="text"/> Middle 1 <input type="text"/> <input type="text"/> Middle 2 <input type="text"/> <input type="text"/> Bottom <input type="text"/> <input type="text"/> Total <input type="text"/> <input type="text"/>	Average <input type="text"/> Amt.      % Top <input type="text"/> <input type="text"/> Middle 1 <input type="text"/> <input type="text"/> Middle 2 <input type="text"/> <input type="text"/> Bottom <input type="text"/> <input type="text"/> Total <input type="text"/> <input type="text"/>
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## Appendix VII - Grain Particle Size Length Determination on Screens

### Equipment needed:

Metal sieves for separating grains (USA Standard Testing Sieve; ASTM E-11 Specification).

I use the 8-inch diameter, brass screens from Fisher Scientific (800/766-7000, [www3.fishersci.com](http://www3.fishersci.com)). These were the cheapest type of metal sieves that they sell - about \$250 USD for the set. An alternate source is Seedburo Equipment Corp., Chicago, IL (312/738-3700, [www.seedburo.com](http://www.seedburo.com)). You need the following size screens in the sieves:

#4 (1/4 inch)

#8 (1/8 inch)

#16 (1/16 inch)

#30 (1/30 inch)

Pan

Note: screens and pan must be the same size and type in order to properly stack together

Plastic tray to collect and weigh separated grain particles (same tray as used for the forage particle length determinations)

Gram scale to weigh corn on the different screens and pan (same scale as for forage particle length)

Measuring cup for 1-cup measurement

Form to record and calculate results (see attached)

### Procedure:

1. Carefully sample the grain – make sure that the sample you are separating is representative of the entire lot of grain.
2. Measure 1 cup of the grain.
3. Stack the screens and pan, with the coarsest screen on top and the pan on the bottom.
4. Pour the 1-cup sample onto the top screen.
5. Shake and tap the screens until the amount of grain remaining on the top (#4) screen is constant. We are not worried about long particles tipping up and sliding through the screen, so over-

- shaking is not possible. Once the top screen is finished, take it off, set it aside, and shake/tap the remaining screens until the amount of grain on the next screen (#8) is consistent. Set this screen aside, and shake/tap until the next screen (#16) is done. Repeat this until all of the screens are finished.
6. Weigh the amount of grain present on each of the 4 screens and on the bottom pan. Calculate the % particles on each screen and on the pan. All of these calculations are done on an as-fed basis – it is not necessary to correct the amounts for % dry matter.
  6. Compare your results to those listed on the table on the next page. The recommended particle size distribution depends on the moisture of the grain being tested. Interpret the results loosely - no grain sample will fit the ideal distribution perfectly. We are looking for major errors in grain processing with this test. It is not intended to “fine tune” a dairy’s grain processing methods.

#### Interpretation of Grain Screening Results:

Feed Ingredient:	Percent on Top of Screen:				
	#4	#8	#16	#30	Pan
HMSC, <70% dry matter	65	20	<5	<5	<5
HMSC, 70 to 73% dry matter	29	50	20	<5	<5
HMSC, 74 to 77% dry matter	10	25	30	25	10
HMSC, >77% dry matter	0	0	30	50	20
Dry shelled corn	0	0	30	50	20

**Grain Screening Results**

USA Standard Testing Sieve; ASTM E-11 Specification

Farm Name: \_\_\_\_\_

Date: \_\_\_\_\_

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Appendix VIII – Example Ration Worksheet, with TMR Bunk Sample Analysis

<b>Herd Ration Worksheet</b>										
<b>Example Herd</b>	<i>Pre-Fresh TMR - Pens 7 and 8</i>									
<b>Feed Ingredients:</b>	<b>Formulated Ration:</b>				<b>Our Estimated Ration:</b>					
	Date: 2/19/06				Date: 2/20/06					
	As-Fed	DM	DM	% of Ration	As-Fed	DM	DM	% of Ration		
	(lbs)	(%)	(lbs)	(DM basis)	(lbs)	(%)	(lbs)	(DM basis)		
Corn Silage (pile)	19.00	41.5	7.89	32.5%	16.58	39.1	6.48	30.7%	42.0%	of forage DM
Wheat Straw (bales)	7.50	90.0	6.75	27.8%	6.54	89.0	5.82	27.5%	37.7%	of forage DM
Western Hay (bales)	4.00	88.0	3.52	14.5%	3.49	90.0	3.14	14.9%	20.3%	of forage DM
Hi Moist Sh Corn (HVST)	2.75	82.2	2.26	9.3%	2.40	81.6	1.96	9.3%		
Soybean Meal, 47%	2.25	90.2	2.03	8.4%	1.96	89.0	1.74	8.2%		
Prefresh Mix	2.00	91.5	1.83	7.5%	2.09	95.4	1.99	9.4%		
Water	10.00	0.0	0.00	0.0%	8.73	0.0	0.00	0.0%		
<b>Totals:</b>	<b>47.50</b>		<b>24.28</b>	<b>100.0%</b>	<b>41.78</b>		<b>21.14</b>	<b>100.0%</b>	<b>73.1%</b>	<b>forage</b>
<b>Nutrient Analysis (DM Basis)</b>	<b>Amount Req'd:</b>			<b>Formulated Ration:</b>			<b>Estimated Ration:</b>		<b>Lab Analysis, Bunk Sample:</b>	
Dry matter, %	>40			51.1			50.6		51.7	
NEL, Mcal/lb	.70 - .72			0.62			0.64		0.52	
Ether extract, %	<4.5			2.4			2.5		2.2	
Crude protein, %	12 - 14.5			14.5			15.4		9.8	
RUP, % of CP	>32			---			41.2		---	
Soluble P, % of CP	25 - 40			23.5			24.7		33.3	
ADF, %	>21			27.6			27.7		42.0	
NDF, %	32 - 40			43.6			42.0		62.7	
Lignin, %	---			---			6.0		7.5	
NFC*, %	35 - 40			29.6			28.7		15.8	
Ash**, %	---			9.8			11.4		9.5	
Calcium, %	>0.50			1.47			1.64		0.82	
Chlorine, %	>0.20			0.70			0.57		0.56	
Magnesium, %	>0.35			0.46			0.59		0.32	
Phosphorus, %	.30 - .40			0.40			0.45		0.29	
Potassium, %	>0.65			1.30			1.28		1.33	
Sodium, %	>0.10			0.12			0.16		0.15	
Sulfur, %	>0.20			0.33			0.39		0.24	
DCAD, meq/kg	---			-19			-7		98	
Cobalt, ppm	>0.10			2.05			2.60		---	
Copper, ppm	>15			43			45		36	
Iodine, ppm	>0.70			---			1.50		---	
Iron, ppm	>50			---			257		394	
Manganese, ppm	>50			131			143		113	
Suppl. Se, ppm	0.30			0.49			0.60		---	
Zinc, ppm	>60			132			159		113	
Suppl. Vit A, KIU/lb	>2.20			9.37			10.90		---	
Suppl. Vit D, KIU/lb	>1.00			1.44			0.70		---	
Suppl. Vit E, IU/lb	15 - 40			95.1			121.0		---	
*for estimated ration, NFC = 100 - (CP + EE + NDF + Ash)										
**for formulated ration, Ash = 100 - (CP + EE + NDF + NFC)										

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# Ohio Dairy Veterinarians Meeting

January 8-9, 2010

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## Overview of Nutrient Definitions Used in Dairy Nutrition

Garrett R. Oetzel, School of Veterinary Medicine, UW-Madison

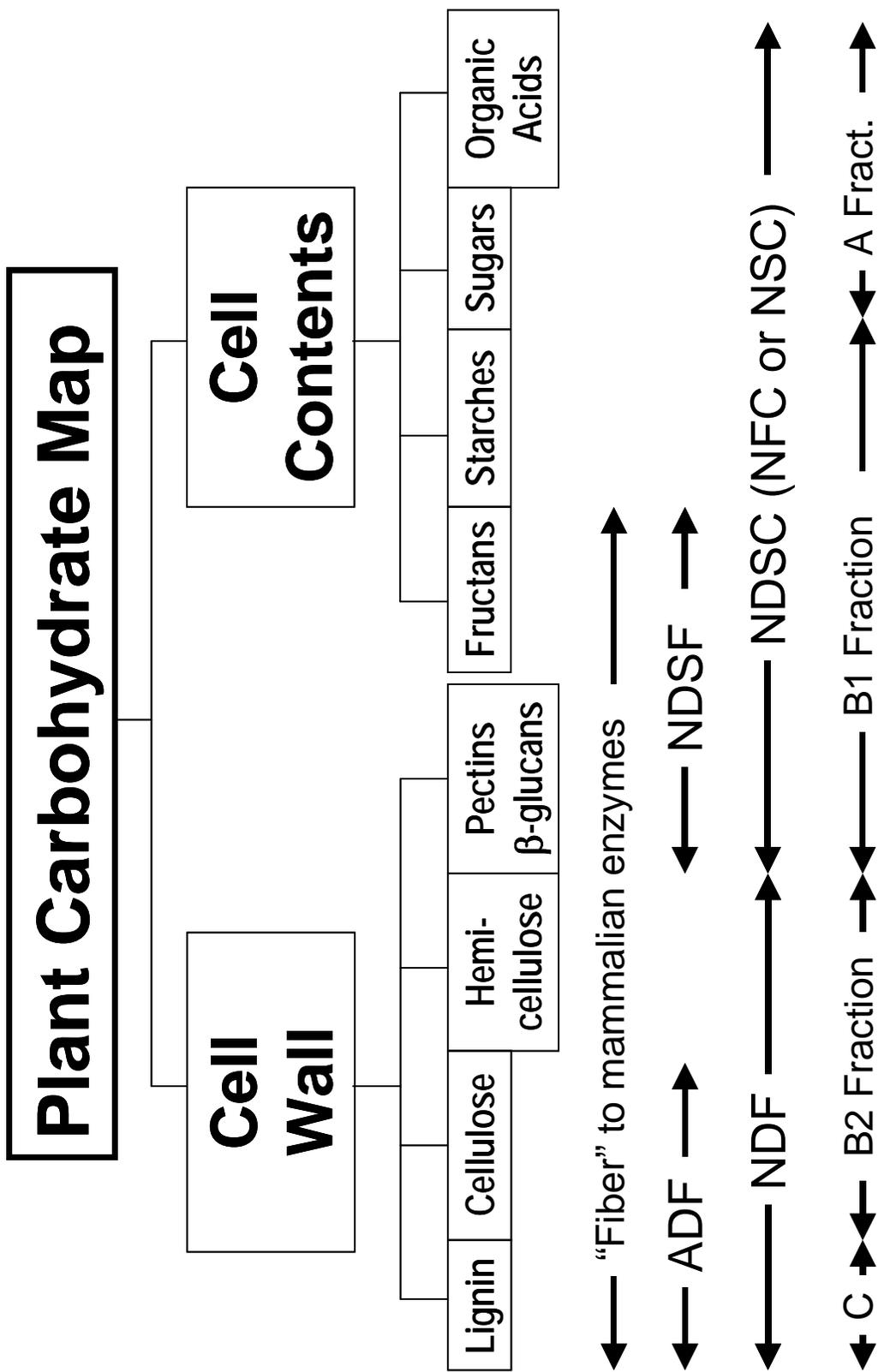
### Defining Dairy Nutrients

1. Different dairy nutritionists and dairy nutrition programs use different sets of nutrients. There is no agreed upon standard set of nutrients that is "best" for dairy rations. Most nutritionists use more nutrients than those described by NRC alone.
2. The following pages include a dairy nutrient map, plant carbohydrate map, and the protein fractions map. These summarize nutrient relationships within different nutrient groups.
3. After the nutrient maps, there is a description of different dairy nutrient definitions that I have seen used in dairy ration formulation.

DAIRY NUTRIENT MAP										
Dr. G.R. Oetzel, University of Wisconsin-Madison										
CATEGORY:	CARBOHYDRATES				FATS	PROTEINS		MINERALS		VITAMINS
LAB METHOD:	Proximate Analysis, Van Soest Analysis				Ether Extract	Kjeldahl N.		Ash, Mineral Assays		Vitamin Assays
CHEMICAL COMPOUNDS:	Lignin	Cellulose	Hemi-cellulose	Pectin	Starch	Sugar	Amino Acids		NPN	Fat Sol
PLANT:	_____ Cell Wall _____				_____ Cell Cytoplasm _____					
NUTRIENTS:	_____ NEL, ME, or TDN _____									
Energy →	_____ Mcal/lb or %									
Fat →	_____ EE _____ %									
Protein →	_____ CP _____ %									
	True Protein NPN									
	RUP RDP									
	Insoluble SIP									
Fibers →	_____ CF _____ %									
	_____ ADF _____ %									
	_____ NDF _____ %									
	_____ NFE _____ %									
	_____ NFC _____ %									
Minerals →	Macrominerals (%): Ca, Cl, Mg, P, K, Na, S									
	Microminerals (ppm): Co, Cu, I, Fe, Mn, Se, Zn									
	Fat-Soluble Vitamins (KIU or IU/lb): A, D, E, K									
Vitamins →	H <sub>2</sub> O-Soluble Vitamins (g or mg/lb): B Complex Vitamins									

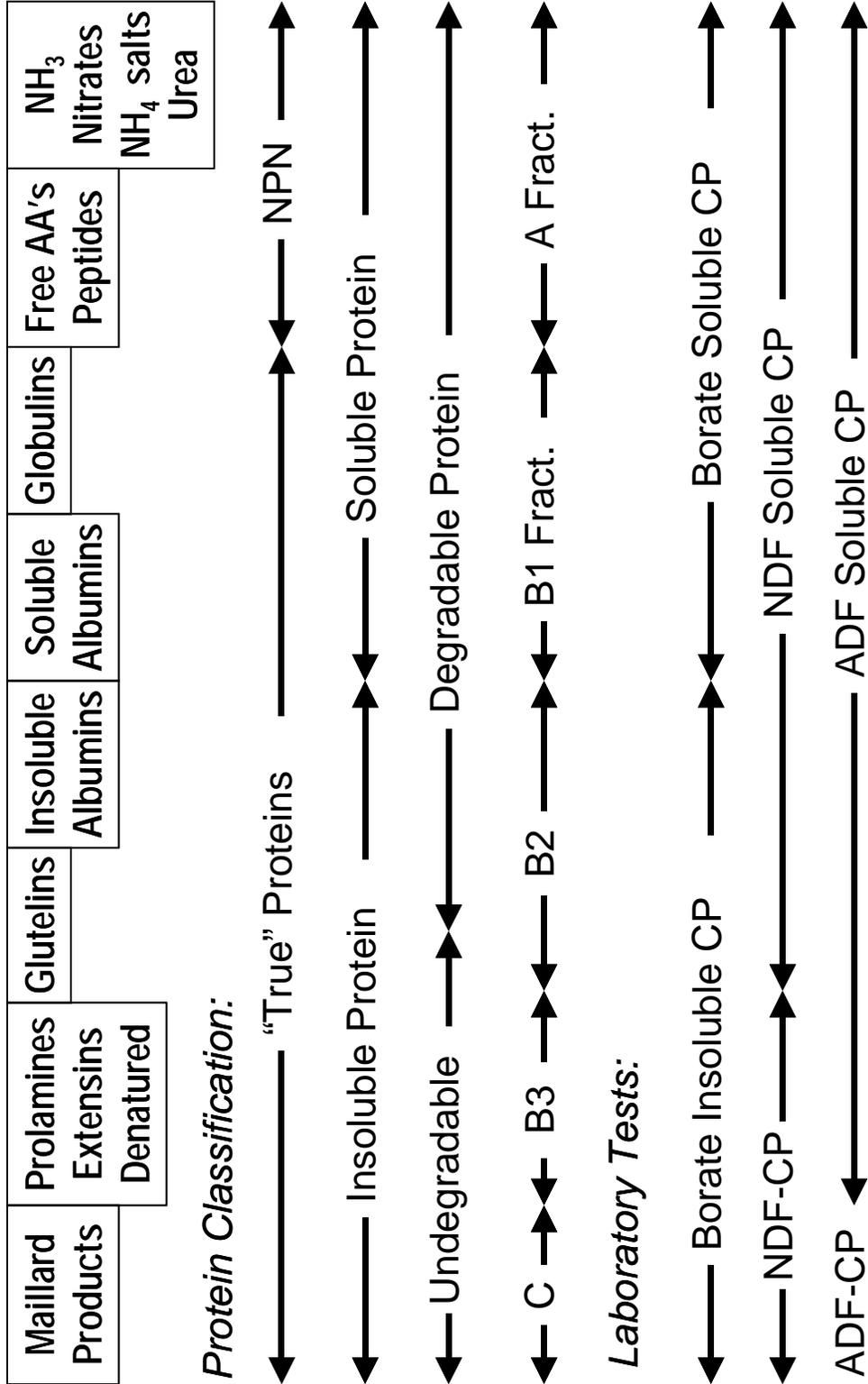
## Explanation of Abbreviations and Terms in the Dairy Nutrient Map

1. Proximate Analysis - Series of laboratory methods of determining the nutrient content of a feed ingredient. Includes dry matter determination, ash, ether extract, crude fiber, and crude protein determinations; nitrogen-free extract is then determined by difference.
2. Van Soest Analysis - Determination of ADF (acid detergent fiber) and NDF (neutral detergent fiber) by measuring the residue left of the feed sample after reflux in an acid or neutral detergent.
3. Ether Extract - method of determining total lipids (fats) in a feed ingredient.
4. Kjeldahl Nitrogen - method of determining total nitrogen in a feed ingredient. Nitrogen is then converted to crude protein by dividing by .16 (same as multiplying by 6.25). This calculation is based on the assumptions that all feed nitrogen is in amino acids and that all amino acids are 16% nitrogen.
5. Ash - method of determining all of the inorganic material (mineral) in a feed sample. The sample is burned in a muffle furnace at 600°C for 2 hours.
6. Digestible Energy (DE) - the gross energy of a feed ingredient minus the fecal energy. Digestible energy is approximately equivalent to TDN (Total Digestible Nutrients). Digestible energy is usually estimated from some more easily measured nutrient(s) (e.g., CF, ADF, EE, and/or CP).
7. Metabolizable Energy (ME) - the digestible energy of a feed ingredient minus the urinary energy and gaseous energy.
8. Net Energy (NE) - the metabolizable energy of a feed ingredient minus the heat increment produced by digesting and metabolizing that feed. As with DE and ME, NE values are usually calculated from some more easily measured nutrient(s). Net energy is usually expressed in terms of the final production outcome, e.g., net energy for lactation (NEL).
9. Crude Protein (CP) - total estimated protein in a feed ingredient; based on Kjeldahl nitrogen ( $N \times 6.25$ ).
10. Non-Protein Nitrogen - nitrogen in a feed ingredient not included in true protein. Includes urea, ammonia, ammonium salts, nitrates, free amino acids, and peptides.
11. Undegradable Intake Protein (UIP) - true protein that is not degraded in the rumen, but passes as intact amino acids into the abomasum. Estimated from *in vivo* data from dactron bags in the rumen.
12. Degradable Intake Protein (DIP) - amino acids and NPN that are degraded in the rumen into rumen ammonia, then either synthesized into microbial protein by rumen microorganisms or excreted via urea in the urine.
13. Soluble Intake Protein (SIP) - the most rapidly degradable portion of the DIP; usually determined by a borate-phosphate buffer test in the laboratory.
14. Crude fiber (CF) - the residue left after a feed sample is refluxed in a dilute, strong acid, and then in a dilute, strong base. Includes some lignin, most of the cellulose, and some hemicellulose. Part of the proximate analysis series of procedures. Not a useful predictor of fiber in dairy cattle rations.
15. Nitrogen-Free Extract (NFE) - determined by subtracting the CP, Ash, EE, and CF from 100% (DM basis). Not used in dairy cattle rations.
16. Acid detergent fiber (ADF) - the residue left after a feed sample is refluxed in an acid detergent solution. Part of the Van Soest procedures.
17. Neutral detergent fiber (NDF) - the residue left after a feed sample is refluxed in a neutral detergent solution. Includes the cell wall components lignin, cellulose, and hemicellulose. Part of the Van Soest procedures. Pectin is technically part of the cell wall also, but behaves as though it is part of the cell cytoplasm because it is soluble and highly digestible.
18. Non-Fiber Carbohydrate (NFC) - determined by subtracting the CP, Ash, EE, and NDF from 100% (DM basis). Approximates carbohydrates that can be rapidly fermented in the rumen.



Adapted from Hall, M.B., *Compendium* S158, 8/97

# Protein Fractions Map



## Specific Dairy Nutrient Definitions

NEL - Net Energy for Lactation. Represents the net energetic potential from carbohydrates, fats, and proteins. NEL is used for both dry cow and lactating cow rations. NEL is estimated for individual feed ingredients using specific formulas for that ingredient (usually based on the ADF). The Ohio (OARDC) equation calculates NEL based on ether extract, crude protein, NDF-CP, NDF, lignin, and ash analysis results. This equation can be applied to most feeds and also to feed mixes or TMR's. Examples of NEL equations are given below: NEL is typically the energy system used for lactation and dry cow rations. Other energy systems (NEM, NEG, ME, or TDN) are typically used for replacement heifer diets.

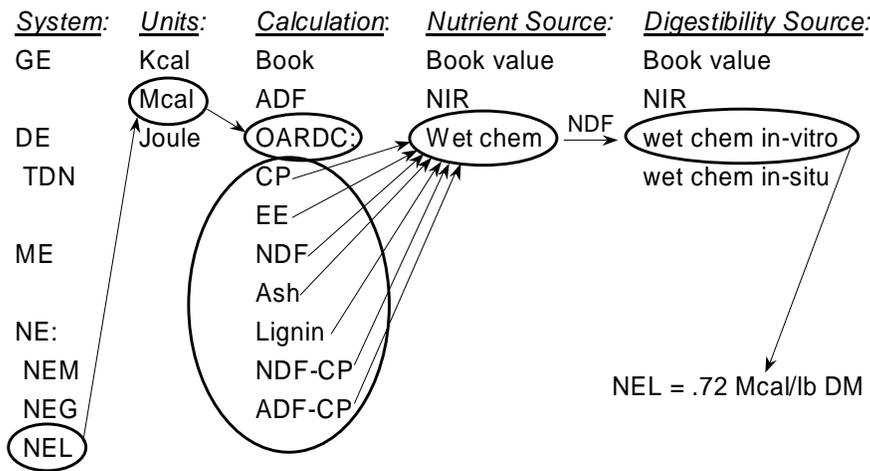
The energy content of feeds and energy requirements of cattle can be confusing to define. I find it helpful to describe energy in terms of the energy system used, the energy units used, the calculation method chosen, and the source of the nutrient values used for the calculations, and a description of digestibility estimates used, and any special modifiers applied to the energy value. These are summarized in Table 1 (below) and illustrated in Figure 1 (top of the next page).

**Table 1. Summary of Energy Terminology and Key Energy Nutrition Principles**

Energy System		Energy Units	Calculation Method (Equation Type)	Nutrient Source	Digestibility Estimate	Special Modifiers
GE	Gross or Total Energy	Kcal (Calorie)	Book value only (no calculation)	book values	book value	intake level (1X to 5X)
DE or TDN	DE = GE – Fecal E	Mcal	Traditional (from ADF)	lab wet chem analysis	lab wet chem or NIR	corn silage processing
ME	ME = DE – Urinary E and Gaseous E	Joule	OARDC (from CP, EE, NDF, ash, lignin, NDF-CP, and ADF-CP)	lab NIR analysis	NDF or OM	
NE (NEM, NEG or NEL)	NE = ME – Heat Increment	% (TDN)			<i>in-vitro</i> (24 to 48-hr)	
					<i>in-situ</i> (24 to 48-hr)	

NEL values are always calculated, and formulas plus the inputs that go into those formulas vary considerably among feeds labs and nutritionists. The best estimates come from analyzing the feeds by wet chemistry procedures for all of the Ohio energy equation variables, then using this equation to calculate the energy density of the feed.

Figure 1. Example Feed Energy Value



Although energy is an extremely important and foundational concept for dairy nutrition, diets should not be formulated to a strict energy value. Other factors in the diet (particularly the digestibility of carbohydrate sources and the balance between fibrous and non-fiber carbohydrates determines the range of energy density that a diet can have.

**NEM** - Net Energy for Maintenance. This energy system is used in applied dairy nutrition only for replacement heifer rations. The NEL system already includes all maintenance energy requirements. If you use the NE system for balancing replacement heifer rations, you must use **both** the NEM and NEG together. As for NEL, a variety of equations are used by various feed analysis laboratories to report NEM values.

**NEG** - Net Energy for Gain. As for NEM, this energy system is used in applied dairy nutrition only for replacement heifer rations. The NEL system already includes growth requirements for 1st and 2nd lactation animals. When balancing replacement heifer rations, you must use **both** the NEM and NEG energy systems. As for NEL, a variety of equations are used by various feed analysis laboratories to report NEG values.

**ME** - Metabolizable Energy. An energy system that can be used for lactating, dry period, or replacement heifer diets. In theory, this system does not account for the variable energy losses due to the heat increment of the feed ingredient (heat produced during digestion is generally higher for forages than for concentrates). Some software problems use ME for some (or all) of the energy calculations. ME values for feeds and ME dietary requirements for diets are numerically higher than for NE, because the heat increment has been removed from the NE values.

**TDN** - Total Digestible Nutrients. An older energy system that can be used for lactating, dry period, or replacement heifer diets. In theory, this system does not account for the variable energy losses due to urinary energy, gaseous energy, or heat increment. These losses can be variable within feed ingredients. In practice, NEL and other energy measures are in fact often first calculated from an estimate of the TDN.

**EE** - Ether Extract, an estimate of the amount of lipid in the ingredient or diet. Ether extract is essentially synonymous with fat; software programs may use either term. Ether extract is not a perfect measure of total dietary lipids, but it comes close and is essentially the only laboratory test used for lipid determinations.

**CP** - Crude Protein, determined by multiplying the Kjeldahl N by 6.25.

**ADF-CP** - The amount of CP that is left in the residue from an ADF determination. It is sometimes expressed as Acid Detergent Insoluble Nitrogen (ADIN), ADF-N, Unavailable Protein, or Bound Protein. Be careful to determine whether it is expressed on a Nitrogen (N) basis or on a CP basis. Also be careful to determine if it is expressed as a % of CP or as a % of diet dry matter. Feeds that have undergone heated (drying of wet by-product feeds or poor silage fermentation) are the most likely to have high ADF-CP values. Often these feeds have a slightly burnt or “tobacco” smell. Alfalfa haylages that were ensiled too dry or distillers grains that were dried too rapidly are the most common feed ingredients with high ADF-CP.

**Adjusted CP** - The amount of Crude Protein left after adjusting for ADF-CP in the feed ingredient. If more than 12% of the CP is represented by ADF-CP, then the CP value is adjusted downward by the amount of CP over the 12% limit. If not noted, assume that “CP” in software programs, ration formulations, and nutrient requirements is actually “Adjusted CP.” In many software programs you have to make this adjustment manually (often it is reported in the lab analysis of the ingredient) and enter the adjusted CP value into the computer in the “CP” box. Other programs ask that you enter the unadjusted CP value and then the ADF-CP value separately. The program then makes the adjustments for you.

**NDF-CP** - The amount of CP that is left in the residue from an NDF determination. It is sometimes expressed as Neutral Detergent Insoluble Nitrogen (NDIN). Also be careful to determine if it is expressed as a % of CP or as a % of diet dry matter. NDF-CP is increased by heating and is necessarily greater than but typically proportional to ADF-CP. NDF-CP is not used to adjust CP values but is used to correct the “double counting” of CP that remains in the NDF fraction of a feed ingredient. This is important for nutrients calculated by difference (e.g., non-fiber carbohydrates and formulas for estimating energy density of feeds).

**RUP** - Ruminally Undegradable Protein, expressed either as % of the CP or as % of total ration DM. Ration RUP is calculated by multiplying the CP by the % of the CP as RUP. RUP is typically not determined by laboratory procedures (because it is a biological test that requires placing a sample into a fistulated cow's rumen), but rather by estimated book values of the % of the CP in the RUP fraction for different types of feeds. Because RUP increases with higher feed intakes (and thus higher rates of passage), it is most accurate to estimate RUP dynamically based on the level of total feed intake. Many software programs do this; others use a single, static proportion of RUP within the CP.

**RDP** - Ruminally Degradable Protein, expressed either as % of the CP or as % of total ration DM. 100% of the adjusted CP must be contained in the RUP and RDP fractions combined. Ration RDP is calculated as the remaining CP after RUP is accounted for. Because RDP is calculated from the RUP estimate, its accuracy is no better than the accuracy of the RUP estimate. RDP is nutritionally significant because it represents nitrogen (primarily rumen ammonia) that is available in the rumen for microbial protein synthesis.

**SIP** - Soluble Intake Protein, expressed either as % of the CP or as % of total ration DM. SIP is the most rapidly degradable portion of the RDP. Unfortunately, some of the SIP in fact may not be degradable. SIP determined by laboratory tests that typically involve protein loss after incubation in a warm buffer solution for a few hours. SIP is nutritionally significant because elevated amounts are associated with ruminal ammonia overflow and high urea nitrogen (UN) concentrations in blood and milk. Low SIP could indicate insufficient ruminal ammonia for microbial protein synthesis (Although total RDP is most commonly used for this purpose). Interestingly, SIP determinations in high moisture corn have been used as a marker for increasing starch digestibility that occurs during storage. This happens as the protein matrix around the corn starch granules is gradually broken down in the silo.

**NPN** - Non-Protein Nitrogen, the amount of elemental N (not CP or CP equivalent!) in a feed ingredient coming from a NPN source. For example, urea is 280% CP and contains 45% NPN. Other sources of NPN include ammoniated forages, ammonium salts, nitrates, and nitrites. Some software programs track NPN as a nutrient; others assume that the nutritional implications of high or low NPN feeding are already accounted for by RDP and SIP.

**CP Equiv NPN** - Crude protein equivalent from NPN. This nutrient is calculated by multiplying the NPN by 6.25. This is the most common expression of NPN content used in feed tags for manufactured feeds containing NPN. It is not commonly seen in software programs or ration reports.

**Urea** - Urea is a feed ingredient rather than a nutrient. Some software programs track urea separately, along with the nutrients. Urea is the most commonly used source of NPN in dairy diets and some nutritionists want to track the total amount of urea in their diets.

**Methionine** - Methionine can be expressed as % of the RUP, % of the CP, or as % of total diet DM. Methionine is nutritionally significant to the cow only if it is within the RUP fraction. Thus, the accuracy of the methionine estimate in the diet depends first on the accuracy of the RUP estimate (particularly whether it is dynamic or static). Methionine in the RDP fraction is inconsequential as it by definition simply becomes rumen ammonia. The methionine content of the RUP fraction is typically not measured, but is estimated from book values. It is assumed that the methionine content in the RUP fraction is the same as the methionine content in the entire CP. Methionine in the RUP fraction may be the first limiting amino acid in dairy diets containing substantial amounts of by-pass protein. Protected methionine products and corn gluten meal are the main feed ingredient sources of extra by-pass methionine.

**Lysine** - Lysine can be expressed as % of the RUP, % of the CP, or as % of total diet DM. Lysine is nutritionally significant to the cow only if it is within the RUP fraction. Thus, the accuracy of the lysine estimate in the diet depends first on the accuracy of the RUP estimate (particularly whether it is dynamic or static). As for methionine, lysine in the RDP fraction is inconsequential as it by definition simply becomes rumen ammonia. The lysine content of the RUP fraction is typically not measured, but is estimated from book values. It is generally assumed that the lysine percentage in the RUP fraction is the same as the lysine content in the entire CP. Lysine in the RUP fraction may be the first limiting amino acid in some dairy diets, but is more commonly second limiting. Protected lysine products and blood meal are the main feed ingredient sources of extra by-pass methionine.

**CF** - Crude Fiber, which roughly represents the some of the lignin and most of the cellulose in a feed ingredient. This is an old fiber measure that is not very useful at all in ruminant nutrition. It mostly shows up on some feed tags. Ruminant diets should not be balanced for crude fiber.

**ADF** - Acid Detergent Fiber, which roughly represents the lignin and cellulose in a feed ingredient (or diet). ADF is a more traditional fiber measure. It is generally not as reliable in predicting the fiber effect of feed ingredients or diets as NDF is.

**NDF** - Neutral Detergent Fiber, which roughly represents the lignin, cellulose, and hemicelluloses in a feed ingredient (or diet). Some labs treat the feed samples with  $\alpha$ -amylase prior (and sodium sulfite) prior to running the NDF assay; this improves the results by improving starch solubilization. These labs may express their results as 'aNDF.' Amylase treatment lowers NDF values slightly. NDF is the best single

chemical predictor of the fiber effect of a feed ingredient or diet. Chemical fiber, however, still cannot account for all of the fiber effect of a feed ingredient or diet. A variety of systems have been developed to modify the NDF values to better represent the fiber effectiveness of a feed ingredient or diet. These include forage NDF (fNDF), effective NDF (eNDF), physically effective NDF (peNDF).

**fNDF** - Forage NDF, which consists of all of the NDF coming from a forage source, whole cottonseed, or whole sunflowers. Either all or none of the NDF counts as fNDF in this system. fNDF is calculated by multiplying the NDF by the fNDF factor, which is either 1 or 0. This was the earliest NDF modification system. It still appears in some software programs. Suggested minimum requirements for fNDF are typically about 21 to 24% of total ration DM.

**eNDF** – Effective NDF. For research purposes, eNDF has been defined as the ability of a feed ingredient to replace forage and maintain milk fat test. For applied dairy nutrition purposes, eNDF was actually an early version of the physically effective fiber system developed by Mertens and then distributed with the Spartan Dairy Ration Evaluator. In this system, the NDF is multiplied by an eNDF factor to determine the eNDF value. The eNDF factors originally used are listed below. Suggested minimum requirements for fNDF are were typically about 21 of total ration DM. This system is not commonly used anymore.

<b>Feed Ingredient Type</b>	<b>eNDF Factor</b>
Forages	1.00
Very finely chopped forages (all particles less than 1 inch long)	0.50 to 0.90
Whole fuzzy cottonseeds	0.50
Other feeds	0.25

**peNDF** - Physically Effective NDF. The peNDF system was devised to predict the fraction of dietary fiber that stimulates chewing and contributes to the mat layer in the rumen. Physically effective NDF is determined by multiplying the NDF content of a dried feed ingredient (or TMR sample) by the proportion of it that is retained on top of a 1.18 mm screen after vertical shaking (Mertens, J. Dairy Sci. 80:1463, 1997). Although not designed to predict ruminal pH, peNDF was the dietary measure that most accurately predicted ruminal pH in a recent meta-analysis of previously published data (Zebeli et al., J. Dairy Sci. 91:2046, 2008). This study also reported that a peNDF level of about 30 to 33% was optimal for minimizing the risk of SARA and maximizing milk production efficiency. Dry matter intake was slightly depressed at these high concentrations of peNDF; however, milk production efficiency was maximized. High total dry matter intakes were apparently offset by a higher risk for SARA and reduced percentage of milk components. The optimal amount of peNDF suggested by this study is quite high

compared to Mertens' original suggestion of a minimum of 21% peNDF. It is common to find a variety of different suggested minimum requirements for peNDF used in the field. Precise determination of peNDF as described by Mertens is primarily limited to research studies because of the practical difficulties in dry sieving feed ingredient and TMR samples. Table values for different feed ingredients can give less precise estimates of the appropriate peNDF factors for different feed ingredients.

<b>Feed Ingredient Type</b>	<b>peNDF Factor</b>
<b>Alfalfa Hays:</b>	
long	.95
coarsely chopped	.90
medium chopped or cubes	.85
finely chopped	.70
ground or pelleted	.40
<b>Alfalfa silages</b>	
coarsely chopped	.85
medium chopped	.80
finely chopped	.70
<b>Grass Hays:</b>	
long	1.00
coarsely chopped	.95
medium chopped	.90
ground or pelleted	.40
<b>Grass Silages</b>	
coarsely chopped	.95
medium chopped	.90
finely chopped	.85
<b>Corn Silage</b>	
coarsely chopped	.90
medium chopped	.85
finely chopped	.80
<b>Pasture</b>	
grass	.70
legume	.65
<b>Green Chop</b>	
legume	.80

<b>Feed Ingredient Type</b>	<b>peNDF Factor</b>
<b>Concentrate Feeds</b>	
whole cottonseed	.85
hi-moist corn, rolled	.80
rolled barley	.70
dry corn, coarse grind	.60
non-forage fiber sources	.40
dry corn, medium grind	.40
concentrate mixes, ground	.40
concentrate mixes, pelleted	.30
liquid feeds	.00

The manually-operated Penn State Particle Separator (PSPS) can be used for on-farm determinations of forage particle length without prior drying of the sample. It is important to note that this technique (which uses undried samples and employs horizontal shaking) is not the same as the research technique (dried samples and vertical shaking) for determining the factor used to calculate peNDF. Even though both methods use the same 1.18 mm screen, the results are considerably different (Yang and Beauchemin, J. Dairy Sci. 89:2618, 2006). Some nutritionists have used results from the PSPS (either above the 1.18 mm screen or above the 8 mm screen) as alternative factors for calculating peNDF. While such approaches may have merit, they have created considerable confusion regarding the definition and application of peNDF.

A new forage sieving system (the “Z-Box”) has been developed and may provide a more practical, wet-sieving alternative for estimating pe factors compared to dry sieving procedures done in research labs. Note that the Z-Box is not a replacement for the PSPS, which can be used to estimate long particles in the feed ingredient or TMR.

**Long Particles** – The proportion of particles in a forage ingredient that are over about 1.5 inches in length. This can be determined by the Wisconsin standard method (particles retained on the top two screens) or by the PSPS (particles retained on the top screen). All concentrates have no long particles. Some software programs are set up to quantify total long particles in the diet, although this is uncommon. Minimum requirements for total daily intake of long particles are not well-understood. Simply testing the TMR mix gives a direct measurement of the proportion of long particles in the TMR, which is the main information needed. Tracking the expected proportion of long particles in a TMR through a ration software program and comparing this number to the actual proportion of long particles can be used to provide an estimate of how much reduction in long particles is occurring during the mixing and feed delivery process.

**Lignin** – Either the chemically-determined or book value for the lignin content of a feed ingredient. Diets are not balanced for lignin content, so this is considered a monitor variable only. Lignin has some value as a marker for overall digestibility and is used in the Ohio formula to calculate NEL.

**Cellulose** – Determined by subtracting the ADF from the lignin. Diets are not balanced for cellulose content, so this is considered a monitor variable only.

**Hemicellulose** – Determined by subtracting the NDF from the ADF. Grasses tend to be high in hemicellulose relative to legumes. Diets are not balanced for hemicellulose content, so this is considered a monitor variable only.

**NFC** - Non-Fiber Carbohydrate, usually calculated as  $100 - EE - CP - NDF - Ash$ . The result of this calculation is an approximation of the amount of pectins, starches, sugars, and organic acids in a feed ingredient. This value can be very misleading for feeds that are high in NPN. Adding the CP Equiv from NPN back to the NFC value and subtracting the NPN value will correct for this problem. NFC generally represents rapidly fermentable carbohydrates in the rumen (unless the organic acid content of the ingredient is atypical), but does not completely describe the rate of fermentation or the expected fermentation end-products (propionate vs. lactate, etc.). Most older software programs (and AminoCow) use this formula for NFC.

Some software programs and some feeds laboratories report NFC values as  $100 - EE - CP - NDF - Ash + NDF-CP$ . Adding the NDF-CP back in is technically correct; this protein was “double subtracted” because it was present in both the CP and NDF fractions. NDF-CP is typically about 2% of the total ration DM. However, the uneven adoption of this NFC formula and the lack of a unique name for it can create confusion in the field. Maybe it should be called ‘corrected’ or ‘cNFC’ - although I’ve never seen this proposed or used. It is up to you to keep track of this and make mental adjustments as needed. For example, if the suggested requirement for NFC is 35 to 40% of total ration DM using the original or uncorrected NFC formula, then the suggested requirement for NFC with the corrected formula is 37 to 42%.

**Sugars** - The chemically determined (or book value) amount of sugars in a feed ingredient or diet. Sugars are essentially 100% ruminally fermentable. Modest amounts of sugars promote optimal ruminal fermentation and help capture SIP as microbial protein. Although sugar requirements at this time are preliminary, it appears that about 3.5% to 5.5% sugars in the diet is optimal. Higher sugar concentrations increase the risk for SARA - particularly if over 7.5%.

Grass hays and pastures are generally higher in sugars compared to legume hays and pasture. Grasses have almost no sugar early in the morning but could have sugar values of 15-20% by late afternoon. Silages are lower in sugars because they may be used in fermentation.

**Starch** – The chemically determined (or book value) amount of starch in a feed ingredient or diet. Most laboratory procedures measure starch separately from sugars. Dietary requirements for starch are

becoming better defined but are still considered preliminary. It is typical to balance lactating cow diets for about 22 to 26% starch (DM basis).

**Starch Fermentability** - An estimate of the ruminal fermentability of the starch in a feed ingredient or diet. Starch fermentability is quite dependent on the moisture content of feed ingredients (higher moisture means higher fermentability). AminoCow suggests that each 1% increase in moisture increases starch fermentability by 0.5%. The physical form of the ingredient also has an effect on starch fermentability (with finer processing better fermented). A finely ground dry corn may be about 4% more ruminally fermentable than a coarsely ground dry corn.

**Organic Acids** - The chemically determined amount of organic acids in a feed ingredient or diet. Lactic and acetic acid are the major organic acids present in ensiled feeds. Propionic acid may be present in smaller amounts; butyric acid is highly undesirable and should not be present at all. Organic acids are often called volatile fatty acids (VFA); however, this is a misnomer because lactic acid is not volatile. Yet, it appears that the VFA label is established and will persist. Diets are not balanced for organic acid content, so this is considered a monitor variable only. Organic acids by default are included in the NFC fraction; however, they are directly absorbed (or converted and then absorbed) and do not contribute directly to microbial growth in the rumen. It is intriguing to consider what their effect might be on animal performance. They can account for about 0 to 5% of total ration DM.

Neutral Detergent Soluble Fiber (NDSF) - Calculated as NFC – (starch + sugar + organic acids). Also known as Neutral Detergent Solubles (SolNDF) - this terminology is used in AminoCow. NDSF includes mostly pectins,  $\beta$ -glucans, and fructans. These carbohydrates are generally more slowly fermented than sugars or starches. They are not usually fermented to lactic acid, which adds to their desirability. There are no clearly defined requirements for NDSF, so this is considered a monitor variable. It is calculated internally by software programs but doesn't appear on feed analysis reports.

AminoCow gives a warning error message when the calculated SolNDF value goes below zero for a feed ingredient. This indicates that something is incorrect in one or more of values entered for any of the variables used to calculate SolNDF (CP, EE, NDF, Ash, starch, sugars, or organic acids). Re-check your values and/or re-analyze the feed ingredient if this warning appears.

**Macrominerals** – Ash, Ca, Cl, Mg, P, K, Salt, Na, and S, all calculated as % of the ration DM. Ash is not an essential nutrient per se but is often included in software programs because it is required for the calculation of NFC. High total ash content can be an indication of excessive soil contamination.

**Salt** - Salt is sometimes included in software programs as though it was a nutrient, although it is actually a feed ingredient (similar situation as urea). The Na and Cl contribution of salt are included in the Na and Cl portion of the diet.

**Buffer** – Buffers are not essential nutrients, but are sometimes included in software programs for the convenience of being able to track their inclusion in diets. Sodium bicarbonate, sodium sesquicarbonate (marketed as S-carb, which is a mixture of sodium carbonate and sodium bicarbonate), trona (also a mixture of sodium carbonate and sodium bicarbonate), magnesium oxide, potassium bicarbonate, and potassium carbonate are all considered 100% buffer. All other feed ingredients are considered 0% buffer. Dietary cation-anion difference is a better expression of the buffering of a diet.

**DCAD** - Dietary Cation-Anion Difference, calculated on a meq/lb basis. DCAD is calculated as the milliequivalents of  $(\text{Na}+\text{K}) - (\text{Cl}+\text{S})$ . Percents may be converted to milliequivalents by the following factors:

**Na** – multiply % Na by 198

**K** –multiply % K by 116

**Cl** – multiply % Cl by 128

**S** – multiply % S by 284

This standard DCAD equation tends to over-value the acid-base effect of S and does not consider the minor acid-base effects of Ca, Mg, and P. However, as long as S remains relatively constant and Ca, Mg, and/or P are not fed in unusual amounts, this equation predicts acid-base effects quite accurately. This equation has become the standard for DCAD calculations, although a variety of units have been applied to it (meq/kg, meq/lb, meq/100g). DCAD is useful to quantify acidification of pre-fresh diets to reduce the risk for milk fever and in lactation diets to quantify buffering.

**Microminerals** - Co, Cu, I, Fe, Mn, Se, and Zn, all usually calculated on a ppm (same as mg/kg) basis. If presented on a percentage basis, remember that 1% = 10,000 ppm. There can be some variation among nutritionists in how they handle background vs. supplemental sources of Microminerals. Selenium is almost always counted only if it comes from a supplemental source; any background Se is a “bonus” and is not included in the ration calculations. Background amounts of the other microminerals are often (but not always) included in the micromineral calculations. Micromineral content of feed ingredients is either estimated (book values) or can be determined by wet chemistry for Cu, Fe, Mn, and Zn. There are no readily-available tests for Co, I, or Se content of feed ingredients.

**Vitamins** - Vitamins A, D, and E. These nutrients are mostly straightforward; the only thing to be aware of is differences in units. Vitamins A and D are most likely to be calculated as KIU/lb, IU/lb and even IU or KIU/gram or kg sometimes show up in software programs. Vitamin E is almost always calculated as IU/lb. Only supplemental sources of vitamins are usually considered. Background vitamins are considered a bonus and are not included in the ration calculations. Ensiled feeds or baled hays after prolonged storage probably contain no significant amounts of active vitamins anyway. Recently baled hays may contain some active vitamins. Pastures contain large amounts of active vitamins – enough to eliminate the need for vitamin supplementation.

There are no readily-available tests for the vitamin content of feed ingredients. Therefore, we are at the mercy of the accuracy of the feed tag analyses provided by the manufacturers of vitamin supplements. Vitamin content of stored feeds decreases over time and with exposure to heat or chemicals.

Vitamins are often expressed only as total daily intake (e.g., KIU/day) as opposed to concentration within the diet (e.g., KIU/lb). Some software programs display them both ways. Expressing nutrients as total daily intake almost always is the most accurate approach. However, expressing nutrients as ratios (concentration within the diet) is usually much more convenient, and is accurate as long as total dry matter intakes are expected and reasonable.

**Additives** – Additives are not essential nutrients, and there are no requirements for them. However, it is convenient to be able to track the concentrations of commonly-used feed additives in dairy diets. Some software programs do this. Additives that may be tracked include niacin, monensin, lasalocid, choline, and biotin. Monensin is the most common and significant of these.

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# Ohio Dairy Veterinarians Meeting

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## Overview of Nutrient Definitions Used in Dairy Nutrition

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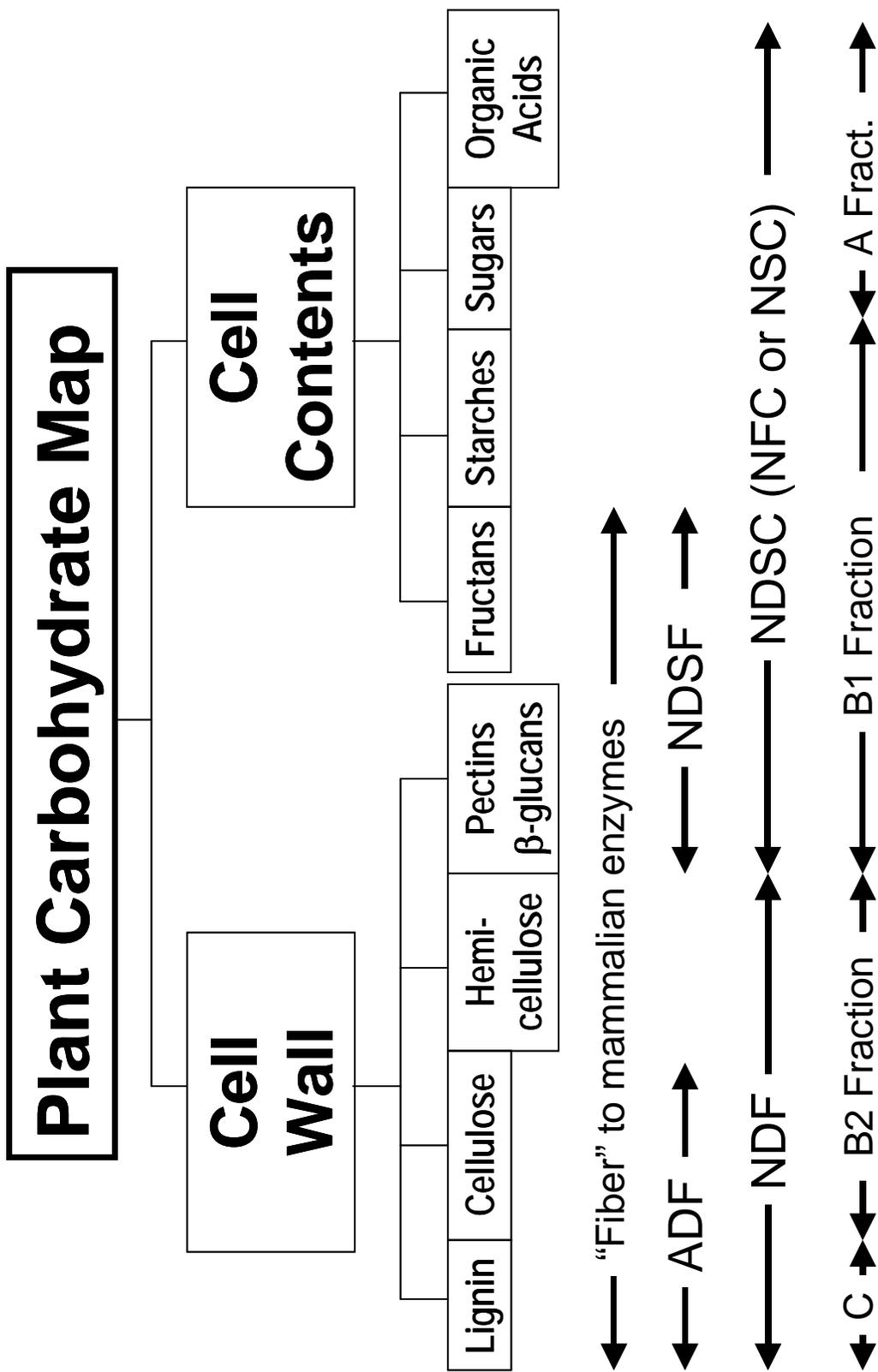
### Defining Dairy Nutrients

1. Different dairy nutritionists and dairy nutrition programs use different sets of nutrients. There is no agreed upon standard set of nutrients that is "best" for dairy rations. Most nutritionists use more nutrients than those described by NRC alone.
2. The following pages include a dairy nutrient map, plant carbohydrate map, and the protein fractions map. These summarize nutrient relationships within different nutrient groups.
3. After the nutrient maps, there is a description of different dairy nutrient definitions that I have seen used in dairy ration formulation.

DAIRY NUTRIENT MAP										
Dr. G.R. Oetzel, University of Wisconsin-Madison										
CATEGORY:	CARBOHYDRATES				FATS	PROTEINS		MINERALS		VITAMINS
LAB METHOD:	Proximate Analysis, Van Soest Analysis				Ether Extract	Kjeldahl N.		Ash, Mineral Assays		Vitamin Assays
CHEMICAL COMPOUNDS:	Lignin	Cellulose	Hemi-cellulose	Pectin	Starch	Sugar	Amino Acids		NPN	Fat Sol
PLANT:	Cell Wall				Cell Cytoplasm					
NUTRIENTS:	NEL, ME, or TDN									
Energy →	Mcal/lb or %									
Fat →	EE %									
Protein →	CP %									
	True Protein NPN									
	RUP RDP									
	Insoluble SIP									
Fibers →	CF %									
	ADF %									
	NDF %									
	NFE %									
	NFC %									
Minerals →	Macrominerals (%): Ca, Cl, Mg, P, K, Na, S									
	Microminerals (ppm): Co, Cu, I, Fe, Mn, Se, Zn									
	Fat-Soluble Vitamins (KIU or IU/lb): A, D, E, K									
Vitamins →	H <sub>2</sub> O-Soluble Vitamins (g or mg/lb): B Complex Vitamins									

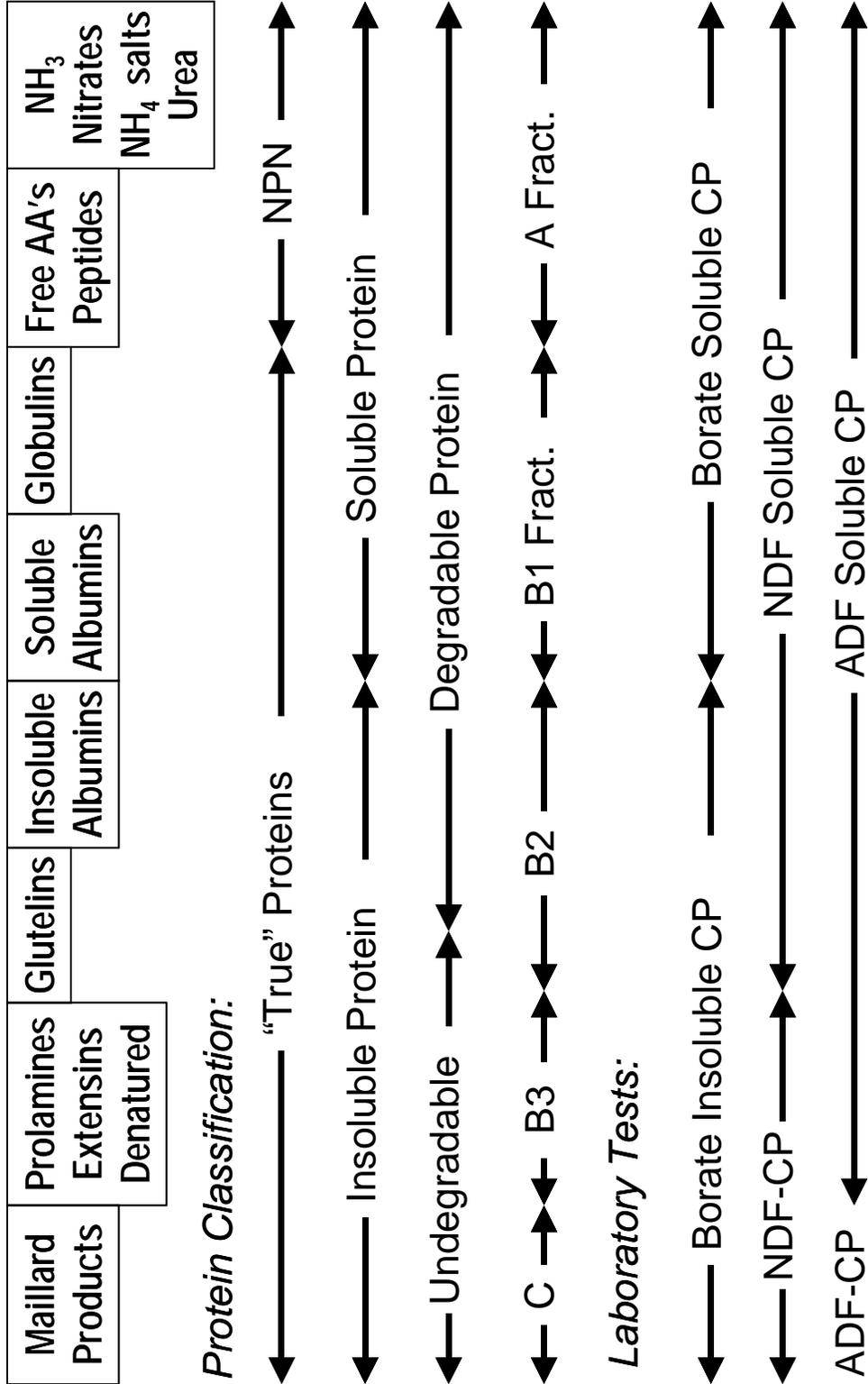
## Explanation of Abbreviations and Terms in the Dairy Nutrient Map

1. Proximate Analysis - Series of laboratory methods of determining the nutrient content of a feed ingredient. Includes dry matter determination, ash, ether extract, crude fiber, and crude protein determinations; nitrogen-free extract is then determined by difference.
2. Van Soest Analysis - Determination of ADF (acid detergent fiber) and NDF (neutral detergent fiber) by measuring the residue left of the feed sample after reflux in an acid or neutral detergent.
3. Ether Extract - method of determining total lipids (fats) in a feed ingredient.
4. Kjeldahl Nitrogen - method of determining total nitrogen in a feed ingredient. Nitrogen is then converted to crude protein by dividing by .16 (same as multiplying by 6.25). This calculation is based on the assumptions that all feed nitrogen is in amino acids and that all amino acids are 16% nitrogen.
5. Ash - method of determining all of the inorganic material (mineral) in a feed sample. The sample is burned in a muffle furnace at 600°C for 2 hours.
6. Digestible Energy (DE) - the gross energy of a feed ingredient minus the fecal energy. Digestible energy is approximately equivalent to TDN (Total Digestible Nutrients). Digestible energy is usually estimated from some more easily measured nutrient(s) (e.g., CF, ADF, EE, and/or CP).
7. Metabolizable Energy (ME) - the digestible energy of a feed ingredient minus the urinary energy and gaseous energy.
8. Net Energy (NE) - the metabolizable energy of a feed ingredient minus the heat increment produced by digesting and metabolizing that feed. As with DE and ME, NE values are usually calculated from some more easily measured nutrient(s). Net energy is usually expressed in terms of the final production outcome, e.g., net energy for lactation (NEL).
9. Crude Protein (CP) - total estimated protein in a feed ingredient; based on Kjeldahl nitrogen ( $N \times 6.25$ ).
10. Non-Protein Nitrogen - nitrogen in a feed ingredient not included in true protein. Includes urea, ammonia, ammonium salts, nitrates, free amino acids, and peptides.
11. Undegradable Intake Protein (UIP) - true protein that is not degraded in the rumen, but passes as intact amino acids into the abomasum. Estimated from *in vivo* data from dactron bags in the rumen.
12. Degradable Intake Protein (DIP) - amino acids and NPN that are degraded in the rumen into rumen ammonia, then either synthesized into microbial protein by rumen microorganisms or excreted via urea in the urine.
13. Soluble Intake Protein (SIP) - the most rapidly degradable portion of the DIP; usually determined by a borate-phosphate buffer test in the laboratory.
14. Crude fiber (CF) - the residue left after a feed sample is refluxed in a dilute, strong acid, and then in a dilute, strong base. Includes some lignin, most of the cellulose, and some hemicellulose. Part of the proximate analysis series of procedures. Not a useful predictor of fiber in dairy cattle rations.
15. Nitrogen-Free Extract (NFE) - determined by subtracting the CP, Ash, EE, and CF from 100% (DM basis). Not used in dairy cattle rations.
16. Acid detergent fiber (ADF) - the residue left after a feed sample is refluxed in an acid detergent solution. Part of the Van Soest procedures.
17. Neutral detergent fiber (NDF) - the residue left after a feed sample is refluxed in a neutral detergent solution. Includes the cell wall components lignin, cellulose, and hemicellulose. Part of the Van Soest procedures. Pectin is technically part of the cell wall also, but behaves as though it is part of the cell cytoplasm because it is soluble and highly digestible.
18. Non-Fiber Carbohydrate (NFC) - determined by subtracting the CP, Ash, EE, and NDF from 100% (DM basis). Approximates carbohydrates that can be rapidly fermented in the rumen.



Adapted from Hall, M.B., *Compendium* S158, 8/97

# Protein Fractions Map



## Specific Dairy Nutrient Definitions

NEL - Net Energy for Lactation. Represents the net energetic potential from carbohydrates, fats, and proteins. NEL is used for both dry cow and lactating cow rations. NEL is estimated for individual feed ingredients using specific formulas for that ingredient (usually based on the ADF). The Ohio (OARDC) equation calculates NEL based on ether extract, crude protein, NDF-CP, NDF, lignin, and ash analysis results. This equation can be applied to most feeds and also to feed mixes or TMR's. Examples of NEL equations are given below: NEL is typically the energy system used for lactation and dry cow rations. Other energy systems (NEM, NEG, ME, or TDN) are typically used for replacement heifer diets.

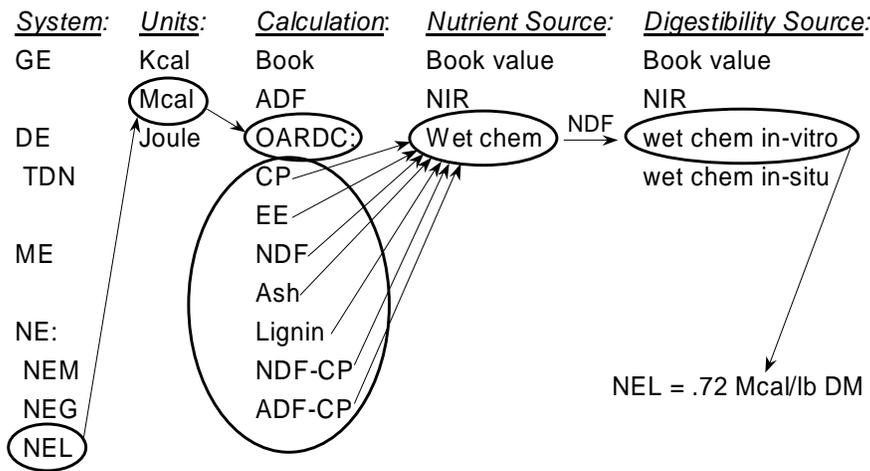
The energy content of feeds and energy requirements of cattle can be confusing to define. I find it helpful to describe energy in terms of the energy system used, the energy units used, the calculation method chosen, and the source of the nutrient values used for the calculations, and a description of digestibility estimates used, and any special modifiers applied to the energy value. These are summarized in Table 1 (below) and illustrated in Figure 1 (top of the next page).

**Table 1. Summary of Energy Terminology and Key Energy Nutrition Principles**

Energy System		Energy Units	Calculation Method (Equation Type)	Nutrient Source	Digestibility Estimate	Special Modifiers
GE	Gross or Total Energy	Kcal (Calorie)	Book value only (no calculation)	book values	book value	intake level (1X to 5X)
DE or TDN	DE = GE – Fecal E	Mcal	Traditional (from ADF)	lab wet chem analysis	lab wet chem or NIR	corn silage processing
ME	ME = DE – Urinary E and Gaseous E	Joule	OARDC (from CP, EE, NDF, ash, lignin, NDF-CP, and ADF-CP)	lab NIR analysis	NDF or OM	
NE (NEM, NEG or NEL)	NE = ME – Heat Increment	% (TDN)			<i>in-vitro</i> (24 to 48-hr)	
					<i>in-situ</i> (24 to 48-hr)	

NEL values are always calculated, and formulas plus the inputs that go into those formulas vary considerably among feeds labs and nutritionists. The best estimates come from analyzing the feeds by wet chemistry procedures for all of the Ohio energy equation variables, then using this equation to calculate the energy density of the feed.

Figure 1. Example Feed Energy Value



Although energy is an extremely important and foundational concept for dairy nutrition, diets should not be formulated to a strict energy value. Other factors in the diet (particularly the digestibility of carbohydrate sources and the balance between fibrous and non-fiber carbohydrates determines the range of energy density that a diet can have.

**NEM** - Net Energy for Maintenance. This energy system is used in applied dairy nutrition only for replacement heifer rations. The NEL system already includes all maintenance energy requirements. If you use the NE system for balancing replacement heifer rations, you must use **both** the NEM and NEG together. As for NEL, a variety of equations are used by various feed analysis laboratories to report NEM values.

**NEG** - Net Energy for Gain. As for NEM, this energy system is used in applied dairy nutrition only for replacement heifer rations. The NEL system already includes growth requirements for 1st and 2nd lactation animals. When balancing replacement heifer rations, you must use **both** the NEM and NEG energy systems. As for NEL, a variety of equations are used by various feed analysis laboratories to report NEG values.

**ME** - Metabolizable Energy. An energy system that can be used for lactating, dry period, or replacement heifer diets. In theory, this system does not account for the variable energy losses due to the heat increment of the feed ingredient (heat produced during digestion is generally higher for forages than for concentrates). Some software problems use ME for some (or all) of the energy calculations. ME values for feeds and ME dietary requirements for diets are numerically higher than for NE, because the heat increment has been removed from the NE values.

**TDN** - Total Digestible Nutrients. An older energy system that can be used for lactating, dry period, or replacement heifer diets. In theory, this system does not account for the variable energy losses due to urinary energy, gaseous energy, or heat increment. These losses can be variable within feed ingredients. In practice, NEL and other energy measures are in fact often first calculated from an estimate of the TDN.

**EE** - Ether Extract, an estimate of the amount of lipid in the ingredient or diet. Ether extract is essentially synonymous with fat; software programs may use either term. Ether extract is not a perfect measure of total dietary lipids, but it comes close and is essentially the only laboratory test used for lipid determinations.

**CP** - Crude Protein, determined by multiplying the Kjeldahl N by 6.25.

**ADF-CP** - The amount of CP that is left in the residue from an ADF determination. It is sometimes expressed as Acid Detergent Insoluble Nitrogen (ADIN), ADF-N, Unavailable Protein, or Bound Protein. Be careful to determine whether it is expressed on a Nitrogen (N) basis or on a CP basis. Also be careful to determine if it is expressed as a % of CP or as a % of diet dry matter. Feeds that have undergone heated (drying of wet by-product feeds or poor silage fermentation) are the most likely to have high ADF-CP values. Often these feeds have a slightly burnt or “tobacco” smell. Alfalfa haylages that were ensiled too dry or distillers grains that were dried too rapidly are the most common feed ingredients with high ADF-CP.

**Adjusted CP** - The amount of Crude Protein left after adjusting for ADF-CP in the feed ingredient. If more than 12% of the CP is represented by ADF-CP, then the CP value is adjusted downward by the amount of CP over the 12% limit. If not noted, assume that “CP” in software programs, ration formulations, and nutrient requirements is actually “Adjusted CP.” In many software programs you have to make this adjustment manually (often it is reported in the lab analysis of the ingredient) and enter the adjusted CP value into the computer in the “CP” box. Other programs ask that you enter the unadjusted CP value and then the ADF-CP value separately. The program then makes the adjustments for you.

**NDF-CP** - The amount of CP that is left in the residue from an NDF determination. It is sometimes expressed as Neutral Detergent Insoluble Nitrogen (NDIN). Also be careful to determine if it is expressed as a % of CP or as a % of diet dry matter. NDF-CP is increased by heating and is necessarily greater than but typically proportional to ADF-CP. NDF-CP is not used to adjust CP values but is used to correct the “double counting” of CP that remains in the NDF fraction of a feed ingredient. This is important for nutrients calculated by difference (e.g., non-fiber carbohydrates and formulas for estimating energy density of feeds).

**RUP** - Ruminally Undegradable Protein, expressed either as % of the CP or as % of total ration DM. Ration RUP is calculated by multiplying the CP by the % of the CP as RUP. RUP is typically not determined by laboratory procedures (because it is a biological test that requires placing a sample into a fistulated cow's rumen), but rather by estimated book values of the % of the CP in the RUP fraction for different types of feeds. Because RUP increases with higher feed intakes (and thus higher rates of passage), it is most accurate to estimate RUP dynamically based on the level of total feed intake. Many software programs do this; others use a single, static proportion of RUP within the CP.

**RDP** - Ruminally Degradable Protein, expressed either as % of the CP or as % of total ration DM. 100% of the adjusted CP must be contained in the RUP and RDP fractions combined. Ration RDP is calculated as the remaining CP after RUP is accounted for. Because RDP is calculated from the RUP estimate, its accuracy is no better than the accuracy of the RUP estimate. RDP is nutritionally significant because it represents nitrogen (primarily rumen ammonia) that is available in the rumen for microbial protein synthesis.

**SIP** - Soluble Intake Protein, expressed either as % of the CP or as % of total ration DM. SIP is the most rapidly degradable portion of the RDP. Unfortunately, some of the SIP in fact may not be degradable. SIP determined by laboratory tests that typically involve protein loss after incubation in a warm buffer solution for a few hours. SIP is nutritionally significant because elevated amounts are associated with ruminal ammonia overflow and high urea nitrogen (UN) concentrations in blood and milk. Low SIP could indicate insufficient ruminal ammonia for microbial protein synthesis (Although total RDP is most commonly used for this purpose). Interestingly, SIP determinations in high moisture corn have been used as a marker for increasing starch digestibility that occurs during storage. This happens as the protein matrix around the corn starch granules is gradually broken down in the silo.

**NPN** - Non-Protein Nitrogen, the amount of elemental N (not CP or CP equivalent!) in a feed ingredient coming from a NPN source. For example, urea is 280% CP and contains 45% NPN. Other sources of NPN include ammoniated forages, ammonium salts, nitrates, and nitrites. Some software programs track NPN as a nutrient; others assume that the nutritional implications of high or low NPN feeding are already accounted for by RDP and SIP.

**CP Equiv NPN** - Crude protein equivalent from NPN. This nutrient is calculated by multiplying the NPN by 6.25. This is the most common expression of NPN content used in feed tags for manufactured feeds containing NPN. It is not commonly seen in software programs or ration reports.

**Urea** - Urea is a feed ingredient rather than a nutrient. Some software programs track urea separately, along with the nutrients. Urea is the most commonly used source of NPN in dairy diets and some nutritionists want to track the total amount of urea in their diets.

**Methionine** - Methionine can be expressed as % of the RUP, % of the CP, or as % of total diet DM. Methionine is nutritionally significant to the cow only if it is within the RUP fraction. Thus, the accuracy of the methionine estimate in the diet depends first on the accuracy of the RUP estimate (particularly whether it is dynamic or static). Methionine in the RDP fraction is inconsequential as it by definition simply becomes rumen ammonia. The methionine content of the RUP fraction is typically not measured, but is estimated from book values. It is assumed that the methionine content in the RUP fraction is the same as the methionine content in the entire CP. Methionine in the RUP fraction may be the first limiting amino acid in dairy diets containing substantial amounts of by-pass protein. Protected methionine products and corn gluten meal are the main feed ingredient sources of extra by-pass methionine.

**Lysine** - Lysine can be expressed as % of the RUP, % of the CP, or as % of total diet DM. Lysine is nutritionally significant to the cow only if it is within the RUP fraction. Thus, the accuracy of the lysine estimate in the diet depends first on the accuracy of the RUP estimate (particularly whether it is dynamic or static). As for methionine, lysine in the RDP fraction is inconsequential as it by definition simply becomes rumen ammonia. The lysine content of the RUP fraction is typically not measured, but is estimated from book values. It is generally assumed that the lysine percentage in the RUP fraction is the same as the lysine content in the entire CP. Lysine in the RUP fraction may be the first limiting amino acid in some dairy diets, but is more commonly second limiting. Protected lysine products and blood meal are the main feed ingredient sources of extra by-pass methionine.

**CF** - Crude Fiber, which roughly represents the some of the lignin and most of the cellulose in a feed ingredient. This is an old fiber measure that is not very useful at all in ruminant nutrition. It mostly shows up on some feed tags. Ruminant diets should not be balanced for crude fiber.

**ADF** - Acid Detergent Fiber, which roughly represents the lignin and cellulose in a feed ingredient (or diet). ADF is a more traditional fiber measure. It is generally not as reliable in predicting the fiber effect of feed ingredients or diets as NDF is.

**NDF** - Neutral Detergent Fiber, which roughly represents the lignin, cellulose, and hemicelluloses in a feed ingredient (or diet). Some labs treat the feed samples with  $\alpha$ -amylase prior (and sodium sulfite) prior to running the NDF assay; this improves the results by improving starch solubilization. These labs may express their results as 'aNDF.' Amylase treatment lowers NDF values slightly. NDF is the best single

chemical predictor of the fiber effect of a feed ingredient or diet. Chemical fiber, however, still cannot account for all of the fiber effect of a feed ingredient or diet. A variety of systems have been developed to modify the NDF values to better represent the fiber effectiveness of a feed ingredient or diet. These include forage NDF (fNDF), effective NDF (eNDF), physically effective NDF (peNDF).

**fNDF** - Forage NDF, which consists of all of the NDF coming from a forage source, whole cottonseed, or whole sunflowers. Either all or none of the NDF counts as fNDF in this system. fNDF is calculated by multiplying the NDF by the fNDF factor, which is either 1 or 0. This was the earliest NDF modification system. It still appears in some software programs. Suggested minimum requirements for fNDF are typically about 21 to 24% of total ration DM.

**eNDF** – Effective NDF. For research purposes, eNDF has been defined as the ability of a feed ingredient to replace forage and maintain milk fat test. For applied dairy nutrition purposes, eNDF was actually an early version of the physically effective fiber system developed by Mertens and then distributed with the Spartan Dairy Ration Evaluator. In this system, the NDF is multiplied by an eNDF factor to determine the eNDF value. The eNDF factors originally used are listed below. Suggested minimum requirements for fNDF are were typically about 21 of total ration DM. This system is not commonly used anymore.

<b>Feed Ingredient Type</b>	<b>eNDF Factor</b>
Forages	1.00
Very finely chopped forages (all particles less than 1 inch long)	0.50 to 0.90
Whole fuzzy cottonseeds	0.50
Other feeds	0.25

**peNDF** - Physically Effective NDF. The peNDF system was devised to predict the fraction of dietary fiber that stimulates chewing and contributes to the mat layer in the rumen. Physically effective NDF is determined by multiplying the NDF content of a dried feed ingredient (or TMR sample) by the proportion of it that is retained on top of a 1.18 mm screen after vertical shaking (Mertens, J. Dairy Sci. 80:1463, 1997). Although not designed to predict ruminal pH, peNDF was the dietary measure that most accurately predicted ruminal pH in a recent meta-analysis of previously published data (Zebeli et al., J. Dairy Sci. 91:2046, 2008). This study also reported that a peNDF level of about 30 to 33% was optimal for minimizing the risk of SARA and maximizing milk production efficiency. Dry matter intake was slightly depressed at these high concentrations of peNDF; however, milk production efficiency was maximized. High total dry matter intakes were apparently offset by a higher risk for SARA and reduced percentage of milk components. The optimal amount of peNDF suggested by this study is quite high

compared to Mertens' original suggestion of a minimum of 21% peNDF. It is common to find a variety of different suggested minimum requirements for peNDF used in the field. Precise determination of peNDF as described by Mertens is primarily limited to research studies because of the practical difficulties in dry sieving feed ingredient and TMR samples. Table values for different feed ingredients can give less precise estimates of the appropriate peNDF factors for different feed ingredients.

<b>Feed Ingredient Type</b>	<b>peNDF Factor</b>
<b>Alfalfa Hays:</b>	
long	.95
coarsely chopped	.90
medium chopped or cubes	.85
finely chopped	.70
ground or pelleted	.40
<b>Alfalfa silages</b>	
coarsely chopped	.85
medium chopped	.80
finely chopped	.70
<b>Grass Hays:</b>	
long	1.00
coarsely chopped	.95
medium chopped	.90
ground or pelleted	.40
<b>Grass Silages</b>	
coarsely chopped	.95
medium chopped	.90
finely chopped	.85
<b>Corn Silage</b>	
coarsely chopped	.90
medium chopped	.85
finely chopped	.80
<b>Pasture</b>	
grass	.70
legume	.65
<b>Green Chop</b>	
legume	.80

<b>Feed Ingredient Type</b>	<b>peNDF Factor</b>
<b>Concentrate Feeds</b>	
whole cottonseed	.85
hi-moist corn, rolled	.80
rolled barley	.70
dry corn, coarse grind	.60
non-forage fiber sources	.40
dry corn, medium grind	.40
concentrate mixes, ground	.40
concentrate mixes, pelleted	.30
liquid feeds	.00

The manually-operated Penn State Particle Separator (PSPS) can be used for on-farm determinations of forage particle length without prior drying of the sample. It is important to note that this technique (which uses undried samples and employs horizontal shaking) is not the same as the research technique (dried samples and vertical shaking) for determining the factor used to calculate peNDF. Even though both methods use the same 1.18 mm screen, the results are considerably different (Yang and Beauchemin, J. Dairy Sci. 89:2618, 2006). Some nutritionists have used results from the PSPS (either above the 1.18 mm screen or above the 8 mm screen) as alternative factors for calculating peNDF. While such approaches may have merit, they have created considerable confusion regarding the definition and application of peNDF.

A new forage sieving system (the “Z-Box”) has been developed and may provide a more practical, wet-sieving alternative for estimating pe factors compared to dry sieving procedures done in research labs. Note that the Z-Box is not a replacement for the PSPS, which can be used to estimate long particles in the feed ingredient or TMR.

**Long Particles** – The proportion of particles in a forage ingredient that are over about 1.5 inches in length. This can be determined by the Wisconsin standard method (particles retained on the top two screens) or by the PSPS (particles retained on the top screen). All concentrates have no long particles. Some software programs are set up to quantify total long particles in the diet, although this is uncommon. Minimum requirements for total daily intake of long particles are not well-understood. Simply testing the TMR mix gives a direct measurement of the proportion of long particles in the TMR, which is the main information needed. Tracking the expected proportion of long particles in a TMR through a ration software program and comparing this number to the actual proportion of long particles can be used to provide an estimate of how much reduction in long particles is occurring during the mixing and feed delivery process.

**Lignin** – Either the chemically-determined or book value for the lignin content of a feed ingredient. Diets are not balanced for lignin content, so this is considered a monitor variable only. Lignin has some value as a marker for overall digestibility and is used in the Ohio formula to calculate NEL.

**Cellulose** – Determined by subtracting the ADF from the lignin. Diets are not balanced for cellulose content, so this is considered a monitor variable only.

**Hemicellulose** – Determined by subtracting the NDF from the ADF. Grasses tend to be high in hemicellulose relative to legumes. Diets are not balanced for hemicellulose content, so this is considered a monitor variable only.

**NFC** - Non-Fiber Carbohydrate, usually calculated as  $100 - EE - CP - NDF - Ash$ . The result of this calculation is an approximation of the amount of pectins, starches, sugars, and organic acids in a feed ingredient. This value can be very misleading for feeds that are high in NPN. Adding the CP Equiv from NPN back to the NFC value and subtracting the NPN value will correct for this problem. NFC generally represents rapidly fermentable carbohydrates in the rumen (unless the organic acid content of the ingredient is atypical), but does not completely describe the rate of fermentation or the expected fermentation end-products (propionate vs. lactate, etc.). Most older software programs (and AminoCow) use this formula for NFC.

Some software programs and some feeds laboratories report NFC values as  $100 - EE - CP - NDF - Ash + NDF-CP$ . Adding the NDF-CP back in is technically correct; this protein was “double subtracted” because it was present in both the CP and NDF fractions. NDF-CP is typically about 2% of the total ration DM. However, the uneven adoption of this NFC formula and the lack of a unique name for it can create confusion in the field. Maybe it should be called ‘corrected’ or ‘cNFC’ - although I’ve never seen this proposed or used. It is up to you to keep track of this and make mental adjustments as needed. For example, if the suggested requirement for NFC is 35 to 40% of total ration DM using the original or uncorrected NFC formula, then the suggested requirement for NFC with the corrected formula is 37 to 42%.

**Sugars** - The chemically determined (or book value) amount of sugars in a feed ingredient or diet. Sugars are essentially 100% ruminally fermentable. Modest amounts of sugars promote optimal ruminal fermentation and help capture SIP as microbial protein. Although sugar requirements at this time are preliminary, it appears that about 3.5% to 5.5% sugars in the diet is optimal. Higher sugar concentrations increase the risk for SARA - particularly if over 7.5%.

Grass hays and pastures are generally higher in sugars compared to legume hays and pasture. Grasses have almost no sugar early in the morning but could have sugar values of 15-20% by late afternoon. Silages are lower in sugars because they may be used in fermentation.

**Starch** – The chemically determined (or book value) amount of starch in a feed ingredient or diet. Most laboratory procedures measure starch separately from sugars. Dietary requirements for starch are

becoming better defined but are still considered preliminary. It is typical to balance lactating cow diets for about 22 to 26% starch (DM basis).

**Starch Fermentability** - An estimate of the ruminal fermentability of the starch in a feed ingredient or diet. Starch fermentability is quite dependent on the moisture content of feed ingredients (higher moisture means higher fermentability). AminoCow suggests that each 1% increase in moisture increases starch fermentability by 0.5%. The physical form of the ingredient also has an effect on starch fermentability (with finer processing better fermented). A finely ground dry corn may be about 4% more ruminally fermentable than a coarsely ground dry corn.

**Organic Acids** - The chemically determined amount of organic acids in a feed ingredient or diet. Lactic and acetic acid are the major organic acids present in ensiled feeds. Propionic acid may be present in smaller amounts; butyric acid is highly undesirable and should not be present at all. Organic acids are often called volatile fatty acids (VFA); however, this is a misnomer because lactic acid is not volatile. Yet, it appears that the VFA label is established and will persist. Diets are not balanced for organic acid content, so this is considered a monitor variable only. Organic acids by default are included in the NFC fraction; however, they are directly absorbed (or converted and then absorbed) and do not contribute directly to microbial growth in the rumen. It is intriguing to consider what their effect might be on animal performance. They can account for about 0 to 5% of total ration DM.

Neutral Detergent Soluble Fiber (NDSF) - Calculated as NFC – (starch + sugar + organic acids). Also known as Neutral Detergent Solubles (SolNDF) - this terminology is used in AminoCow. NDSF includes mostly pectins,  $\beta$ -glucans, and fructans. These carbohydrates are generally more slowly fermented than sugars or starches. They are not usually fermented to lactic acid, which adds to their desirability. There are no clearly defined requirements for NDSF, so this is considered a monitor variable. It is calculated internally by software programs but doesn't appear on feed analysis reports.

AminoCow gives a warning error message when the calculated SolNDF value goes below zero for a feed ingredient. This indicates that something is incorrect in one or more of values entered for any of the variables used to calculate SolNDF (CP, EE, NDF, Ash, starch, sugars, or organic acids). Re-check your values and/or re-analyze the feed ingredient if this warning appears.

**Macrominerals** – Ash, Ca, Cl, Mg, P, K, Salt, Na, and S, all calculated as % of the ration DM. Ash is not an essential nutrient per se but is often included in software programs because it is required for the calculation of NFC. High total ash content can be an indication of excessive soil contamination.

**Salt** - Salt is sometimes included in software programs as though it was a nutrient, although it is actually a feed ingredient (similar situation as urea). The Na and Cl contribution of salt are included in the Na and Cl portion of the diet.

**Buffer** – Buffers are not essential nutrients, but are sometimes included in software programs for the convenience of being able to track their inclusion in diets. Sodium bicarbonate, sodium sesquicarbonate (marketed as S-carb, which is a mixture of sodium carbonate and sodium bicarbonate), trona (also a mixture of sodium carbonate and sodium bicarbonate), magnesium oxide, potassium bicarbonate, and potassium carbonate are all considered 100% buffer. All other feed ingredients are considered 0% buffer. Dietary cation-anion difference is a better expression of the buffering of a diet.

**DCAD** - Dietary Cation-Anion Difference, calculated on a meq/lb basis. DCAD is calculated as the milliequivalents of  $(\text{Na}+\text{K}) - (\text{Cl}+\text{S})$ . Percents may be converted to milliequivalents by the following factors:

**Na** – multiply % Na by 198

**K** –multiply % K by 116

**Cl** – multiply % Cl by 128

**S** – multiply % S by 284

This standard DCAD equation tends to over-value the acid-base effect of S and does not consider the minor acid-base effects of Ca, Mg, and P. However, as long as S remains relatively constant and Ca, Mg, and/or P are not fed in unusual amounts, this equation predicts acid-base effects quite accurately. This equation has become the standard for DCAD calculations, although a variety of units have been applied to it (meq/kg, meq/lb, meq/100g). DCAD is useful to quantify acidification of pre-fresh diets to reduce the risk for milk fever and in lactation diets to quantify buffering.

**Microminerals** - Co, Cu, I, Fe, Mn, Se, and Zn, all usually calculated on a ppm (same as mg/kg) basis. If presented on a percentage basis, remember that 1% = 10,000 ppm. There can be some variation among nutritionists in how they handle background vs. supplemental sources of Microminerals. Selenium is almost always counted only if it comes from a supplemental source; any background Se is a “bonus” and is not included in the ration calculations. Background amounts of the other microminerals are often (but not always) included in the micromineral calculations. Micromineral content of feed ingredients is either estimated (book values) or can be determined by wet chemistry for Cu, Fe, Mn, and Zn. There are no readily-available tests for Co, I, or Se content of feed ingredients.

**Vitamins** - Vitamins A, D, and E. These nutrients are mostly straightforward; the only thing to be aware of is differences in units. Vitamins A and D are most likely to be calculated as KIU/lb, IU/lb and even IU or KIU/gram or kg sometimes show up in software programs. Vitamin E is almost always calculated as IU/lb. Only supplemental sources of vitamins are usually considered. Background vitamins are considered a bonus and are not included in the ration calculations. Ensiled feeds or baled hays after prolonged storage probably contain no significant amounts of active vitamins anyway. Recently baled hays may contain some active vitamins. Pastures contain large amounts of active vitamins – enough to eliminate the need for vitamin supplementation.

There are no readily-available tests for the vitamin content of feed ingredients. Therefore, we are at the mercy of the accuracy of the feed tag analyses provided by the manufacturers of vitamin supplements. Vitamin content of stored feeds decreases over time and with exposure to heat or chemicals.

Vitamins are often expressed only as total daily intake (e.g., KIU/day) as opposed to concentration within the diet (e.g., KIU/lb). Some software programs display them both ways. Expressing nutrients as total daily intake almost always is the most accurate approach. However, expressing nutrients as ratios (concentration within the diet) is usually much more convenient, and is accurate as long as total dry matter intakes are expected and reasonable.

**Additives** – Additives are not essential nutrients, and there are no requirements for them. However, it is convenient to be able to track the concentrations of commonly-used feed additives in dairy diets. Some software programs do this. Additives that may be tracked include niacin, monensin, lasalocid, choline, and biotin. Monensin is the most common and significant of these.

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# Prevention of Nutritional and Metabolic Diseases in Dairy Cattle

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### **Subacute Ruminal Acidosis Prevention**

Ruminal acidosis is the consequence of feeding high grain diets to ruminant animals, which are adapted to digest and metabolize predominantly forage diets. Feeding diets that are progressively higher in grain tends to increase milk production, even in diets containing up to 75% concentrates. However, short-term gains in milk production are often substantially or completely negated by decreased milk fat percentage and long-term compromises in cow health when high grain diets are fed.

Compromises in dairy cow health due to ruminal acidosis are a concern for reasons of good animal welfare as well as for economic reasons. Lameness is probably most important animal welfare issue today in dairy herds, and a good portion of the lameness observed in dairy cows may be attributed to laminitis secondary to high grain feeding (Nordlund et al., 2004). Lameness (along with secondary reproductive failure and low milk production) is commonly the most important cause of premature, involuntary culling and unexplained cow deaths in a dairy herd.

Acute ruminal acidosis (uncompensated decline in ruminal pH, accumulation of ruminal lactate, and obvious clinical signs in affected cows) is uncommon in dairy cattle. Subacute ruminal acidosis (SARA) is more common in dairy herds and is characterized by spontaneous recovery from periods of low ruminal pH, transient or no accumulation of ruminal lactate, and subtle clinical signs during the time of low ruminal pH.

### *Monitoring SARA in Dairy Herds*

A major limitation in our understanding of SARA is the difficulty in monitoring it in dairy herds. There is no single herd-level monitor for SARA; rather, it is evaluated by considering several different factors that are individually limited but can be considered together to monitor SARA.

Subacute ruminal acidosis is defined by some degree of transient depression in ruminal pH is the definition of SARA. However, ruminal pH varies considerably by time after feeding and between individual cows (Krause and Oetzel, 2006). Thus, continuous monitoring of a substantial number of cows is necessary to evaluate ruminal pH within a herd. There no practical means to accomplish this with

current technology. Spot checks of ruminal pH can be done via rumenocentesis; however, this procedure is limited and can only detect herds with very high prevalences of low ruminal pH (Garrett et al., 1999).

Even using continuous monitoring of ruminal pH, the exact ruminal pH cut point that defines SARA has not been determined. Ruminal pH cut points of 5.5, 5.6, and 5.8 have been proposed. Additionally, the degree to which ruminal pH must be below a certain cut point before it is considered SARA also varies. Examples from the literature include ruminal pH below 5.8 for more than about 5 hours per day (Zebeli et al., 2008) or ruminal pH below 5.6 for more than about 3 hours per day (Plaizier et al., 2009). Criteria for defining SARA by ruminal pH must also take into consideration the location of the sample within the rumen and the method by which it was collected.

A high prevalence of lameness in a herd may indicate SARA, especially if claw horn disorders are the main cause of lameness (Nordlund et al., 2004). However, other factors such as exposure to concrete, type of stall surface, type of walking surface, feed bunk space and design, pen layout, overstocking, heat stress, and stall use behavior also contribute to claw horn lesions (Cook et al., 2004).

Herds with a high prevalence of SARA may have low body condition scores despite apparently adequate energy density in the diets (Nordlund et al., 1995). This may be explained by secondary complications of SARA that reduce feed intake (e.g., lameness, hepatic abscesses, or renal abscesses) or by the energetic cost of inflammatory responses to rumenitis and other complications of SARA. However, other nutritional problems and disease processes can also cause low body condition scores despite adequate dietary energy density.

Herds with a high prevalence of SARA typically have high herd turnover rates, with removals scattered across the lactation cycle. Other causes of high herd turnover rates are often biased toward early or late lactation. However, other herd problems (or combinations of problems) can cause herd removal patterns similar to those observed with SARA.

Occasional cases of bilateral epistaxis (nosebleed) and/or hemoptysis (coughing up blood) are sometimes observed in herds with a high prevalence of SARA. These signs are almost always caused by caudal vena cava syndrome, which is the showering of the lungs with septic emboli from liver abscesses caused by SARA. These septic emboli eventually cause pulmonary bleeding. However, many herds with substantial SARA have no history of cows showing epistaxis or hemoptysis.

Fecal consistency is inconsistently affected by SARA. Affected herds may have a high prevalence of cows with loose manure that may be bright, yellowish, foamy, have a sweet-sour smell, or contain undigested feed particles. However, changes in fecal characteristics are not a consistent feature of SARA (Kleen et al., 2009). Factors other than SARA, such as protein feeding and hindgut carbohydrate fermentation, also affect fecal consistency. Infectious diseases such as Johne's disease, salmonellosis, or winter dysentery can also affect fecal consistency.

The pH of manure may have some association with SARA. If collected at the same time as ruminal pH, fecal pH is not associated with ruminal pH (Enemark et al., 2004). Limited research data from a SARA challenge model suggest that fecal pH can be associated with ruminal pH, but lags by 6 to 8 hours (Oetzel, unpublished data). It is not known if this relationship exists in typical feeding situations. If the nadir in ruminal pH is reached about 8 to 14 hours after the first feeding of the day (Krause and Oetzel, 2005), then the fecal pH nadir would be expected to occur about 14 to 22 hours after this feeding (typically the middle of the night). This is a difficult time to gather and analyze samples.

Milk fat percentage is sometimes depressed by SARA. However, this effect is inconsistent (Enemark, 2009) and may be present only if SARA persists more than a few days (Krause and Oetzel, 2005). Milk fat percentage in early lactation cows is particularly unresponsive to SARA (Enemark et al., 2004). Many dietary factors unrelated to SARA also influence milk fat percentage (Bauman and Griinari, 2003).

The challenge to the nutritionist, veterinarian, and dairy producer is to evaluate herd performance in all of these areas and then make a clinical judgment about the presence or absence of SARA based on the combined evidence. No single herd indicator is diagnostic for SARA, but a combination of several factors leading to the same conclusion is sufficient evidence.

#### *Nutritional Causes of SARA: Excessive Intake of Rapidly Fermentable Carbohydrates*

Excessive intake of rapidly fermentable carbohydrates is the most obvious and direct cause of SARA in dairy cattle. Total intake of rapidly fermentable carbohydrates is inversely proportional to the intake of fibrous carbohydrates (defined as carbohydrates that are slowly or not fermented in the rumen). Thus, the ability of diets to cause SARA may be expressed either as a measure of fermentable or of fibrous carbohydrates.

Nutritionists have devised a variety of systems to determine the effect of diet on SARA. These include neutral detergent fiber (NDF), forage NDF, non-fiber carbohydrates, starch, and physically effective NDF (peNDF). The peNDF system was devised to predict the fraction of dietary fiber that stimulates chewing and contributes to the mat layer in the rumen. Physically effective NDF is determined by multiplying the NDF content of a dried feed ingredient (or TMR sample) by the proportion of it that is retained on top of a 1.18 mm screen after vertical shaking (Mertens, 1997). Although not designed to predict ruminal pH, peNDF was the dietary measure that most accurately predicted ruminal pH in a recent meta-analysis of previously published data (Zebeli et al., 2008). This study also reported that a peNDF level of about 30 to 33% was optimal for minimizing the risk of SARA and maximizing milk production efficiency. Dry matter intake was slightly depressed at these high concentrations of peNDF; however, milk production efficiency was maximized. High total dry matter intakes were apparently offset by a higher risk for SARA and reduced percentage of milk components. The optimal amount of peNDF suggested by this study is quite high compared to Mertens' original suggestion of a minimum of 21% peNDF.

Determination of peNDF as described by Mertens is primarily limited to research studies because of the practical difficulties in dry sieving feed ingredient and TMR samples. The manually-operated Penn State

Particle Separator (PSPS) can be used for on-farm determinations of forage particle length without prior drying of the sample (Kononoff et al., 2003). It is important to note that this technique (which uses undried samples and employs horizontal shaking) is not the same as the research technique (dried samples and vertical shaking) for determining the factor used to calculate peNDF. Even though both methods use the same 1.18 mm screen, the results are considerably different (Yang and Beauchemin, 2006). Some nutritionists have used results from the PSPS (either above the 1.18 mm screen or above the 8 mm screen) as alternative factors for calculating peNDF. While such approaches may have merit, they have created considerable confusion regarding the definition and application of peNDF.

The relationship between ruminal pH and diet is very complex and multifaceted. No single measure of fiber adequacy can accurately predict ruminal pH. Although peNDF is the best single measure available, it does not account for rumen fermentability, which has a major effect on ruminal pH (Krause et al., 2002). Unfortunately, there is no laboratory test for rumen fermentability.

The proportion of forage in a diet may be an additional determinant of ruminal pH, independent of its influence on peNDF or other indicators of fiber adequacy. Increasing the proportion of forage in a diet helps prevent SARA via the cumulative effect of increased chewing time, increased meal frequency, and decreased ruminal acid production. Low forage diets are problematic because of their inherently high fermentability. Increasing forage particle length cannot compensate for lack of forage in the diet (Yang and Beauchemin, 2009).

Limited as it may be, evaluating the dietary content nutrients is an important first step in determining the cause of SARA in a dairy herd. This requires a careful evaluation of the diet actually being consumed by the cows. A cursory evaluation of the 'paper' ration formulated by the herd nutritionist is usually of little value. Ascertaining the diet actually consumed by the cows requires a careful investigation of how feed is delivered to the cows, accurate weights of the feed delivered, and updated nutrient analyses of the feeds delivered (particularly the dry matter content of the fermented feed ingredients). Careful bunk sampling and wet chemistry analyses of total mixed rations (TMR) may uncover unknown errors in feed composition or feed delivery (Krause and Oetzel, 2006).

Dairy herds that use component feeding in early lactation often increase grain feeding in early lactation at a more rapid rate than the cow's increase in dry matter intake. This puts cows at great risk for SARA, since they cannot eat enough forage to compensate for the extra grain consumed.

Grains that are finely ground, steam-flaked, extruded, and/or very wet will ferment more rapidly and completely in the rumen than unprocessed or dry grains, even if their chemical composition is identical. Similarly, starch from wheat or barley is more rapidly and completely fermented in the rumen than starch from corn. Corn silage that is very wet, finely chopped, or kernel-processed also poses a greater risk for SARA than drier, coarsely chopped, or unprocessed corn silage.

Particle size analysis of grains is a useful adjunct test when assessing the risk for SARA in a dairy herd. Very finely ground grains, especially if they are moist, will increase their rate of fermentation in the rumen and increase the risk for SARA.

Feeding a large proportion of a lactation diet as corn silage often puts cows at higher risk for SARA compared to diets containing more dry hay or hay crop silages. Corn silages vary considerably in the amount of corn grain that they contain and in the extent of processing of that grain (e.g., kernel processing).

Corn silage is also difficult to feed because it typically does not contribute enough long particles to a TMR. Very long chopping of corn silage is not recommended, because it impairs fermentation and increases the risk for sorting at the feed bunk. It is a common (and necessary) practice to add chopped long-stem dry hay or chopped dry straw to TMR containing a high proportion of the forage as corn silage. However, it can be difficult to process the dry forage so that it distributes evenly throughout the TMR and so that the cows cannot sort it. Vertical mixers or grinding the dry forage before adding it to the mixer is often necessary.

Feed delivery and feed access are often overlooked as risk factors for SARA. Dairy cattle groups are commonly fed for ad libitum intake (typically a 5% daily feed refusal) in order to maximize potential dry matter intake and milk yield. However, slightly limiting intake in dairy cattle at high risk for SARA would in theory reduce their risk of periodic over-consumption and SARA. Feed efficiency would likely be improved. This approach has been successfully used in beef feedlots. However, dairy cow groups are much more dynamic than feedlot groups. This makes it considerably more challenging for dairy cattle feeders to slightly limit intakes without letting the feed bunks be without palatable feed more than about four hours a day. It can be done, but only with adequate bunk space and excellent feed bunk management. Perhaps ad libitum feeding with a 5% daily feed refusal is the best option for most dairy herds. This would especially apply to the pre- and post-fresh cow groups because they have rapid turnover and because individual cows have rapidly changing dry matter intakes during these time periods.

Meal size is likely an important aspect of nutritional management of SARA. Cows are often able to self-regulate their ruminal pH if they have continuous and predictable access to the same TMR every day. However, even modest bouts of feed restriction can cause cows to subsequently consume meals that are too large. Therefore, good feed bunk management practices are critical SARA prevention - even when chemical fiber, particle length, and grain processing are optimal. Higher forage diets have the added benefit of decreasing meal size and increasing meal frequency (Yang and Beauchemin, 2009).

Primiparous cows have lower dry matter intakes than older cows; thus, it seems that they should be a lower risk for SARA. However, results of several investigations indicate that primiparous cows are at higher risk for SARA (Enemark et al., 2004; Krause and Oetzel, 2006). Primiparous cows may need time to learn to regulate their feed intake when introduced to a high-energy diet for the first time after calving. They may also have difficulty gaining access to feed bunks when older cows are present in the same

group. This might lead to larger and less frequent meals, which could increase the risk for SARA. Overstocking of pens alters feeding and social behavior of dairy cattle by decreasing feeding time and increasing standing time, especially for cows ranked lower in the social hierarchy (Huzzey et al., 2006).

Dairy cattle fed in pasture-based systems are also at risk for SARA (Bramley et al., 2008; O'Grady et al., 2008). Grass pastures may contain high concentrations of rapidly fermentable carbohydrate and may also be low in physically effective fiber. Excessive grain supplementation should be avoided when pasture is the main source of forage. It is likely that dairy cattle with SARA in pasture systems do not develop lameness as readily as cattle in conventional housing because cows on pasture have little or no exposure to concrete. However, other adverse effects of SARA (rumenitis, hepatic abscesses, etc.) may similarly affect pastured cattle.

An important goal of effective dairy cow nutrition is to feed as much concentrate as possible, in order to maximize production, without causing ruminal acidosis. This is a difficult and challenging task in the field because the indications of feeding excessive amounts of fermentable carbohydrates (decreased dry matter intake and milk production) are very similar to the results from feeding excessive fiber (again, decreased dry matter intake and milk production). An important distinction is that even slightly over-feeding fermentable carbohydrates causes chronic health problems due to SARA, while slightly under-feeding fermentable carbohydrates does not compromise cow health.

#### *Nutritional Causes of SARA - Inadequate Ruminal Buffering*

Ruminant animals have a highly developed system for buffering the organic acids produced by ruminal fermentation of carbohydrates. While the total effect of buffering on ruminal pH is relatively small, it can still account for the margin between health and disease in dairy cows fed large amounts of fermentable carbohydrates. Ruminal buffering has two aspects – dietary and endogenous buffering.

Dietary buffering is the inherent buffering capacity of the diet and is largely explained by dietary cation-anion difference (DCAD). Diets high in Na and K relative to Cl and S have higher DCAD concentrations, tend to support higher ruminal pH, and increase dry matter intake and milk yield. Lactating diets should contain between about +230 to +330 mEq/kg DCAD (Chan et al., 2005). Formulating diets with a high DCAD typically requires the addition of buffers such as sodium bicarbonate or potassium carbonate. Alfalfa forages tend to have a higher DCAD than corn silage, although this depends considerably on the mineral composition of the soil on which they were grown. Concentrate feeds typically have low or negative DCAD, which adds to their already high potential to cause ruminal acidosis because of their high fermentable carbohydrate content.

Endogenous buffers are produced by the cow and secreted into the rumen via the saliva. The amount of physical fiber in the diet determines the extent of buffer production by the salivary glands. Coarse, fibrous feeds contain more effective fiber and stimulate more saliva production during eating than do finely ground feeds or fresh pasture. Coarse, fibrous feeds also make up the mat layer of the rumen, which is the stimulus for rumination.

The ability of a diet and feeding system to promote maximal amounts of ruminal buffering should be evaluated as part of the work-up of a herd diagnosed with SARA. Wet chemistry analysis of a carefully collected TMR bunk sample can be particularly effective in determining the actual DCAD of the diet delivered to the lactation cows. Diets with measured DCAD values below about +230 mEq/kg of  $(\text{Na} + \text{K}) - (\text{Cl} + \text{S})$  should be supplemented with additional buffers to provide more Na or K relative to Cl and S.

Endogenous buffering can be estimated by observing the number of cows ruminating (a goal is at least 40% of cows ruminating at any given time) and by measuring the particle length of the TMR actually consumed by the cows using the PSPS. Diets with less than 7% long particles put cows at increased risk for SARA, particularly if these diets are also borderline or low in chemical fiber content (Grant et al., 1990). Increasing chemical fiber content of the diet may compensate for short particle length (Beauchemin et al., 1994).

Diets with excessive (over about 15%) long forage particles can paradoxically increase the risk for SARA. This happens when the long particles are unpalatable and sortable. Sorting of the long particles occurs soon after feed delivery, causing the cows to consume a diet that is low in physically effective fiber after feeding. The diet consumed later in the feeding period is then excessively high in physically effective fiber and low in energy. Socially dominant cows are particularly susceptible to SARA in this scenario, since they are likely to consume more of the fine TMR particles soon after feed delivery. Cows lower on the peck order then consume a very low energy diet. Thus, cows on both ends of the social spectrum become thin and produce poorly. Overstocking cows appears to increase the risk for increased TMR sorting (Hosseinkhani et al., 2008).

It is very difficult to quantitatively evaluate the extent that a TMR is sorted. The most rigorous approach is to gather representative samples of the TMR at approximately 2 hours after feeding and then do particle length analysis at each time point. Gathering representative TMR bunk samples is tedious (gather 12 or more representative along the length of the bunk, mix, and, and then shake down two six-cup subsamples), and repeating this procedure six to ten times over the course of a day is not very practical. A more reasonable approach is to first evaluate the particle length, coarseness of the long forage particles, and dry matter of the TMR. If the proportion of long particles is <15%, if the long particles are not coarse stemmy hay, and the TMR dry matter is below 50%, then it is probably unnecessary to do any further evaluation of TMR sorting. If there are problems in one or more of these areas, then it is practical to start by comparing particle lengths of TMR refusals to the particle lengths of the TMR offered. If the refusals contain no more than about 5 to 10% more total long particles than the TMR offered, then sorting is unlikely to be a major issue. For example, if the TMR offered contains 18% long particles and the TMR refusal is 24% long particles, then sorting is probably not a major issue. But if the TMR refusal contains >28% long particles, then this is cause for concern.

The most common cause of excessive TMR sorting is the inclusion of unprocessed, coarse, dry baled hay in a TMR. Despite the claims of manufacturers, most TMR mixers (except for some vertical mixers) are

unable to adequately reduce the particle size of coarse dry hay. Processing this hay before adding it to the mixer is often necessary. In many cases, the dry hay can be eliminated from the TMR, provided there are adequate long particles from haylage and corn silage. The risk for SARA in a herd can sometimes be lowered by removing the baled hay from the TMR.

Provision of free-choice low-moisture molasses blocks containing buffer helped decrease the severity and duration of episodes of low ruminal pH following a SARA challenge (Krause et al., 2009). Free choice buffer intake did not increase during periods of low ruminal pH, suggesting that cows do not have the nutritional wisdom to consume their own buffers as needed. Rather, the benefits of the buffer blocks in this study were apparently due to consistent daily intake.

#### *Nutritional Causes of SARA - Inadequate Adaptation to High Carbohydrate Diets*

Cows in early lactation should in theory be particularly susceptible to SARA if they are poorly prepared for the lactation diet they will receive. Ruminal adaptation to diets high in fermentable carbohydrates apparently has two key aspects – microbial adaptation (particularly the lactate-utilizing bacteria, which grow more slowly than the lactate-producing bacteria) and ruminal papillae length (longer papillae promote greater VFA absorption and thus lower ruminal pH) (Dirksen et al., 1985).

The known principles of ruminal adaptation suggest that increasing grain feeding toward the end of the dry period should decrease the risk for SARA in early lactation cows. However, increased grain feeding the dry period had no beneficial effect on early lactation ruminal pH or dry matter intake (Andersen et al., 1999). The practical impacts of ruminal adaptation may be small or even inconsequential in dairy herds - particularly when cows are fed a TMR after calving.

#### *Specifics for Prevention of Subacute Ruminal Acidosis in Dairy Herds*

The basic principles of preventing SARA in dairy herds have been discussed above and include limiting the intake of rapidly fermentable carbohydrates, providing adequate ruminal buffering, and allowing for ruminal adaptation to high grain diets. However, SARA will likely remain an important dairy cow problem even when these principles are understood and applied, because the line between optimal milk production and over-feeding grain is exceedingly fine. In many dairy herd situations, overfeeding grain will transiently increase milk production and see beneficial. However, the long-term health and economic consequences caused by SARA can be devastating. Furthermore, once a cow experiences an episode of SARA, she becomes more prone to further bouts of increasingly severe acidosis (Dohme et al., 2008). Any additional nutritional interventions that might prevent SARA without unduly limiting grain feeding are highly desirable.

#### *SARA Prevention - Direct-Fed Microbials*

Live yeast (*Saccharomyces cerevisiae*) have been shown to strengthen reducing conditions in the ruminal environment, prevent the accumulation of lactate, and stabilize ruminal pH (Marden et al., 2008).

*Aspergillus oryzae* had a modest effect in stabilizing ruminal pH, although interestingly it was beneficial only at the lower dose evaluated (Chiquette, 2009).

A novel application of direct-fed microbials for SARA prevention is to provide lactate producers that provide a steady but small source of lactate in the rumen. In theory this enhances the ruminal lactate-utilizing bacteria and improves ruminal responsiveness to SARA. A mixture of *Enterococcus faecium* (a lactate producer) and *Saccharomyces cerevisiae* provided the best stabilization of ruminal pH in a SARA challenge study (Chiquette, 2009).

#### *SARA Prevention - Malate Supplementation*

*Selenomonas ruminantium* is one of the bacteria that convert ruminal lactate to VFA. *S. ruminantium* is apparently stimulated to utilize lactate by malate (Martin and Streeter, 1995). Supplementing diets with malate as a feed additive may be cost-prohibitive; however, incorporation of forage varieties high in malate may allow for economical inclusion of malate in dairy diets (Callaway et al., 2000).

#### *SARA Prevention - Supplementation with Ionophores*

Feeding ionophores reduces ruminal lactate production; this effect appears to be caused by inhibition of lactate-producing bacteria, competitive enhancement of lactate utilizers, and possibly by reducing meal size (Owens et al., 1998). Monensin is approved for use in lactating dairy cattle in the US to improve feed efficiency. However, it does not appear to stabilize ruminal pH in lactating dairy cows, at least during early lactation (Fairfield et al., 2007). Monensin is probably more effective in preventing acute ruminal acidosis, which is characterized by very high ruminal lactate concentrations.

### **Milk Fever Prevention**

Prevention, rather than treatment, of milk fever is imperative in dairy herds. Cow affected with clinical milk fever that respond well to treatment still produce about 14% less milk in the subsequent lactation (Block, 1984). Most cows with clinical milk fever respond well to a single treatment with an intravenous solution containing a calcium salt; however, about 25% of cases will relapse and require additional treatment (Mullen, 1975). More alarmingly, 15% of all cows affected with clinical milk fever and presented in sternal recumbency will either die or require disposal (Fenwick, 1969).

Cows that survive clinical milk fever have impaired reproductive performance in the subsequent lactation. The first evidence for a role of milk fever in determining reproductive performance comes from epidemiological evidence which shows increased risk of other periparturient disorders in cows with clinical milk fever. A large study of 7761 lactation records from 34 commercial dairy herds (Correa et al., 1993) showed that cows with clinical milk fever had 2.6 times greater risk of dystocia, 2.4 times greater risk of ketosis, and 2.3 times greater risk of left-displaced abomasum. Dystocia was then linked to 2.2 times greater risk of retained placenta and 2.1 times greater risk of metritis. If retained placenta was present, then the risk of metritis increased 6.0 times. An earlier analysis of a subset of this data (Curtis et

al., 1983) showed that clinical milk fever directly increased the risk of retained fetal membranes 3.2 times and the risk of metritis 1.7 times.

Milk fever has also been associated with uterine prolapse; 53 cows with uterine prolapse had significantly lower serum calcium concentrations than 53 matched cows (Risco et al., 1984). Multiparous cows with uterine prolapse were more likely to be hypocalcemic than primiparous cows with uterine prolapse. Delayed cervical and uterine involution during hypocalcemia may explain why hypocalcemia is associated with uterine prolapse (Odegaard, 1977; Risco et al., 1984).

Milk fever has also been qualitatively linked with increased incidence of cystic ovarian disease (Archbald et al., 1992). No direct mechanism for this link has been established. Cystic ovarian disease may be associated with any episode of periparturient disease.

The theoretical link between milk fever and decreased reproductive performance, which is based on data from retrospective studies, has been substantiated in a large, prospective field study (Beede et al., 1992). Cows fed anionic salts in this study had less clinical milk fever and subclinical hypocalcemia than cows not fed anionic salts. Cows fed the anionic salts also had higher pregnancy rates, lower services per pregnancy, reduced days to first heat, and reduced days open for pregnant cows. The positive results seen in this study are likely the net effect of the prevention of periparturient diseases that are associated with both clinical milk fever and reduced reproductive performance. An additional mechanism for explaining this effect could be increased dry matter intake in early lactation in the cows that did not get either clinical or subclinical milk fever. This mechanism has not been evaluated in a research study, but there is indirect evidence to support it. Subclinical hypocalcemia was present in 50% of the control cows in this study, but only 19% of the cows receiving the anionic salts were classified as having subclinical hypocalcemia. Calcium is necessary for smooth muscle contractions in the body, including the gastro-intestinal tract (Huber et al., 1981). Impaired motility of the gastro-intestinal tract in early lactation may impair dry matter intake during this critical period. One indication that postpartum dry matter intake depression may occur with hypocalcemia is the observed overall higher milk production in cows that receive anionic salts prior to calving (Beede et al., 1992; Block, 1984). If hypocalcemia does impair dry matter intake in early lactation, then negative energy balance will be exacerbated and reproductive performance will be correspondingly impaired.

#### *Milk Fever Prevention by Dietary Calcium Restriction*

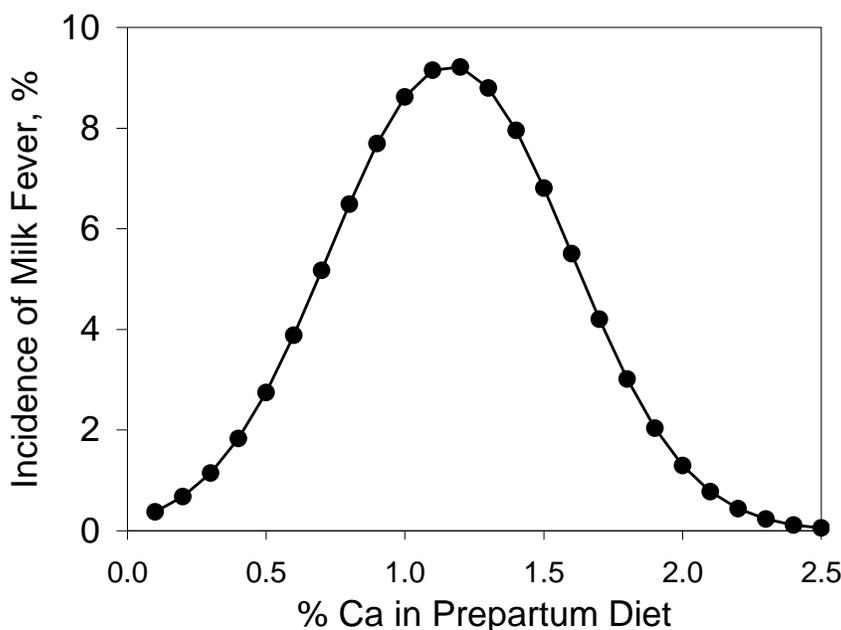
The traditional method of preventing milk fever has been to restrict calcium intake during the dry period. If extremely low calcium diets (< 20 grams of daily calcium) are fed before parturition and high-calcium diets are fed after parturition, the incidence of milk fever can be drastically reduced (Green et al., 1981). Low calcium diets prior to calving apparently prevent the cow's active intestinal calcium absorption and bone calcium resorption mechanisms from becoming quiescent and unable to respond to the sudden calcium outflow that occurs at parturition. Calcium intake during the dry period is usually restricted by replacing some or all of the alfalfa in a dry cow diet with a grass hay and using additional corn silage and

concentrates. This approach can work in some dairy herds. If milk fever (clinical and subclinical) is not a problem in a herd and this feeding program is being used, then it probably should not be changed.

Switching feed ingredients in the dry period diet with the exclusive goal of lowering calcium intake does not work well in some dairy herds and can have several drawbacks. Feeding larger amounts of corn silage and/or concentrates to dry cows may be expensive and may predispose cows to abomasal displacements if fed in excess (Coppock, 1974). Eliminating alfalfa from the dry period diet simply because of its high calcium content can be an expensive decision. On many dairies, alfalfa is the most readily available forage and is also an inexpensive source of dietary protein. In these herds, alfalfa is likely to be the primary forage in the lactating cow diets, and there are advantages to maintaining similar forage type before and after calving.

#### *Milk Fever Prevention - Dietary Acidification.*

Dietary acidity or alkalinity is more important in controlling milk fever than calcium intake (Oetzel et al., 1988; Oetzel, 1991; Oetzel, 1993). Alkalogenic diets fed prior to calving tend to cause milk fever, while acidogenic diets tend to prevent it. A large meta-analysis of previously published milk fever studies showed that dietary calcium influences the incidence of milk fever; however, it does so in a limited and non-linear fashion (see Figure 1). Both high and low dietary calcium were associated with slightly lower incidence rates of milk fever in this analysis (Oetzel, 1991). High concentrations of dietary potassium (a strong cation and dietary alkalinizer) caused milk fever (Goff and Horst, 1995), but differing levels of dietary calcium had no effect on milk fever incidence.



**Figure 1.** Sample relationship of dietary Ca to the incidence rate of milk fever using a logistic regression model. Points plotted were calculated for mixed breed cows, lactation number = 5, Na = .20%, and S = .35%. Adapted from (Oetzel, 1991).

Two mechanisms have been proposed to explain why acidogenic diets help prevent milk fever. Both mechanisms involve increased resorption of calcium from bone, which is then used to support blood calcium concentrations. Acidogenic diets first promote bone mobilization by stimulating osteocytic bone resorption. This occurs because bone acts as a buffer against excessive systemic acidity by exchanging calcium ions for hydrogen ions from the bloodstream. Acidogenic diets have also been shown (Goff et al., 1991) to increase the amount of 1,25 dihydroxyvitamin D produced per unit increase in parathyroid hormone. This increases osteoclastic resorption of calcium from bone. When bone is already being mobilized via these two mechanisms, cows are better able to respond to the sudden calcium demand of early lactation.

The potential of a diet to be either acidogenic or alkalogenic can be estimated by calculating its DCAD (Dietary Cation-Anion Difference). Understanding how DCAD affects systemic acid-base balance first requires a short review of chemistry. Dietary electrolytes can be classified as either anions or cations. Anions have a negative charge; cations have a positive charge. The charge carried by these electrolytes affects acid-base balance and ultimately calcium metabolism. Important dietary cations are sodium, potassium, calcium, and magnesium; important dietary anions are chloride, sulfur, and phosphorus. Sodium, potassium, sulfur, and chloride are thought to exert the strongest ionic effects on acid-base balance and are referred to as the "strong ions" (Stewart, 1983). Strong (or "fixed") ions are defined as ions that are highly bioavailable and not metabolized within the body (Block, 1994).

Dietary cation-anion difference can be used to quantify the relationship between strong cations and anions and thus predict whether a diet will evoke an acidic or alkaline response when fed to a dairy cow. Several methods of calculating DCAD of a diet have been utilized, including the following equations:

$$\text{DCAD (meq)} = (\text{Na} + \text{K}) - (\text{Cl})$$

$$\text{DCAD (meq)} = (\text{Na} + \text{K}) - (\text{Cl} + \text{S})$$

$$\text{DCAD (meq)} = (\text{Na} + \text{K}) - (\text{Cl} + 0.60 \text{ S})$$

$$\text{DCAD (meq)} = (\text{Na} + \text{K} + \text{Ca} + \text{Mg}) - (\text{Cl} + \text{S} + \text{P})$$

$$\text{DCAD (meq)} = (\text{Na} + \text{K} + 0.15 \text{ Ca} + 0.15 \text{ Mg}) - (\text{Cl} + 0.20 \text{ S} + 0.30 \text{ P})$$

$$\text{DCAD (meq)} = (\text{Na} + \text{K} + 0.15 \text{ Ca} + 0.15 \text{ Mg}) - (\text{Cl} + 0.60 \text{ S} + 0.50 \text{ P})$$

$$\text{DCAD (meq)} = (\text{Na} + \text{K} + 0.38 \text{ Ca} + 0.30 \text{ Mg}) - (\text{Cl} + 0.60 \text{ S} + 0.50 \text{ P})$$

The second equation  $[(\text{Na}+\text{K}) - (\text{Cl}+\text{S})]$  has become the *de facto* standard for calculating DCAD among dairy nutritionists. It is useful as long as excessive Ca, Mg, and S are not added to the diet. The third equation is apparently the most accurate (Charbonneau et al., 2009) but is not commonly used. Adding contributions of Ca, Mg, and P to the DCAD calculation does not improve their ability to predict urinary pH or risk for hypocalcemia (Charbonneau et al., 2009).

The equations used to calculate DCAD and the units used to express it vary among ration evaluation software programs and among feed laboratories that report DCAD calculations. For example, one program only counts the contribution of sulfur to DCAD if it comes from a mineral source.

Calculation of the DCAD of a diet, regardless of the equation employed, requires using the equivalent weights of the electrolytes. This is necessary because acid-base balance is affected by electrical charge rather than mass. The equivalent weight is equal to the molecular weight divided by the valence (electrical charge strength). The term milliequivalent (meq) is used to express equivalent weights; one milliequivalent equals 1/1000th of an equivalent. Table 2 provides reference values for calculating equivalent weights of important electrolytes and converting from percent of diet dry matter (DM) to milliequivalents per kilogram. Once milliequivalents are calculated, DCAD can then be computed by subtracting the anions from the cations.

**Table 2.** Molecular weights, equivalent weights, and conversions from percent to milliequivalents of anions and cations used in calculating DCAD. Adapted from (Oetzel, 1993).

Element	Molecular Weight	Valence	Equivalent Weight	To convert from % diet DM to meq, multiply by:	
	(g)			(g)	(meq/kg)
Sodium (Na)	23.0	1	23.0	434.98	197.72
Potassium (K)	39.1	1	39.1	255.74	116.25
Chloride (Cl)	35.5	1	35.5	282.06	128.21
Sulfur (S)	32.1	2	16.0	623.75	283.52
Calcium (Ca)	40.1	2	20.0	499.00	226.82
Magnesium (Mg)	24.3	2	12.2	822.64	373.93
Phosphorus (P)	31.0	1.8 <sup>a</sup>	17.2	581.14	264.15

<sup>a</sup> The valence of P is 1.8 based on the normal distribution of mono-hydrogen and di-hydrogen forms of phosphorus in the body.

Manipulation of DCAD does not usually result in clinically significant changes in blood pH, because both kidney and bone compensate to maintain normal blood pH. For example, strongly anionic diets (low DCAD) are acidogenic, but blood pH remains nearly constant because urinary pH is reduced from about 8.0 to about 7.0. Similarly, cationic diets (high DCAD) are alkalogenic but have little effect on blood pH because the urine becomes more alkaline.

Most typical diets fed to dry cows will have a DCAD [using the formula (Na + K) - (Cl + S)] of about +100 to +250 meq/kg DM. Addition of a cationic salt (such as sodium bicarbonate) to the dry cow diet increases DCAD and would increase the incidence rate of milk fever. Adding an anionic salt or a mixture of anionic salts (minerals high in Cl and S relative to Na and K) to the diet lowers the DCAD and reduces the incidence of milk fever. Examples of different anionic salts, their equivalent weights, and costs are given in Table 3.

### *Milk Fever Prevention by Feeding Anionic Salts*

*Are the anionic salts safe?* It is known that force-feeding large amounts of these salts can be detrimental. However, lack of palatability limits the likelihood of toxicity if the salts are overdosed. A combination of salts is probably best, because it decreases the potential of toxicity from the cation (Mg, NH<sub>4</sub>, Al, etc.)

that must necessarily accompany each salt. It is possible to exceed NRC maximum tolerable amounts of sulfur (.40%), magnesium (.50%) and NPN (.50%) by feeding large amounts of any single anionic salt.

**Table 3.** Approximate retail costs and properties of anionic salts used in prevention of milk fever. Adapted from (Oetzel, 1993).

Anionic salt	Molecular Weight (g)	Equivalent Weight (g)	Mg (%)	Ca (%)	NPN <sup>a</sup> (%)	CP <sup>b</sup> (%)	Cl (%)	S (%)	Cost: <sup>c</sup> (\$/cwt)	(¢/eq)
MgCl <sub>2</sub> ·6H <sub>2</sub> O	203.3	101.7	11.96	—	—	—	34.87	—	92.50	20.7
MgSO <sub>4</sub> ·7H <sub>2</sub> O	246.5	123.3	9.86	—	—	—	—	13.01	30.00	8.1
CaCl <sub>2</sub> ·2H <sub>2</sub> O	147.0	73.5	—	27.26	—	—	48.22	—	21.00	3.4
CaSO <sub>4</sub> ·2H <sub>2</sub> O	172.2	86.1	—	23.28	—	—	—	18.62	19.00	3.6
NH <sub>4</sub> Cl	53.5	53.5	—	—	26.2	163	66.26	—	40.00	4.7
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	132.1	66.1	—	—	21.2	133	—	24.26	21.50	3.1

<sup>a</sup> NPN = Nonprotein nitrogen.

<sup>b</sup> CP = Crude protein.

<sup>c</sup> Approximate wholesale prices of anionic salts; gathered from numerous feed sources.

*Are the anionic salts palatable?* It appears that the salts are not very palatable and that they are best fed in a total mixed ration (TMR) rather than in a grain or mineral mix alone. Palatability problems are minimal (not statistically significant) when the salts are added to a TMR (Block, 1984; Oetzel et al., 1988; Oetzel et al., 1991).

Palatability of the salts in component-fed diets is not good. It is best if the salts can be hand-mixed with a wet forage (corn silage or alfalfa haylage). If only dry forages or pasture are used, then the salts can be added to a grain mix, but with some difficulty. It appears that the salts must be mixed with more than at least 5 lbs. of a grain mix, and even then palatability may still be impaired (Oetzel and Barmore, 1993). Pelletting a mixture of anionic salts does not appear to increase their palatability, but it does provide advantages in product formulation and helps prevent separation of the anionic salts in a concentrate mixture. Pre-mixing loose salts with a carrier that has a strong flavor of its own (dried distillers grains or molasses) may be helpful and is commonly practiced. If ammonium salts are pre-mixed into a concentrate mixture during warm weather ammonia gas release and feed refusal may result. The hygroscopic nature of most anionic salts may cause caking. MgSO<sub>4</sub> is apparently the most palatable of the commonly used salts, and CaCl<sub>2</sub> is apparently the least palatable (Oetzel and Barmore, 1993). Sulfates are poor urinary acidifiers and their use should be limited.

*What combination of anionic salts is most effective?* Direct comparisons of the abilities of the individual anionic salts to prevent milk fever have not been done (such trials would require extremely large sample sizes). Estimates of each salt's potential to prevent milk fever (measured as acid-base balance and calcium metabolism) have been made (Oetzel et al., 1991). All of the salts tested in one study had significant effects on calcium metabolism and acid-base balance (see Table 4); ammonium chloride had a slight advantage over the other salts in its acidifying ability. Interactions among anionic salt combinations have not been evaluated; however, there is no theoretical basis to suspect significant

interactions. Selection of a mixture of anionic salts is generally made on the basis of price, availability, palatability, and avoidance of potential toxicity.

**Table 4.** Effect of anionic salt treatments on diet, acid-base balance, and calcium metabolism. Adapted from (Oetzel et al., 1991).

Item	Diet (control or with added anionic salts)						
	Control	MgCl <sub>2</sub> ·6H <sub>2</sub> O	MgSO <sub>4</sub> ·7H <sub>2</sub> O	CaCl <sub>2</sub> ·2H <sub>2</sub> O	CaSO <sub>4</sub> ·2H <sub>2</sub> O	NH <sub>4</sub> Cl	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>
Salt added, g/d	0	204	246	147	172	107	132
Salt added, eq/d	0	2.0	2.0	2.0	2.0	2.0	2.0
Added NPN, %	0	0	0	0	0	.24	.24
DCAD, <sup>a</sup> meq/kg	-4	-172	-171	-170	-171	-172	-175
DM intake, % BW	1.70	1.70	1.65	1.63	1.68	1.68	1.67
Blood pH	7.38	7.38	7.38	7.38	7.38	7.37	7.38
Urinary pH	8.10	7.66	7.96	7.65	7.51	7.39	7.76
FECa, <sup>b</sup> %	.79	2.17	1.32	1.49	2.71	1.71	1.29

<sup>a</sup> DCAD = dietary cation-anion difference, calculated as [(Na+K) - (Cl+S)].

<sup>b</sup> FECa = fractional excretion of ionized calcium.

*How long must the salts be fed before parturition?* The time period of feeding the salts in previous trials has ranged from 21 to 45 days before expected parturition. It may be possible to feed the salts for a shorter time period; however, this theory has not been tested. The author's experience suggests that cows must consume the salts for at least 10 days in order to receive maximal benefit. There have been no reports of detrimental effects of feeding anionic salts for the entire dry period.

*Will use of the anionic salts cause udder edema?* A large field trial (Wang et al., 1991) found no differences in umbilical-udder edema scores taken 1 to 2 weeks postpartum between cows receiving an anionic salts mixture and cows who did not. Another trial showed slightly reduced udder edema scores in first lactation heifers fed calcium chloride (Lema et al., 1992). Because udder edema is a sporadic disease of poorly understood etiology, there is a tendency to blame the anionic salts for any case of udder edema that occurs after the onset of their use.

*Are the anionic salts cost-effective?* Current costs of 2 to 3 equivalents of the salts are about 20 to 35 cents per cow per day. Costs of milk fever (both clinical and subclinical) are substantially greater than this. If gains of milk production of 3 to 7% can be expected, then the economic return from feeding the salts is about 10 to 1 for increased milk production alone (Beede et al., 1992).

No studies have been conducted to titrate the exact dose required to satisfactorily decrease the incidence rate of milk fever. Most of the studies to date have used doses of about 2 to 3 eq/d of anionic salts. It may be useful to adjust the dose of salts to a desired final DCAD (typically about 0 to -150 meq/kg DM). However, the optimal final DCAD is not known, and a wide range of DCAD's have shown apparent effectiveness in milk fever prevention. Difficulties in laboratory

Anionic salts have been added to prepartum diets either by using standard doses or by systematic calculation of mineral content and DCAD. An example of a standard daily dose is 4 ounces  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  plus 4 ounces  $\text{NH}_4\text{Cl}$  (3.0 eq of anions). While standard doses of anionic salts may perform satisfactorily in many herds, this dosing strategy does not properly adjust for the existing mineral content of the prepartum diet. A more systematic approach to adding anions to a prepartum diet is outlined in Figure 2. Intake depression may occur when  $>300$  meq of anions/kg of diet DM (about 3.5 eq/d at 26 lbs of DM intake) are added (Horst et al., 1994).

analysis for chlorine and sulfur (or use of reference values for these electrolytes) may limit the accuracy of calculated DCAD values. It has been suggested that monitoring urinary pH after feeding anionic salts may be the most direct and useful approach to establishing the optimal dose of anionic salts within a herd (Jardon, 1995). Mean urinary pH values in a group of close-up dry cows should be between about 7.0 if anionic salts are fed and the diet is properly formulated and delivered. Variations in urinary pH after feeding are minimal as long as cows have constant access to feed. If feed access is limited, then urinary pH measurements should be taken a few hours after feeding.

There is some uncertainty regarding the optimal concentration of dietary calcium should be used when anionic salts are fed. Research has not definitively answered this question. There is evidence that the salts work best when dietary calcium is high (Beede et al., 1992; Oetzel et al., 1988). Clinical experience suggests that the anionic salts should not be used when dietary calcium is very low (less than about 60 g per day). Total calcium concentrations of 1.1 to 1.5% of ration DM appear to be reasonable for pre-fresh cows.

There is also uncertainty regarding the optimal concentration of dietary phosphorus. Dry cow diets high in phosphorus ( $>80$  g of  $\text{PO}_4$  per day) will increase the risk of milk fever due to inhibitory effects on vitamin D metabolism (Horst et al., 1994). Most nutritionists provide about 40 g of daily phosphorus in dry cow diets containing anionic salts.

If dry cows are fed individually rather than as a group, it would be advantageous to feed the salts only to those cows at highest risk for milk fever, such as older cows and cows with previous episodes of milk fever. If only a few cows are fed the salts, then the extra labor of hand-preparing a TMR could be justified. If the anionic salts mixture must be part of a grain mix, then measures should be taken to improve the palatability of the mixture of salts (premixing, etc.). Dry cows should be brought up gradually, over a three day period, to the full feeding rate of the anionic salts mixture. If DM intake drops when the cow receives the full dose of the salts, then decrease the dose to the point that DM intake is acceptable. Excessive loss of DM intake just prior to calving is very undesirable and may lead to ketosis and/or fatty infiltration of the liver.

**Figure 2. Systematic approach to milk fever prevention.**

1. Analyze available forages and concentrates fed to the pre-fresh cows for Ca, P, Mg, Na, K, Cl, and S content by wet chemistry procedures.
2. Select feed ingredients with low Dietary-Cation Anion Difference (DCAD). It is particularly important to use forages low in K.
3. Calculate the DCAD of the diet without any anion sources. If  $>250$  meq/kg of  $(\text{Na}+\text{K})-(\text{Cl}+\text{S})$ , then replace some of the highest K forage with either lower K forages or with high-fiber, low-DCAD concentrate feed ingredients such as brewer's grains, beet pulp, or malt sprouts.
4. Balance dietary Mg at .40%, dry matter basis, by adding additional magnesium chloride ( $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ ) or magnesium sulfate ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ). Magnesium chloride is preferred (where available) because it is the better urinary acidifier. Magnesium oxide ( $\text{MgO}$ ) is the least desirable magnesium source for pre-fresh cows because it is slightly alkalogenic.
5. Evaluate feeding management of the pre-fresh cows. Areas to evaluate include bunk space, preservation quality of forages, intensity of monitoring forage dry matter content, knowledge of dry matter intake of the pre-fresh cows, and current level of dry matter intake of the pre-fresh cows. If bunk space is  $>30$  inches per cow, forages are well-preserved and highly palatable, if forage dry matter content is measured at least twice weekly, and if the current dry matter intake of the pre-fresh group is  $>25$  lbs/cow/day (for mixed parity groups), then additional sources of anions (see point #6 below) can be added to the pre-fresh diet. If the above criteria are not met, then do not add additional anions to the diet. Either correct the deficiencies before attempting to add additional anions to the diet, or simply feed a diet based on points 1 through 4 above.
6. Add additional chloride to the diet to lower DCAD to about 0 to -100 meq/kg, dry matter basis. If dry matter intake in the pre-fresh cows is marginal or if palatability of the chloride source is a general concern, then consider using a pre-blended product treated with hydrochloric acid (HCl) such as Bio-Chlor, Anion Booster, or Soy-Chlor. On-farm use of HCl is strongly discouraged because it is difficult to handle safely. If there are not concerns about palatability and intake in the pre-fresh cows, then chloride may be less expensively added as either calcium chloride ( $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ ) or ammonium chloride ( $\text{NH}_4\text{Cl}$ ). Do not add more than a total of about 3.0 equivalents per day of total anion sources; otherwise, dry matter intake of the pre-fresh group may be compromised.
7. Check dietary non-protein nitrogen (NPN) and degradable intake protein (DIP) content of the pre-fresh diet. If NPN is  $>.50\%$  of the diet dry matter or if DIP is  $>70\%$  of CP, then reduce the amount of ammonium salts or other NPN / DIP sources in the diet.
8. Add dietary Ca to a daily intake of about 150 grams per day (1.3% Ca at 25 lbs of dry matter intake). Sources of supplemental calcium for this purpose include limestone, dicalcium phosphate, and/or monocalcium phosphate. Balance for .30 to .40% phosphorus in the final diet. If anions are not being supplemented, then no Ca should be supplemented and dietary Ca should be limited.
9. Monitor dry matter intake of the pre-fresh cows. Consider more palatable anion sources or a reduced dose of anion sources if dry matter intake is depressed.
10. Monitor urinary pH of the pre-fresh cows. Collect urine from at least 8 cows at one time, or over a period of time. Adjust dose of supplemental anions to achieve an average urinary pH of about 7.0.

## Ketosis and Fatty Liver

Proper energy nutrition before and after calving is the key factor in preventing ketosis and fatty liver. Adequate energy in the time period just prior to calving, when dry matter intake is depressed, is especially important (Bertics et al., 1992). Body condition loss just prior to calving strongly predisposes cows to fatty liver and ketosis. Pen moves and over-stocking just prior to or after calving are important causes of negative energy balance and ultimately ketosis. The most important time to avoid pen moves is between three and nine days before actual calving.

Excessive body condition score entering the dry period and/or excessive body condition score gain during the dry period (greater than about 1/4 unit of body condition score) are predisposing factors to ketosis and fatty liver. Fat cows are at greater risk for ketosis and fatty liver because of decreased dry matter intake in early lactation (Treacher et al., 1986).

Recent trends in replacement heifer rearing (higher plane of nutrition, custom heifer rearing, etc.) have unfortunately resulted in increasing body condition scores in heifers just prior to their first calving. These animals are particularly susceptible to the ill-effects of obesity, because it so greatly increases their risk of dystocia. My experience with “feedlot-fat” dairy heifers has been uniformly bad. These heifers experience very high rates of dystocia, C-sections, retained placenta, severe metritis, ketosis, and displaced abomasum. Fatty liver with subsequent immune suppression is probably underlying their poor health situation as well. Mortality rates may exceed 25% within the first few weeks of calving, depending on the degree of obesity. Heifers above a body condition score of 3.50 (as I do the scoring) are at definite risk for post-calving disasters. Heifers over a body condition score of about 3.75 should be sold for beef before they calve and die. Careful monitoring of replacement heifer body condition scores is recommended.

Care must be taken to assure that early lactation cows receive enough dietary energy to prevent problems with primary (underfeeding) ketosis. While most component-fed herds tend to overfeed concentrates in early lactation and cause rumen acidosis, a few do restrict concentrate feeding so severely as to cause primary ketosis. Limited access to forages and/or poor quality forages in early lactation can also contribute to primary ketosis. Useful rules are to keep early lactation cows slightly hungry for concentrates but never without access to the highest-quality forages available on the farm.

TMR-fed herds with post-fresh groups sometimes dramatically increase dietary protein (>19%) and simultaneously decrease energy (<.76 Mcal/lb NEL) in an effort to prevent ruminal acidosis and yet still support good milk production. This combination may increase the risk of ketosis in the herd.

Some herds have persistent ketosis problems that are related to feeding ketogenic silages (Tveit et al., 1992). Hay silages that are chopped too wet (insufficient wilting or direct-cut silages) tend to favor growth of *Clostridium sp.* bacteria, which ferment some carbohydrates to butyric acid instead of the desirable lactic acid. These silages are easy to recognize because of the distinctive odor of butyric acid and protein degradation products of clostridial fermentation. A silage fermentation analysis can confirm

the presence of and the amount of butyric acid present in the silage. Silages containing butyric acid should not be fed to pre- or post-fresh cows if at all possible. In any case, the rate of butyric acid feeding should not exceed about 50 g/cow/day. Appendix 2 gives additional details about feeding silages containing butyric acid.

Rumen epithelial cells directly convert dietary butyric acid into the ketone bodies that cause clinical signs of ketosis. Protein degradation products (putrescine, cadaverine, histamine, etc.) in silages fermented by *Clostridium sp.* bacteria may also depress feed intake and cause other health problems. Direct ingestion of these organisms in theory could cause clostridial diseases, although this link has not been well-established.

Harvesting practices must prevent ensiling overly wet forages. This requires adequate wilting time in the field after cutting and prompt covering of bunker silos if it rains during the filling and packing process.

### **Displaced Abomasum**

Prevention of displaced abomasum is multi-faceted and relatively unpredictable. The etiology, pathogenesis, treatment, and prevention of displaced abomasum have been reviewed (Breukink, 1991). The most important nutritional factor for prevention of displaced abomasum appears to be maintenance of an adequate fiber mat layer in the rumen during the peripartum period (Pehrson and Shaver, 1992). This can be accomplished by providing adequate amounts (2 to 4 lbs/cow/day) of fiber particles greater than 1.5 inches long. Such particles help prevent subclinical rumen acidosis and also help promote maximal rumen distention through the peripartum period, which physically limits movement of the abomasum within the abdominal cavity. Maximal distention of the rumen during the pre-fresh period has the additional benefit of encouraging dry matter intake after calving.

Subacute ruminal acidosis is strongly linked to displaced abomasum. Excessive VFA accumulation in the rumen may increase VFA outflow into the abomasum. Once in the abomasum, VFA impair smooth muscle motility and cause gas production (Svendsen, 1970), which may predispose to abomasal displacement.

Minimizing the degree of subclinical hypocalcemia in early lactation has been associated with lower rates of displaced abomasum (Massey et al., 1993; Oetzel, 1996). Hypocalcemia impairs the contractility of smooth muscle throughout the body. Poor contractility of the abomasum may lead to gas accumulation and ultimately to displacement.

Ketosis is also an important risk factor for displaced abomasum (Duffield et al., 2009). The relationship between ketosis and displaced abomasum is bi-directional. We tend to focus on displaced abomasum causing ketosis, but perhaps more importantly ketosis can cause displaced abomasum.

## Retained Placenta

Retained placenta may occur either when the placental attachments fail to detach after parturition, or when the attachments detach but the placenta is not expelled due to inadequate uterine contractions. Some of the factors involved in these mechanisms are non-nutritional, such as shortened gestation length, twinning, infectious diseases, or improper assistance during calving. Over-conditioned dry cows are at higher risk for retained placenta than properly conditioned cows. Hypocalcemia has been associated with retained placenta, probably because of the stress and subsequent immune suppression associated with hypocalcemia and the essential role of calcium in uterine contractility.

Nutritional factors associated with retained placenta include energy deficiency, protein deficiency, phosphorus deficiency, vitamin E and/or selenium deficiency, vitamin A deficiency, and iodine deficiency (Maas, 1982). Detachment of the placenta is at least in part an immune-mediated response to the placenta, which the body should reject as foreign after calving is complete. Therefore, many of the nutrient deficiencies listed above probably increase the risk of retained placenta because of the impaired immune function that results (Goff and Horst, 1997).

## Udder Edema

The multi-factorial etiology of udder edema makes it a difficult disease to trouble-shoot in problem herds. Improper sodium, potassium, and energy concentrations in the pre-fresh diet may each predispose to udder edema (Van Saun, 1991). Excessive or very low protein feeding and inadequate magnesium supplementation may also be factors (Vestweber and Al-Ani, 1983). Adequate exercise during the dry period and prevention of over-conditioning may help prevent udder edema. Anionic salts have been shown to slightly decrease the incidence and severity of udder edema during the prepartum period in first lactation animals (Lema et al., 1992). Non-nutritional causes of udder edema include genetic predisposition, circulatory disturbances, failure of milk letdown, and prolonged dry periods (Vestweber and Al-Ani, 1983).

Excessive salt feeding may contribute to udder edema (Nestor et al., 1988). However, the amount of salt required to induce udder edema is much higher than typically fed during the pre-fresh period. Salt intake should not be overly restricted in dry cows. Sodium bicarbonate should not be fed to dry cows; it predisposes to both udder edema and milk fever due to its high sodium content.

Excessive potassium intake can also be a major contributing to both udder edema (Sanders and Sanders, 1981) and milk fever. Dairy producers should be encouraged to grow forages for the pre-fresh cows on low-potassium soils. Limiting the application of manure, urine, and potassium-containing fertilizers can reduce potassium content of soils.

High levels of concentrate feeding have been incriminated as a cause of udder edema, especially when the concentrates contain a high proportion of starch. Research results have not consistently supported this clinical observation, however.

## Hypomagnesemia

*Acute Hypomagnesemia (Grass Tetany).* Grass tetany is a relatively rare disorder in dairy cattle. It is most likely to occur in lactating cows consuming lush, succulent grass pastures. These pastures contain less magnesium than found in more mature grass pastures. The incidence of grass tetany may rise as more herds adopt rotational grazing strategies. Prevention of grass tetany is usually not challenging, as it requires only adequate supplementation of magnesium in the diet. If grazing herds consume some concentrates, it is not difficult to supplement those concentrates with adequate magnesium. It is difficult to deliver supplemental magnesium to cattle on pasture that are not receiving supplemental concentrates.

Hypomagnesemia may also be related to excessively high dietary potassium relative to magnesium. Ideal K:Mg ratio for pre-fresh dry cows is less than 4:1. Some areas (e.g., north central Wisconsin) have soil types that tend to lead to high potassium / low magnesium forages. In these situations, it may be necessary to increase dietary magnesium concentrations to .40% or higher by adding extra magnesium oxide to the diet.

*Subclinical hypomagnesemia.* Subclinical hypomagnesemia is poorly understood but may be fairly common in dairy cattle. Subclinical hypomagnesemia may be an important trigger for non-parturient hypocalcemia in lactating dairy cows. A modest drop in blood magnesium may interfere with the PTH – vitamin D mechanisms for maintaining normal blood calcium concentrations (Goff, 2009b).

## Hypophosphatemia

Most cases of clinical milk fever have some degree of hypophosphatemia with the hypocalcemia. This hypophosphatemia occurs because elevations in PTH cause phosphorus loss via saliva and urine. Normal blood phosphorus concentrations are usually restored when the hypocalcemia is corrected with supplemental calcium alone – supplemental phosphorus is not typically required. Restoring normocalcemia halts the PTH secretion and phosphorus loss and increases gastro-intestinal motility, which allows for absorption of the phosphorus lost via the saliva (Goff, 2009a).

Some cows are unable to restore normal blood phosphorus concentrations, even after blood calcium has been corrected and stabilized. Reasons for this are unknown. Whether or not hypophosphatemia causes clinical signs in peripartum cows is unclear and controversial. Treating the hypophosphatemia is prudent, as long as it is not done at the exclusion of other treatments or with a high expectation of success. Treatment could be intravenous administration of an available source of phosphorus (e.g., 30 g of sodium monophosphate in 300 ml distilled water) or by oral phosphorus supplementation (e.g., .5 kg of sodium monophosphate in about 2 gallons of warm water). Hypophosphite sources of phosphorus are unavailable to the cow and are of no value in treating hypophosphatemia (Goff, 2009a).

There is no specific nutritional prevention for hypophosphatemia. The best action is to prevent hypocalcemia. It is practically impossible to formulate a diet that is deficient in phosphorus.

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## Strategies for Dairy Ration Formulation

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### I. Determine Feed Inventory and Ingredient Feasibility

Forage inventory is one of the main determinants of what kind of ration you can put together for your client. It is very unusual to have a situation where you can feed an unrestricted amount of a number of forages on the farm. Rather, you are usually 'locked into' certain minimum and maximum amounts of almost all of the forages you feed.

Not every concentrate feed ingredient available is an option to put into your rations. Knowing what concentrate feeds are feasible within the feeding system of the farm is important.

Know the maximum feeding amounts of the various by-product feeds and do not exceed them.

Do not start re-formulating until you are sure that you have the proper array of feed ingredients to meet the stated requirements. Be particularly aware of having appropriate sources of supplemental salt, Ca, P, Mg (MagOx), S (Dynamate), trace minerals, and vitamins. If you are balancing for a minimum DCAD (lactating cow rations), then you may need a buffer source in order to elevate the ration DCAD.

### II. Options for Reformulating the Ration

#### **Trial and Error (Hand-Balancing)**

Mix and match feed ingredients until you meet the requirements fairly well (staying at the same total dry matter intake!). This method works fairly well when you know (from experience) what combination of ingredients is going to work, or if you don't have a lot of choices in feed ingredient selection.

This method can be very laborious if you have a lot of different feed ingredient options or if you aren't quite sure where to start with the ration.

#### **Least-Cost Formulation**

Using this method, you let the computer select what combination of ingredients will meet the nutrient requirements at the least possible cost. Least-cost formulation can be dangerous if you do not have a good understanding of the limitations of your feed ingredients. In general, dairy rations are never truly

'least-cost,' because there are so many limitations on the amounts (min and max) of the different feed ingredients in the ration.

You **MUST** put numerous 'constraints' on your feed ingredients before you begin to reformulate them. Otherwise, the final diet will be driven almost totally by cost rather than optimal nutrition.

Deciding how to place dollar values on forages can be difficult when using least-cost formulation. In general, I assign fair market value to the forages that a dairyman is feeding. For haylages, this is the market value of the crop as though it were dry hay, adjusted for the moisture content of the haylage. If inventories dictate amounts of forage fed, then you must put the proper constraint on the amount of feed in question. If the producer has ample inventories of forage and wishes to reduce purchased concentrate costs as much as possible, then you could assign an extremely low value to the forage(s), such as \$.01 per cwt. This will force the program to include as much of them in the ration as possible.

Least-cost rations are hardly ever properly balanced on the first run of the program. It usually takes multiple attempts to get a ration that makes sense.

Most software programs do not automatically pull up both minimums and maximums for nutrient requirements. They only include the most commonly significant nutrient constraint. So, it is **ESSENTIAL** that you carefully inspect all of the nutrient densities of a ration before finalizing it. For example, a least-cost ration result could be 22% CP, just because this was the cheapest solution and because the only CP requirement was a minimum of 17.5%. In this case, you must add a maximum constraint to the CP requirement (maybe 18.0%) and run the ration again. Another example might be a least cost ration that contains 32% NFC. In this case, the only default nutrient requirement was a maximum of 40% NFC. So, you must add a minimum NFC constraint (maybe 35% NFC) and run the ration again.

Least-cost ration programs cannot always solve a ration. Some programs pull in "dummy" feed ingredients to show where the problem is. Other times, the ration may not be solvable even with dummy feed ingredients (this is particularly true when there are many nutrients with both minimum or maximum constraints). When least-cost rations cannot be solved, try adding a better source of the nutrient you think is most limiting, or try relaxing the nutrient requirement that you think is most limiting (I often start by lowering the NEL requirement).

The nature of least-cost programs is to take feeds on an 'all or nothing' basis. Minor changes in prices or nutrient constraints can cause the program to take dramatically different amounts of individual feed ingredients. Your job is to practice the art of balancing feed inventories, feed ingredient limitations, and feed costs - all to the best interest of your client.

**Selecting Feed Ingredients for Ration Balancing**

<b>Ration Nutrient Condition</b>	<b>Add This:</b>	<b>Remove This:</b>
NEL needed, fibers excessive	Corn	Forage
NEL needed, fibers at minimum	Fat source (start with cottonseed)	Corn
NEL needed, fibers at minimum and fat at maximum	No correction possible; settle for a lower NEL requirement and harvest better quality forage next year. Or buy good forage now.	
CP only is needed, UIP and SIP are OK	Soybean meal or High quality alfalfa	Corn or Corn silage
UIP and CP are needed	By-pass protein sources (dried distillers or brewers, corn gluten meal, Soy-Plus, blood meal, meat & bone)	Corn
UIP is needed, CP is OK	By-pass protein sources	Soybean meal
SIP is too high, CP is OK	By-pass protein source or soybean meal	Alfalfa haylage or urea
ADF or NDF too low, NEL high	Forage	Corn
ADF or NDF too low, NEL OK	Whole cottonseed or high quality forage	Forage and corn
FNDF low, NEL OK	Whole cottonseed or high quality forage	Forage and corn
NFC too high, NEL OK	Whole cottonseed, fat source, or high quality forage	Corn
NFC too low, NEL OK	Corn	Fat source
Ca only is needed	Limestone	Rest of ration
Ca and P are needed	Dicalcium phosphate	Rest of ration
P only is needed	Monosodium phosphate	Rest of ration
P and CP are needed	Monoammonium phosphate	Rest of ration
Mg only is needed	Magnesium oxide	Rest of ration
K only is needed (lactating cows)	Potassium carbonate (DCAD Plus)	Rest of ration
K is excessive (pre-fresh cows)	Lower K forages (corn silage), beet pulp, or dried brewers grains	Higher K forages
Na and Cl are needed	Salt	Rest of ration
Na only is needed (low DCAD)	Sodium bicarbonate	Rest of ration
S only is needed	Dynamate (potassium and magnesium sulfate blend)	Rest of ration

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