Incorporating Diet and Pen Variation into Ration Formulation

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Summary

The composition of a diet fed to a group of cows varies batch to batch, and depending on the degree of variation, milk production and cow health could be negatively affected. If the batch to batch standard deviations (SD) for important nutrients are known, accurate diet safety factors can be calculated. For example, if you wish to reduce the risk of feeding a diet with inadequate fiber because of nutrient variation, you can use the SD to determine the formulation target for NDF (or any other nutrient). Within a pen, nutrient requirements vary cow to cow. Knowing the within pen SD in milk yields among cows can be used to determine nutrient specification for the diet. On average metabolizable protein allowable milk should be about 1 SD greater than mean milk yield for the pen (if the pen does not contain fresh cows). More emphasis should be placed on knowing variation in diet composition and requirements within a pen. This will require collating feed composition data within a farm so nutrient variation can be calculated and it will require means of obtaining individual cow milk yield data (e.g., milk meters or using DHI data). Incorporating variation in ration formulation should reduce feed costs, while maintaining high milk yields. It could also reduce the amount of nutrients excreted in manure which will reduce environmental issues. Overall farm efficiency could be increased.

Introduction

Most currently available ration software uses definite inputs and produces definite solutions as opposed to using stochastic inputs and producing stochastic results. Examples of definite inputs are the corn silage you are going to use has 41% NDF and the milk production for the pen you are formulating is 85 lbs. Stochastic inputs could be the corn silage averages 41% NDF but varies + 3 percentage units and the pen averages 85 lbs. of milk but milk production by cows within the pen varies by + 30 lbs. In reality, all inputs needed by ration software (e.g., nutrient composition, milk yield, milk composition, body weight, etc.) are not constant but vary and in some cases vary widely. The question is: Should that variation be taken into account when formulating diets?

Variation in nutrient composition

A primary reason to incorporate nutrient variation into diet formulation is to ensure (with a certain amount of uncertainty or risk), that the formulated diet provides adequate nutrients or the formulated diet does not provide excessive nutrients. The nutritionist must decide whether reducing the risk of under feeding or over feeding is more important.

The variation in nutrient composition of feeds can be determined by taking an adequate number of samples from the feed over time and using a spreadsheet or some other means to calculate the standard deviation (SD). The number of samples and the timing of samples varies depending on the feed. For corn silage, 5 or 6 samples taken over a period of a few weeks often is adequate for estimating SD. For alfalfa silage with multiple cuttings, more samples over a longer period of time may be needed. For most forages and wet feeds (e.g., high moisture corn, wet corn gluten feed, or wet brewers grains), an estimate of variation within the farm is needed because of large farm to farm variation (St-Pierre and Weiss, 2015). In other words, those feeds need to be sampled at each farm and the SD is calculated from those samples. You should not go to a national or regional database to obtain the SD. For many other feeds such as dry corn, soybean meal, dry corn gluten feed, and soyhulls, farm to farm variation is not large and you can use the SD from national or regional databases (e.g., www.nanp-nrsp-9.org). However, variation in nutrient composition of ingredients is not the same as variation in nutrient composition of a TMR. If care is followed when making the TMR (i.e., recipe is carefully followed and inclusion rates are adjusted for DM), the variation in nutrient composition of the TMR will almost always be less than the weighted average variation in the ingredients. For example if 70%, 18%, and 12% of the NDF in a diet is provided corn silage (SD=1.7), alfalfa silage (SD=2.0), and concentrate (SD= 0.48) respectively, the weighted average SD for the TMR (SD has to be squared first, then averaged and then converted back to SD) = Square root of [0.7*(1.72) + 0.12*(0.482) + 0.18*(22)] = 1.66. This is not the correct method for calculating SD of a TMR because it assumes the variation within feeds are not independent. However if you sampled (accurately and precisely) the TMR, the SD may only be 60 or 70% as large as that value (these calculations will be discussed below). The reason why the variation in nutrient composition of a TMR is almost always less than the weighted average variation in ingredients is because the nutrient composition of feeds varies independently. For example on Monday, the NDF concentration of corn silage was higher than average but the NDF concentration in the alfalfa was lower than average so the overall deviation in diet NDF would be less than the deviation for either ingredient.

What ultimately matters is not the variation within ingredients but the batch to batch variation in TMR composition; however, obtaining the SD of TMR is difficult. You could sample TMR over several days, have the samples analyzed and calculate the SD, but sampling a TMR is problematic (discussed in another paper in this Proceedings). Another option is to use Monte Carlo simulation using inclusion rates of ingredients and their mean and SD for nutrient of interest. What this approach basically does is calculate expected concentrations of the nutrient (in this example NDF) for hundreds of diets incorporating expected ingredient variation into each calculated diet. The SD for NDF from those hundreds of simulations is then calculated. Spreadsheets such as Excel can do these simulations. Another option is to sample each TMR ingredient over multiple days and then calculate the expected TMR concentration each day using the daily concentration data and inclusion data (preferably actual inclusion as recorded by TMR software). The SD is then calculated from those daily calculated concentrations. We did an experiment to compare SD of TMR calculated as the weighted average SD from ingredients to SD of TMR calculated from daily delivery data (Table 1). For DM, the daily SD (which is the more correct value) ranged from 61 to 103% of the ingredient calculated SD; for NDF the range was 60 to 74% and for CP the difference ranged from 19 to 53%. Across TMR and nutrients the more correct estimate of TMR SD was about 65% of the value calculated from ingredient SD.

If you go to all the trouble of calculating an accurate estimate of batch to batch SD, you need to know what to do with the number. The effect of day to day variation (this reflects batch to batch variation for pens fed once daily) in TMR composition on cows has only recently been researched. We have conducted 4 studies to determine effects of day to day variation in dietary concentrations of CP, DM, NDF, and fat and in most cases we saw no or only very modest negative effects of substantial variation (McBeth et al., 2013; Weiss et al., 2013; Yoder et al., 2013; Brown and Weiss, 2014). However in an epidemiological type study (Sova et al., 2014) found a negative relationship between day to day variation in NEL concentration and milk yield across herds. At this point, data are equivocal, but modest day to day variation in many nutrients probably is not a major issue; hence setting benchmarks for day to day TMR SD and then striving to reduce variation to match the benchmark may not have a great pay off.

Another use of TMR SD is risk management. In other words, knowing the SD for TMR composition can be used to set farm specific safety factors for important nutrients. Underfeeding nutrients for a long enough time (this may be just a few days or several weeks depending on the nutrient) will negatively affect milk production and/or cow health and reproduction. Overfeeding nutrients often inflates feed costs, increases excretion of nutrients in manure, and depending on the nutrient and degree of overfeeding negatively affect health and production of cows. The nutritionist needs to set both upper and lower targets on nutrient composition and determine how much risk he or she is willing to accept. For example, a diet might be formulated to average 30% NDF, but because of past experiences with health issues, the nutritionist does wants the TMR to have <28% NDF (i.e., the target), 95% of the time (i.e., only 1 day out of every 20 days). If one knows the SD for TMR NDF, the formulated concentration of NDF for the diet can be calculated so that the diet is only below 28% NDF 5% of the time (Figure 1). Setting targets (both low and high) can be based on past experience, nutritional models (e.g., a model predicts a significant drop in milk yield if diet protein is less than 15%), feed costs, environmental regulations and other factors. Because of all these factors, these have to be set on a farm to farm basis; I cannot provide universal estimates.

Once the lower or upper target is set, the acceptable risk of feeding a diet greater than or less than that target must be determined. You may determine that a diet that is less than your lower target can be fed once a week without causing a problems (1 out of every 7 days or approximately 14% of the time). Or you may determine you only want to feed a diet that has less than the target value 1 day out of every 20 days (5% of the time). Determining an acceptable risk level is farm specific; however, reducing risk also comes with a cost. For example if you want to essentially eliminate the risk of feeding a ration that is inadequate in protein, you will need to formulate a diet that is extremely excessive in protein. In this case you will probably never underfeed protein but feed costs will be high and a substantial amount of nitrogen will be excreted in manure potentially causing environmental problems. Overfeeding NDF reduces the risk of acidosis but increases the risk of reduced dry matter intake and lower milk yields. When setting risk levels and lower or upper targets the potential cost of over or underfeeding nutrients must be considered. Probabilities of being greater or less than a specific value can be calculated using the normal distribution curve (Figure 1). As good approximations:

15% of values will be < (mean – **1.0***SD); 15% of the values will be > (mean+1*SD)
10% of values will be < (mean – **1.25***SD); 10% of the values will be > (mean+1.25*SD)
5% of values will be < (mean – **1.65***SD); 5% of the values will be > (mean+1.65*SD)

Those risk coefficients (1.0, 1.25, and 1.65) in conjunction with the lower (or upper) Target value are used to calculate the concentration of the nutrient in the formulated diet:

When you are more concerned about a deficiency:
Formulated Concentration = Low Target + (Risk*SD)

Conversely if you are more concerned about excessive concentrations;
Formulated Concentration = High Target – (Risk*SD)

As an example, you determined that you do not want to feed a TMR with <28% NDF more than 5% of the time and the SD for NDF in the TMR is 2.0. Based on above factors, 5% risk = 1.65 SD units. Therefore the formulation target for NDF is 28 + (1.65*2.0) = 31.3% NDF (Figure 2). This means that if you formulate a diet for 31.3% NDF and the SD remains at 2.0, the TMR will have less than 28% NDF about once every 20 days. Conversely it will have more than 33.8% NDF about 1 day out of every 10 days. If you wish to be less conservative and set the risk level at 15% (i.e., 15% of the time your diet has <28% NDF) formulating the diet for 30% NDF is adequate (Figure 1). This calculation can be done for any nutrient if it approximates a normal distribution and you have an estimate of the SD for the TMR.

Variation in cow inputs within a pen

Incorporating within pen variation (i.e., cow to cow) into the diet formulation process should be useful in determining the desired nutrient specifications for a given diet. In this situation, variation over time is usually not a major concern because pen average milk yield, body weight, and milk composition probably does not change much day to day. However within a pen on a given day there may be cows producing 30 lbs. of milk and cows producing 150 lbs. of milk. The primary cow inputs into ration formulation software are body weight (BW), milk yield, milk composition and parity (as a proxy for body growth), and variation in those inputs create variation in calculated nutrient requirements. Increasing BW increases the energy (NEL) and metabolizable protein (MP) requirement of cows; however, the ranges observed in BW of cows within a herd (assuming a single breed) usually are not large enough to substantially affect nutrient requirements. This means that using pen average BW (or even breed average BW) is probably adequate when formulating a diet for the pen. Yields of milk, milk fat and milk protein can vary greatly among cows within a pen, and the observed range will depend on the grouping system used by the farm. Farms that group based on milk production will have smaller within pen ranges in milk yields than farms that group based on other criteria. Yields of milk and milk components have a substantial impact on energy and protein requirements and using a pen mean milk yield when formulating a diet will result in higher producing cows being underfed causing reduced production. To overcome this problem, most nutritionists choose a milk yield greater than pen average and formulate to that value. Often the selected value is rather arbitrary (e.g., , 10 lbs. above the average for the pen). Using the SD in yield of milk within a pen, rather than an arbitrary constant should result in more accurate diet formulation by reducing the risk of underfeeding high producing cows while minimizing the degree of overfeeding lower producing cows.

Not only does nutrient requirements vary within a pen, so does dry matter intake (DMI). Milk yield is positively correlated with DMI but the strength of the correlation depends on stage of lactation. If stage of lactation is not considered, then the correlation is relatively week (e.g., cows in early lactation may have high milk yield but low DMI). When early lactation data are excluded (generally <30 days in milk) the correlation between milk yield and DMI is about 0.7 (Kramer, 2009). This means that if the pen does not contain fresh cows, one should assume higher producing cows are eating more feed than lower producing cows. Therefore when a diet is balanced for an average cow in a pen, the diet will support greater than average milk yields because of greater intake. But when a diet is balanced for mean milk yield, will the greater intake by higher producing cows be adequate to maximize their milk yield? For cows past 30 or 40 days in milk (and assuming similar BW), a 10 lbs. increase in fat-corrected milk yield would be associated with a 3 to 3.5 lbs. greater DMI when cows were fed the same diet. On average, that increase in

DMI will not provide adequate NEL and MP as milk yields exceed mean milk by more than about 15 lbs./day when the diet is formulated to meet requirements for the average cow. For example, if a group of cows (all cows >30 DIM) averages 80 lbs. of milk/day expected DMI is about 54 lbs. (NRC, 2001), If the diet was formulated to exactly meet NEL and MP requirements for the average cow, a cow producing 95 lbs. of milk would be expected to eat about 60 lbs. of DM and that would provide enough NEL and MP to support about 90 lbs. of milk (using NRC, 2001 equations). If all the equations we use are perfectly accurate (which they most definitely are not) and if the high producing cow has similar digestive and metabolic efficiency as the average cow, then when you feed for the average cow, the cow that was producing 95 lbs. would start producing 90 lbs. This is greater than the mean but milk production was lost. Using the same assumptions, a cow that was producing 150 lbs. of milk/day would drop about 25 lbs./day when switched to the 80 lbs. diet. Clearly you do not want to formulate for the average.

Most nutrition models used today will calculate protein and energy allowable milk. These numbers simply mean that if a cow consumed the formulated diet at the stated DMI, she has enough MP and NEL to produce those allowable yields of milk. The optimal degree of overfeeding depends on feed costs and milk price (e.g., the degree of overfeeding should be reduced when feed costs are high and milk price is low). Assuming a typical feed cost to milk price ratio, based on simulations and assuming a normal distribution of milk yields within a pen, and that the pen does not contain cows <30 DIM, MP allowable milk should be about 1 SD above mean milk for the pen (Weiss, 2014; Cabrera, 2016). This is not the same as using the mean + 1SD to formulate the diet. Mean milk and mean DMI (or estimated DMI using mean milk) should be used when formulating but MP allowable milk should be 1 SD above what the diet was formulated for. This degree of overfeeding should not be applied to all nutrients. For most minerals and vitamins, a 20% safety factor is probably adequate (i.e., NRC requirement X 1.2). Overfeeding of NEL has to be evaluated very carefully. The lower producing cows in a pen fed a diet with moderately excess MP simply excrete the excess nitrogen and although this has an environmental and economic cost, it does not affect the cow greatly. However a cow fed excess NEL, if all the equations are correct, will gain BW and condition. In many cases this is desirable but cows may become excessively fat. In general, NEL should be overfed less than MP; however body condition score should be monitored and NEL adjusted to obtain the desired condition.

The main problem with using SD to determine the appropriate degree of MP overfeeding is that the SD in milk yields within a pen is not known on most farms. Based on very limited data (which means it is likely wrong), within pen SD for milk yields on farms that did not group by milk production averaged 16% of the average milk yield. Therefore if a herd averaged 85 lbs. and did not group by milk yield, an estimated SD would be 85 * 0.16 = 13.6 lbs. Using the above information, MP allowable milk for this pen should be approximately 85+13.6 = 98 or 99 lbs./day. When cows are grouped by milk yield the within pen SD should be markedly lower but I do not know how low it would be. The primary reason feed costs should be less when cows are grouped by production is because the degree of overfeeding is reduced (Table 2). If DHI or other production data are available, SD can be calculated and should be used in formulation.

The information above was limited to pens that contained cows >30 DIM. Dry matter intake of fresh cows (less than 3 or 4 weeks in milk) is low relative to milk yield so the above factors are not appropriate for a group of fresh cows. At this time, adequate data are not available to determine the degree of overfeeding for protein that should be applied to this group. Rather than meeting MP and NEL requirements, the primary goal when formulated a diet for this group is to maximize DMI.

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Table 1. Variation (SD) in DM, CP, and NDF for ingredients and TMR (each sampled 6 different days over a 2 week period)[1]

	Standard Deviation, % of DM		
Feed	DM	NDF	CP
Corn silage	1.53	1.31	0.30
Alfalfa silage	2.10	0.57	0.18
Mixed silage	1.27	0.85	0.28
Grass hay	0.85	1.09	0.69
Mixed hay	0.81	2.24	0.33
Concentrate H	0.89	0.53	0.45
Concentrate D	0.32	1.33	1.25
Concentrate C	0.56	1.27	0.86
Whole cottonseed	0.49	4.21	2.20
SD from ingredients[2]			
TMR-H	1.27	0.92	0.32
TMR-D	1.51	1.17	0.59
TMR-C	1.24	1.77	0.89
SD from daily samples[3]			
TMR-H	1.31	0.67	0.061
TMR-D	0.91	0.87	0.31
TMR-C	1.08	1.06	0.36

[1] TMR-H was comprised of corn silage, mixed silage, and concentrate H. TMR-D was comprised for corn silage, alfalfa silage, mixed hay, and concentrate D, and TMR-C was comprised of corn silage, alfalfa silage, grass hay, whole cottonseed and concentrate C.

[2] SD were calculated as weighted average of SD for each ingredient (i.e., incorrect method)

[3] SD were calculated based on daily composition of the TMR. This is the correct method for calculating SD for TMR, however the values shown are just example values, they may not be correct for other situations.

Table 2. Example of how grouping cows to reduce within pen variation in milk yield can reduce feed costs. For the 1 group system, the diet would be formulated to contain adequate metabolizable protein to support 87 lbs. but with a 3 group system, the herd average diet would only need to contain adequate MP to support 81 lbs. of milk.

Grouping system	Average milk, lbs	SD[1], lbs	MP allowable milk, lbs
1 group	75	13	87
3 groups[2]			
Low cows	60	5	65
Medium cows	75	6	81
High cows	90	7	97
Average for herd	75	--	81

[1] SD for 1 group system was assumed to equal 16% of the average. For the 3 group system, SD was assumed to be reduced by 50% (i.e., 8% of mean)

[2]Group sizes were assumed to be equal.

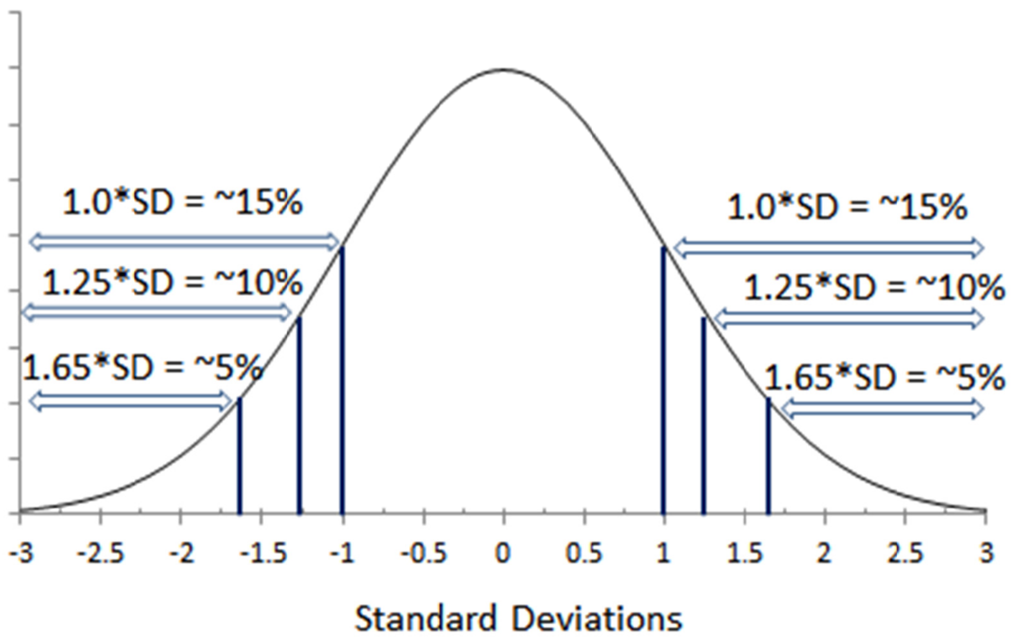

Figure 1. Normal distribution and approximate percentage of samples greater or less than specific distances (in standard deviation units) from the mean

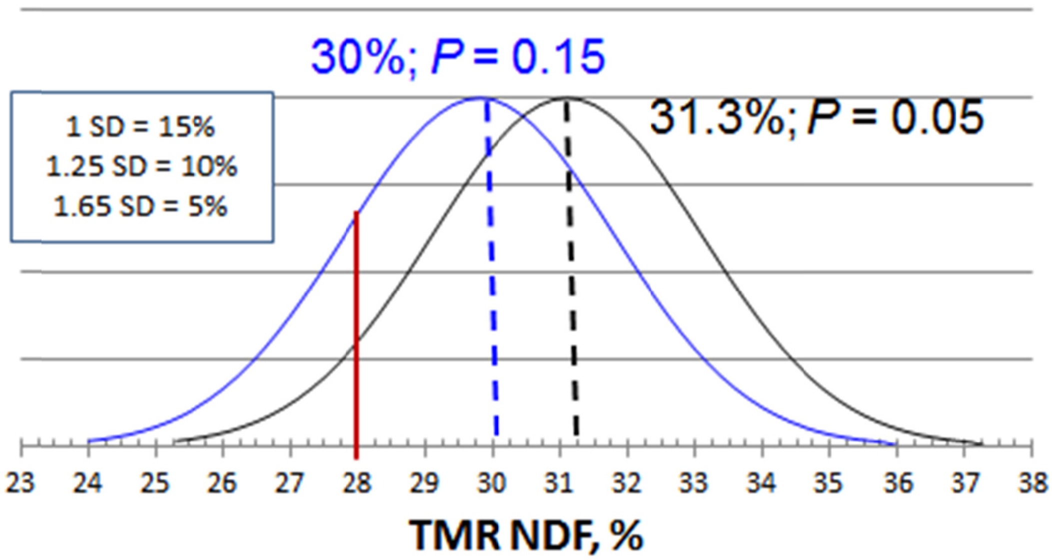

Figure 2. Example of using variation in TMR composition to formulate a diet. In this example, the nutritionist determined that she wanted to reduce the risk of feeding diets with <28% NDF and the SD for TMR NDF was 2.0. If the nutritionist was willing to accept a 15% risk (about once weekly) of feeding diets with <28% NDF, formulating for 30% NDF will be adequate. However, if she wanted to reduce the risk to 5% (1 day out of every 20), the diet should be formulated for 31.3% NDF. That was calculated as Lower limit (28% NDF) + SD (2.0) times risk factor (at 5% it is 1.65): 28 + (2 x 1.65) = 31.3.