Managing Dietary Variation to Maintain or Improve Efficiency

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Take Home Messages

- Feed composition data can vary for several reasons: lab analytical variation (usually quite small), sampling variation (ranges from small to very substantial), farm to farm variation (very large) and true within farm variation (degree of variation depends on many factors).
- Nutritionists often confuse sampling variation with true variation and reformulate a diet when it is unnecessary. This can be detrimental to production.
- Because of the size of sampling variation, especially for many forages, duplicate independent samples should be taken (at least occasionally). Results from the samples should be compared and averaged. Using an average of duplicate samples reduces the probability of unnecessary reformulation.
- Composition of total mixed rations is usually less variable than composition of feeds. Highly variable feeds are often cheap and when used in a TMR at low inclusion rates do not greatly add to diet variation.
- Research evaluating the effects of diet variation on lactating cows is limited but the available data show that cows can handle some variation without adverse effects provided, on average over a period of a few days, a good diet is fed.
- Systematic (i.e., planned) variation in diet dry matter may increase production.
- Oscillating concentration of dietary crude protein from deficient to adequate every other day shows promise in improving nitrogen use efficiency without affecting milk production.

Introduction

With respect to nutrition, we are concerned about variation in ingredient composition (variation caused by the feed), batch to batch variation in total mixed ration (TMR) composition (variation caused by the feeder), and variation in nutrient requirements and feed intake of cows within a pen. Some sources of variation do create problems and we should adopt protocols and procedures that reduce that variation. Other variation is largely uncontrollable so we need to adopt procedures that reduce the effects of that variation. Lastly, some forms of variation may actually enhance production and efficiency and that variation should be exploited. This paper will discuss how we can manage variation in feed and diet nutrient composition and how we can use systematic variation to increase milk yields and perhaps nutrient efficiency.

Variation in Feed and Diet Nutrient Composition

What Causes Variation in Feed Composition Data?

Before we can manage variation in diet composition, we must understand the cause of the variation. Feed composition variation can be divided into farm to farm variation, variation over time, sampling variation and analytical variation (Table 1). Farm to farm variation is by far the largest source of variation and analytical variation is usually the smallest. Sampling and day to day variation can be substantial depending on the type of forage and the skill of the sampler. For this discussion, we are using corn silage as an example, but this is true for any feedstuff. The nutrient composition of multiple corn silages could vary (or differ) because they are from different hybrids, they grew on different soils under different weather conditions, they were harvested at different maturities, there were differences in harvest and storage methods, etc. This variation is called 'true variation' and if not managed could affect the cow. On a given farm, many of these sources of variation are small or nonexistent. For example, all silage may have been harvested the same day and stored in the same structure. Furthermore, soil and weather is usually fairly similar within a farm. However, across farms, these factors may differ substantially so that the nutrient composition of corn silage across farms is much more variable than within a specific farm. Although farm to farm variation is huge, it is managed by sampling the corn silage on each farm and using farm specific composition data in diet formulation. The high degree of farm to farm variation also means that you should not use average values obtained from the literature. The silage on your farm may be close to the mean (average) but it also may be very different. Within a farm, if the corn silage is sampled multiple times (for example each month), the nutrient composition will probably vary. Month to month variation could be true variation (depending on how good the sampler is) and affect the cow (for example, the sample taken in January was grown on a drought-stressed field but the sample in February was from a field that was irrigated) but the January and February samples could also differ because of lab error and sampling variation. Sampling and analytical variation is not 'true' variation and will not necessarily affect the cow. If a corn silage sample was sent to a lab and for some reason you asked them to analyze it twice for protein, the values they get should be very close but probably are not identical; that difference is analytical variation or error. If you had a 500 kg pile of corn silage that was going to be put into a mixer to feed a group of cows and you grabbed a handful of silage and put it into a bag and then took another handful and put that into a different bag, and sent both bags to the lab the difference between those two samples is sampling variation. In some situations, results from the two samples from the same pile will differ by a very large amount. The reason this variation should not affect the cow is because all 500 kg is going to be put in the mixer and mixed up. It will be almost impossible for a cow to only eat silage from one of the sampling sites. However, if sampling variation is large, a nutritionist should not have much confidence in the data from a single sample because the formulated diet may be wrong (and cows will respond negatively). Taking multiple samples and averaging the values is the best option. If sampling error is large, the sampler should follow established protocols (discussed below). Formulating a diet based on bad nutrient composition data can be a very costly mistake.

Table 1. Contribution of different sources of variation to overall variation in nutrient composition of corn silage and hay crop silage. Data are from 11 commercial dairy farms; silages were sampled for 14 days in duplicate (St-Pierre and Weiss, 2015). Farm represents farm to farm variation, Day is day to day variation, Sampling is variation caused by sampling and Analytical is lab variation.

Nutrient	Farm	Day	Sampling	Analytical
Corn silage		**% of total variation**		
DM*	88.9	5.2	3.3	2.6
NDF*	72.6	9.3	13.9	4.3
Starch	72.5	6.8	18.0	2.7
Hay crop silage				
DM	82.6	11.2	5.4	0.8
NDF	89.1	5.1	4.8	1.0
CP*	82.1	4.7	10.7	2.6

*DM is dry matter, NDF is neutral detergent fibre, and CP is crude protein

Control and Interpreting Variation in Composition Data

Analytical variation from good labs is usually quite small and is usually not an issue and will not be discussed. Sampling variation, however, can be substantial depending on the expertise of the sampler and the type of feed being sampled. You can estimate sampling variation by taking at least two independent samples of a feed at about the same time and sending the samples to a lab. Independent means that you take multiple handfuls or scoopfuls of feed, put them into a bucket, mix and then place a subsample into a bag to send to the lab. That entire process is repeated. If the composition values of the two samples are very similar, sampling error is low, otherwise, sampling procedures should be improved. We conducted an experiment to determine sampling variation for corn silage and haycrop (mostly alfalfa) silage. The silages were sampled on 50 farms in the U.S. each month (with duplicate independent samples). Within a farm, over the 12-month period, the average range in dry matter (DM) concentration and neutral detergent fibre (NDF) concentration for corn silage were each about 4 percentage units (Figure 1). For DM, sampling variation accounted for about 30% of the variation and true variation was 70% of total variation. For NDF, sampling and true variation each contributed about 50% of the total variation. The average range in variation for DM within a farm for haycrop silage was 8.5 percentage units (25% of that was from sampling variation) and for NDF the average range was about 5 units and 30% of the total was from sampling. The bottom line is for corn silage much of what we think is true variation is actually sampling variation. To manage this variation you need to follow good sample taking procedures and you should take replicate samples and average the values. Good sampling techniques include mixing what you are going to sample as much as possible before sampling. If you take a grab sample from the face of a bag of corn silage, the sample represents that specific site in the silo. Rather than taking grab samples from the face of the silage, collect samples from the loader bucket when the TMR is being made. When you do that your sample represents the totality of what is being fed We sample physical components of a feed (e.g., a piece of corn cob) we do not sample specific nutrients. Therefore, sampling procedures that allow for segregation of different particles will increase sampling variation if the different particles have different nutrient composition. Corn silage is arguably the most difficult feed to sample properly. It comprises particles that differ greatly in shape, size, density and nutrient composition. Pulling a handful of silage from the face of a bag or bunker silo can result in an enrichment of specific types of particles. Not only should the face of a bunker silo never be sampled because of the real risk of getting killed by a silage avalanche it also can result in a biased sample. Longer pieces (usually leaves and stalks) can be stuck in the silage mass and the handful of silage you pull away will be enriched with smaller particles (likely higher starch particles). Removing a sample with your palm facing down allow smaller particles to drop away, which could reduce the starch concentration of the sample and enrich its NDF concentration. Because of size and density, with movement, larger particles tend to rise to the top of a pile and small particles migrate to the bottom. Not sampling all the vertical strata of a pile could result in a biased sample. Using good sampling techniques and taking duplicate independent samples and averaging the lab results from the two samples will reduce the chance of causing variation in diet composition by reformulating the diet when in reality the diet really did not change.

Managing True Variation in Feed Composition

If a TMR is made correctly (i.e., the recipe is followed exactly), its nutrient composition should be less variable batch to batch or day to day than the nutrient composition of the individual ingredients that go into the mixer because the nutrient composition of the ingredients varies independently. On any given day the NDF concentration of the corn silage may be higher than average but the NDF in the alfalfa may be lower so the two deviations partially cancel out. Using simple probabilities with only two ingredients, 25% of the time both ingredients will have greater than average concentrations of a nutrient, 25% of the time they both will have concentrations less than average and 50% of the time one feed will be higher than average and the other feed lower than average, which will partially cancel out the variation. If the recipe is not followed, then TMR variation will be increased. This can be managed by proper training of the feeder and using TMR monitoring software.

Because the composition of a mix of ingredients is usually less variable than that of individual ingredients, feeds that are highly variable can be successfully used in a TMR if inclusion rates are kept low. Highly variable feeds are often very cheap and if they provide less than about 10% of the total nutrient supply, including them in a mixed diet will have negligible effects on diet variation. Highly variable, cheap feeds can be fed at higher inclusion rates, but diets may have to be formulated differently, which may reduce the cost saving. Using a feed that is highly variable increases the risk that you may feed a diet that is deficient in a nutrient, which can reduce milk production, or is in excess of a nutrient or substance that is detrimental to the cow, reducing milk yield or maybe causing health issues. The only way to reduce risk of an excess is to limit inclusion rate but the risk of a deficiency can be reduced by over formulation. For example, with more consistent ingredients you may formulate a diet to have 16% crude protein (CP) but with highly variable ingredients, you may need to formulate for 16.5 or 17% CP. The saving in feed cost from using a highly variable cheap feed must be more than the cost of increased protein supplementation.

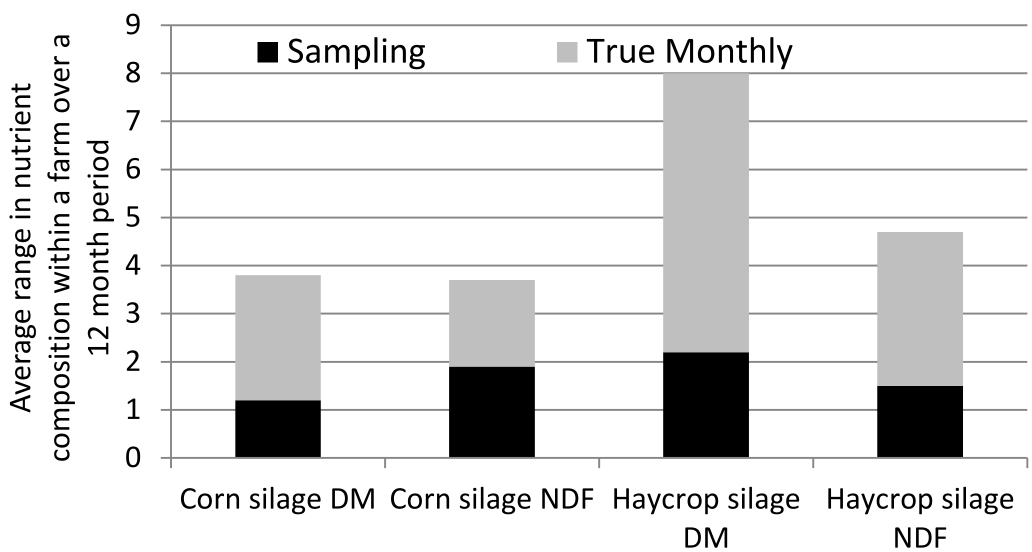

Figure 1. The average range in dry matter (DM) and neutral detergent fibre (NDF) in corn silage and haycrop silage. Variation caused by sampling was determined by duplicate sampling of each silage and true month to month variation was determined by subtracting sampling variation from total variation within each farm. Ranges were determined on 50 commercial dairy farms in the U.S. and silages were sampled each month for 12 months (St-Pierre and Weiss, 2015).

▪ How Much Variation in Nutrient Composition Can Cows Handle?

For years (probably decades) the dogma was that cows need consistent diets and that day to day variation in nutrient composition will have negative effects on cows. However, until very recently, the effects of diet variation on cows were never researched. We conducted a series of experiments evaluating how variation in forage NDF, CP, fat, forage dry matter and forage to concentrate ratio effects short term (usually 3 weeks) production by cows. Across all the studies the results were quite surprising. Feeding a diet with 4.8% fat for four days, then switching to a diet with 7.0% fat for four days and repeating that cycle reduced milk production by 1 kg/d compared with feeding a diet with 5.8% fat continuously (Weiss et al., 2013). On average, both treatments contained the same concentration of fat and the supplemental fat was highly unsaturated (corn oil). Variation also reduced daily dry matter intake (DMI) by about 1 kg. The negative effect of variation appeared to be cumulative. The longer the cows were exposed to the variation, the worse was the negative effect on DMI and milk production.

Because silage is often exposed to rain and snow, its DM concentration can change abruptly. We conducted an experiment to determine whether an abrupt change in silage DM affected midlactation cows. In this experiment (McBeth et al., 2013) we had a control treatment (no change in silage DM content) a treatment in which silage DM content was decreased by 10 percentage units by the addition of water with no other changes in the diet other than increasing feed delivery rate (unbalanced diet), and a treatment that included the wetted silage but we adjusted the forage to concentrate ratio so that nutrient composition (except for DM) was the same as the control (balanced diet). The wetted silage treatments were fed for three consecutive days twice during the 21-day experiment. During the six days the wetted silage was fed, the unbalanced diet had 1.5 percentage units less NDF, 2.6 percentage units less forage NDF, 2 percentage units more starch and 0.1 percentage units more CP. The treatment with the highest milk yield was actually the treatment we hypothesized would be the worst. When cows were abruptly changed to the unbalanced diet, they produced an average of about 1 kg more milk than cows fed the control. This occurred even though the wetted silage was only fed for six days out of the 21-day experimental period (during 15 days of the experiment all cows were fed the exact same diet).Over the 21-day period, milk fat yield did not differ between cows on the unbalanced treatment and control cows but cows on the unbalanced treatment produced about 20 g more protein per day ($P < 0.05$). Cows initially reduced DMI when fed the wetted silage whether diets were adjusted or not and it took cows one to two days to return to normal intake (Figure 2). The surprising finding was that for a day or two after cows were switched back to the normal silage, they ate more than control cows. Incorporating “controlled variation” into diets may be a way to increase production. Once or twice a week cows could be fed a wetter diet with about 5 percentage units less forage and 5 percentage units more concentrate for 3 days and then switched back to normal diet. For this to work, however, excess feed has to be delivered so that when cows want to increase intake, feed is available.

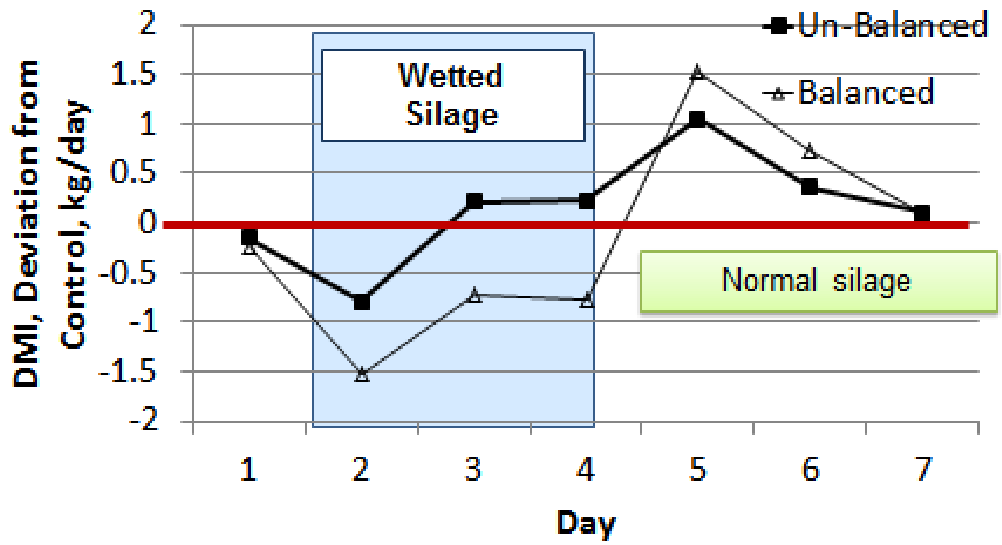

Figure 2. Effect of abruptly changing the DM of silage on DMI of dairy cows. On all days except for 3 days (shaded box) all cows were fed the same diet. During the experimental period, one group of cows was fed the control diet, another set of cows was fed wetted silage (10 percentage unit decrease in DM) with no change in diet (Un-Balanced) and a third set of cows was fed wetted silage, but forage to concentrate ratio was adjusted so on a DM basis, the diet was the same as the control. On all days excess feed was delivered so that the feed bunk was never empty. When cows were first switched to the wetted silage, DMI decreased and it took 2 or 3 days for cows to adjust and return to normal intakes. When cows were switched back to the control diet, cows continued to eat more feed for 1 or 2 days.

In a third experiment we changed the concentration of forage NDF day to day in a random pattern by using forages that differed greatly in quality (Yoder et al., 2013). The proportion of concentrate in the diet and the composition of the concentrate did not change over days. The day to day variation was much greater than what would be typical on a commercial farm. In general, DMI and milk yield followed the expected pattern. On days when cows were fed high forage NDF, DMI and milk yield decreased (usually with a 1-day lag) and on days when cows were fed diets with low forage NDF, intake and milk yield increased. Over the 21-day experiment, the variable treatment had the same average forage NDF as the control diet, which was very consistent day to day. Average intake and milk production (24.5 kg/day DMI and 43 kg/day milk) were the same for both treatments although day to day variation in intake and production was much greater for the variable treatment. We used a random pattern for the variable treatment but generally a diet with high or low NDF was never fed for more than two or three days in a row, which may be why we did not see any overall negative effects. Feeding a bad diet (e.g., excess forage NDF) for more than two or three days in a row will likely reduce DMI and milk yield, and cows may not recover. This experiment does not show that the diet fed to cows does not matter because over a period of a few days, the diet was on average well-balanced. Furthermore, we did not evaluate inconsistencies in making the TMR; we evaluated changes in forage composition. What this study does show is that cows can handle some variation in forage quality without negative effects. If you obtain composition data from a new sample of forage and it differs from the previous sample you do not have to rush to change the diet. You should evaluate the data and try to determine whether it is a real change and then reformulate if necessary. Cows do not need to be fed perfectly every day but they need to be fed a good diet when averaged over a few days.

We and others have also evaluated if oscillating dietary CP concentrations over time affects production and nitrogen (N) utilization efficiency (i.e., g of N for growth or milk N/g of N intake). Oscillating involves feeding a lower CP diet (below requirement) for one or two days followed by feeding a diet that meets requirements for one or two days and that pattern is repeated for weeks. In some experiments, oscillation reduced manure N excretion and increased protein efficiency (we could feed on average a lower protein diet and maintain production). In growing sheep and steers (Cole, 1999; Archibeque et al., 2007; Doranalli et al., 2011), oscillating dietary CP from deficient to adequate levels (average of 10% to 16% CP) every 48 hours reduced the CP required to maintain a similar average daily gain as feeding a higher, adequate level continuously. This also reduced manure N excretion and ultimately improved N balance at the same average CP intake. For growing animals oscillating CP generally improves efficiency but inadequate data are available with lactating cows to reach a conclusion (Figure 3).

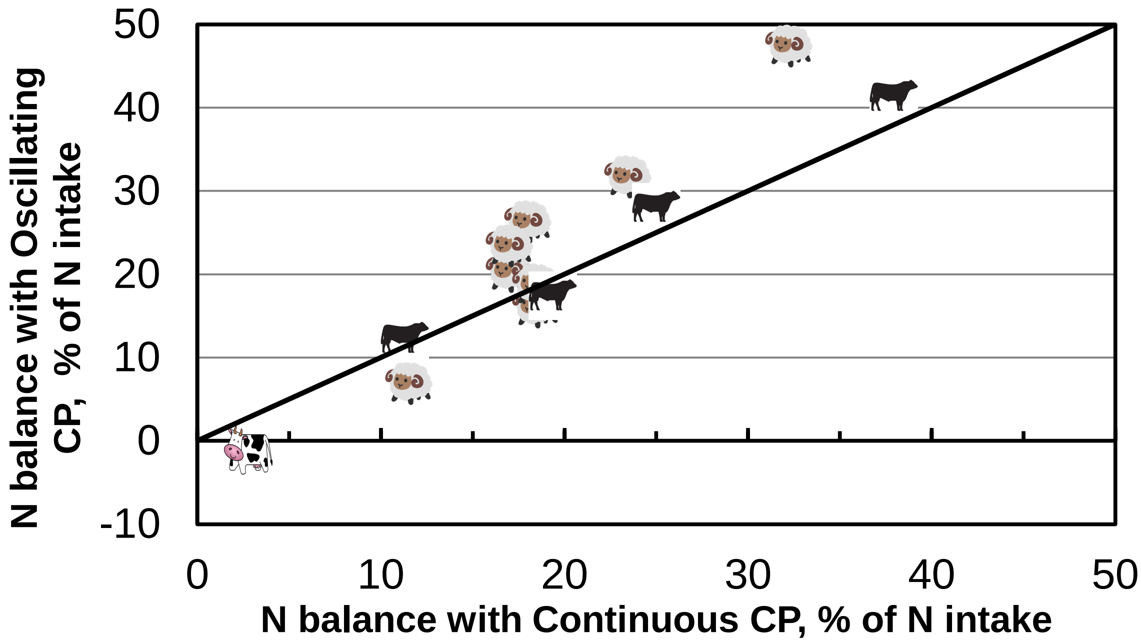

Figure 3. Comparison of nitrogen (N) balance as a % of N intake when oscillating the day-to-day CP concentration versus feeding a similar average CP level continuously to ruminants [adapted from (Reynolds and Kristensen, 2008) with added data]. The different symbols represent the type of animal used in the experiment [sheep (n = 8), beef cattle (n = 4) or lactating dairy cows (n = 1)] and the line represents equal N balance among treatments. Symbols above the line mean that N balance was improved when oscillating CP compared to feeding a similar average CP level continuously.

Fewer data are available for lactating dairy cows. In our first experiment at OARDC (Brown, 2014), oscillating CP every 48 hours from 10.3 to 16.4% CP did not affect N utilization efficiency (g of milk N/g of N intake) compared with continuously feeding a diet with 13.4% CP (i.e., average for the oscillation treatment). However, the oscillation treatment numerically decreased milk production compared with continuously feeding the 13.4% CP diet (33.8 vs. 34.7 kg/day, $P < 0.15$). Less milk production negates any improvement in income over feed cost or reducing the environment impact of dairy farms. However, feeding a low protein diet (10.3%) for 48 hours may have been too long. When we compared production within days, milk yield was reduced about 2 kg/day on the second day of feeding the 10.3% CP diet compared with the first day and remained low on the first day of feeding 16.4% CP diet. The change in production always lagged 1 day after the diet change.

The results above led to our last experiment. We hypothesized and tested whether oscillating the CP concentrations of a marginally deficient diet every 24 hours would improve milk production and reduce manure N excretion in dairy cows. In a 50-day feeding trial, 30 mid-lactation Holsteins were fed one of three treatments: 1) adequate protein fed continuously (16.2%), 2) marginally deficient protein fed continuously (14.1%), or 3) 24-hour oscillations from adequate (16.2%) to deficient protein (11.9%) to be on average equal to the marginally deficient protein diet fed continuously. Total output of urine and feces was used to measure protein digestibility and N balance. Compared with the marginally deficient protein diet fed continuously, oscillating the same average protein level numerically reduced DMI; however, milk yield was similar whether oscillating or feeding a static concentration (Table 2). Milk protein yield was also similar among diets. Milk urea-N tended to be higher with the oscillating CP treatment vs. continuous feeding of the marginally deficient CP diet; this may have occurred because these cows had a higher protein digestibility than cows fed a constant protein diet. However, more of the CP digested was excreted as N in urine rather than being used for milk protein synthesis or increasing body protein stores (i.e., N balance; Table 3). Based on N balance, body composition measurements, and plasma markers of catabolism (i.e., 3-methyl-His), we had no evidence oscillating CP resulted in mobilizing body reserves to support higher milk yield at a lower intake. Overall, this work indicates large, daily changes in dietary CP or oscillating dietary CP concentrations every 24 hours to dairy cows is not detrimental for milk production, but further research is needed before using this feeding method to enhance production efficiency and reduce manure N excretion.

Table 2. Effects of static or oscillating dietary CP concentrations for 50 days on intake and production.

	Treatment[1]				*P*-value	
	16.2%CP	**14.1%CP**	**Oscillating CP**	**SEM[2]**	**16.2 vs. 14.1%CP**	**14.1%CP vs. oscillating**
DMI, kg/day	22.9	23.2	22.2	1.08	0.59	0.11
Milk, kg/day	36.6	35.1	35.3	1.81	0.02	0.78
ECM[2], kg/day	36.3	34.9	33.8	1.89	0.19	0.35
ECM/DMI	1.59	1.52	1.52	0.04	0.13	0.98
Milk fat, %	3.22	3.36	3.10	0.17	0.45	0.17
Milk protein, %	2.94	3.03	2.90	0.05	0.04	0.01
Milk lactose, %	4.83	4.81	4.80	0.07	0.57	0.99
Milk fat, kg/day	1.21	1.19	1.10	0.09	0.77	0.27
Milk protein, kg/day	1.10	1.06	1.05	0.06	0.14	0.59
Milk lactose, kg/day	1.82	1.69	1.73	0.05	0.01	0.24
MUN, mg/dL	12.8	10.2	10.9	0.74	0.01	0.10

[1] Treatments were adequate CP fed continuously (16.2% CP), marginally deficient CP fed continuously (14.1% CP); or 24-h oscillations from adequate (16.2% CP) to deficient CP (11.9% CP)
[2] Energy corrected milk, kg/day = 0.327 × milk, kg/day + 12.95 × milk fat, kg/day + 7.65 × milk protein, kg/day

Table 3. Effects of static or oscillating CP concentrations on CP digestion and N intake and excretion.

	Treatment[1]				*P*-value	
	16.2%CP	**14.1%CP**	**Oscillating CP**	**SEM[2]**	**16.2 vs. 14.1%CP**	**14.1%CP vs. oscillating**
CP digestibility, %	65.2	61.7	65.3	1.44	0.09	0.07
N intake, g/day	561	512	474	16.9	0.01	0.03
N digested, g/day	366	317	310	14.2	0.01	0.66
Milk N, g/day	174	179	164	5.63	0.50	0.06
Urine N, g/day	185	124	151	12.6	0.01	0.13
Retained N, g/day	5.5	14.2	-5.4	10.0	0.49	0.11
Milk N, % of digested N[2]	48.1	56.7	53.8	2.37	0.02	0.35
Urine N, % of digested N[2]	50.5	39.5	49.6	3.10	0.02	0.04

[1] Treatments were adequate CP fed continuously (16.2% CP), marginally deficient CP fed continuously (14.1% CP); or 24-h oscillations from adequate (16.2% CP) to deficient CP (11.9% CP)
[2] Digested N was corrected for negative N retention and then used for milk and urine-N calculations.

▪ Conclusions

The nutrient composition of feeds and diets varies sample to sample, whether those samples are taken the same day or months apart. Some of this variation is real (a new cutting of hay, a new batch of distillers grains, or today's silage came from a weedy part of a field) but much of the sample to sample variation we observe is simply caused by sampling variation. The feed or diet may not have changed at all, but the sample we took was not a good representation of the feed. If we assume all changes in nutrient composition are real and reformulate a diet based on that change, the resulting diet may be wrong. Diets should be formulated based on average composition from at least two samples, and nutritionists should evaluate their sampling skills by comparing results from duplicate independent samples. We are currently investigating whether we can use 'controlled' variation to enhance production, and contrary to standard dogma, intentionally varying certain diet components systematicaly may improve production and efficiency. Feeding cows diets that oscillate between adequate and deficient concentrations of CP every other day may improve productive efficiency. Likewise, reducing the forage to concentrate ratio of a diet by adding water to silage for a period of 3 days once per week may also enhance production. The use of controlled variation in diet composition in dairy diets deserves additional research.

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