NUTRIENT VARIABILITY IN FEEDS WITHIN FARMS[1]

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INTRODUCTION

Although variation in nutrient composition of feeds and diets is a well-accepted fact of life, this variation has not been extensively quantified and the effects of variation on cows have not been studied. A group of researchers and extension specialists at The Ohio State University with the help of collaborating nutritionists and dairy farmers are working on a large project designed to determine just how variable feeds and diets are and whether that variation actually affects cows. This paper will concentrate on the degree of variation observed in nutrient composition of common feeds on dairy farms, factors influencing that variation, and implications of that variation on ration formulation.

THE IMPORTANCE OF KNOWING NUTRIENT VARIATION

The amount of variation in the nutrient composition of a feed can affect:

1. Diet formulation strategies. An important component of a good ration formulation strategy is risk management. Diets are formulated, in part, to minimize the risk of a nutrient deficiency that would reduce production or impair cow health. The safety factor included in ration specifications are dependent on factors such as variability in cow factors (stage of lactation, milk yield, parity, etc.) within a pen, overall quality of nutritional management on a farm (monitoring feed bunks, consistency of the total mixed ration, etc.) and the variability in the nutrient composition of feedstuffs. A total mixed ration (**TMR**) based on ingredients that are highly variable in protein will likely be formulated to a greater protein concentration than a diet based on very consistent ingredients. This over-formulation reduces the risk that the diet will be deficient in protein because of changes in the composition of the ingredients, but it has a cost.

2. The economic value of the feed. A diet might be formulated to contain 16% protein when based on consistent ingredients but when based on a highly variable ingredient, the diet might be formulated to contain 17%. The price of the highly variable ingredient must be discounted enough to cover the cost of feeding the higher protein diet. This also has an environmental cost and in many locations that translates directly into an direct economic cost.

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3. The sampling and analysis schedule for the feed. The goal of an optimal sampling schedule is to minimize cost. Sampling too frequently increases analysis cost but sampling too infrequently may result in lost production or health problems because a change in diet composition was not identified in a timely manner. Feeds that are extremely consistent will have a different optimal sampling schedule than that of a highly variable feed.

4. The productivity and health of cows. At this time, little is known (but we are conducting several studies evaluating this) about how variation in nutrient composition of the ration affects dairy cows, but if it affects the cow then those costs will have to be factored into the valuation of the ingredients.

VARIATION IN NUTRIENT COMPOSITION OF FEEDS

Two excellent sources (note: other qualified labs are available for feed analysis) for feed composition data (including variation) are the websites maintained by:

DairyOne Cooperative (Ithaca, NY): www.dairyone.com

Dairyland Laboratories Inc. (Arcadia WI): www.dairylandlabs.com/

For many feeds, these data bases include thousands of samples from a wide geographic area, multiple hybrids and varieties, diverse growing conditions, and different manufacturing or processing systems so that the data represent a national population. In other words, if you take a random sample of corn silage or distillers grain from the U.S. it would most likely fit the population of samples in those two data bases. Although national data are valuable, they most likely do not accurately reflect variation in nutrient composition in feedstuffs within a farm. As a population becomes more specific (e.g., corn silage from across the US vs. corn silage grown on Farm X in 2012), we expect the standard deviation to become smaller because many fewer sources of variation occur on Farm X than what occurs across the U.S. Knowing variation in feed composition at the farm level, rather than at a national or global level, will allow us to fine tune ration safety factors, compare economic value of feeds more accurately and set up optimal sampling schedule for specific farms.

Methodology

To determine variability in feed composition at the farm level, 50 well-managed dairy farms from across the U.S. (20 within Ohio, 30 outside of Ohio) were enrolled in this project. The nutritionists for the farms were given a detailed sampling protocol so that sampling procedures would be consistent across farms and all major ingredients added to the "high group" TMR were sampled monthly for 12 months. All samples from all farms were sent to a common lab (Cumberland Valley Analytical Services, Hagerstown, MD) and analyzed via wet chemistry for dry matter (**DM**), crude protein (**CP**), and neutral detergent fiber (**NDF**). Statistics on nutrient composition were calculated within each farm and feed. The final data set contained 4700 samples from 49 farms from 10 states (CA, IA, MI, NM, NY, OH, SD, UT, TX, and WI). For this paper, only 10 common feedstuffs will be discussed. Day to day variation in haycrop and corn silages was evaluated by sampling those silages on 14 consecutive days on 8 farms near Wooster, OH. On 4 of those farms, independent duplicate samples were taken each day. Corn silage was assayed for DM, NDF, and starch and haycrop silage was assayed for DM, NDF, and CP. All assays were conducted in duplicate at the OARDC Dairy Nutrition Lab using standard wet chemistry methods.

Table 1. Day to day variation in nutrient composition of corn silage and haycrop silage on 8 dairy farms in Northeastern Ohio.[a]

	Corn Silage			Hay Crop Silage		
	DM, %	NDF, %	Starch, %	DM, %	NDF, %	CP, %
Averages[2]						
Mean	38.8	40.4	31.7	43.6	47.6	17.3
SD	2.07	2.52	3.02	3.7	2.38	1.01
CV	5.3	6.2	9.5	8.5	5.0	5.8
Range	7.3	8.8	12.2	11.8	8.5	3.4
Ranges[b]						
Mean	31.5 - 45.7	35.4 - 45.0	27.0 - 39.2	32.5 - 55.7	36.1 - 58.2	15.1 - 21.9
SD	1.50 - 3.04	2.16 - 3.27	2.05 - 5.26	1.00 - 6.66	0.92 - 3.64	0.37 - 1.61
Range	5.1 - 10.4	7.3 - 11.2	6.3 - 27.7	3.4 - 19.1	3.2 - 13.6	1.2 - 4.9

[a] Samples of corn silage and haycrop silage were taken for 14 consecutive days during a time when the silages did not knowingly change. The mean, standard deviation (SD), coefficient of variation (CV) and range (maximum daily value - minimum daily value) were calculated for each farm and then averaged for the 8 farms.
[b] Ranges are between farms (e.g., on the most consistent farm corn silage DM ranged by 5.1 units but on the most inconsistent farm, the range was 10.4 units).

Day to Day Variation in Nutrient Composition of Silages

Within a farm and over a relatively short period, day to day variation in nutrient composition of silages on many farms was substantial (Figure 1 and Table 1). For corn silage, the day to day variation in starch was greater than NDF which was greater than DM (average CV were 9.5, 6.2 and 5.3, respectively). The day to day variation in those nutrients did not follow any discernible pattern (Figure 1). For the 8 farms, the **average** range in starch concentration in corn silage was 12.2 percentage units over a 14 day period. The most consistent corn silage (within a farm) had a range in starch concentration of 6.3 percentage units and the most variable had a range of 27.7 units (Table 1). If that variation is real (i.e., not caused by sampling or laboratory error) a deviation of about 14 units from the mean (i.e., half the range) would alter the starch concentration of the diet by 3.5 percentage units if silage comprised 25% of the TMR.

That degree of change could be enough to cause rumen upset. For NDF, the most consistent farm had a range of 7.3 percentage units whereas the most variable farm had a range of 11.2 percentage units in corn silage NDF. For the most variable farm, a deviation of 5.6 units from the mean would change TMR NDF by about 1.4 percentage units (assuming corn silage had a 25% inclusion rate).   Although DM was more consistent than the carbohydrates, it still ranged within a farm from 5.1 units up to 10.4 units. Because diets are formulated on a DM basis but delivered on an as-fed basis, a deviation of 5 percentage units in DM could substantially alter diet composition.

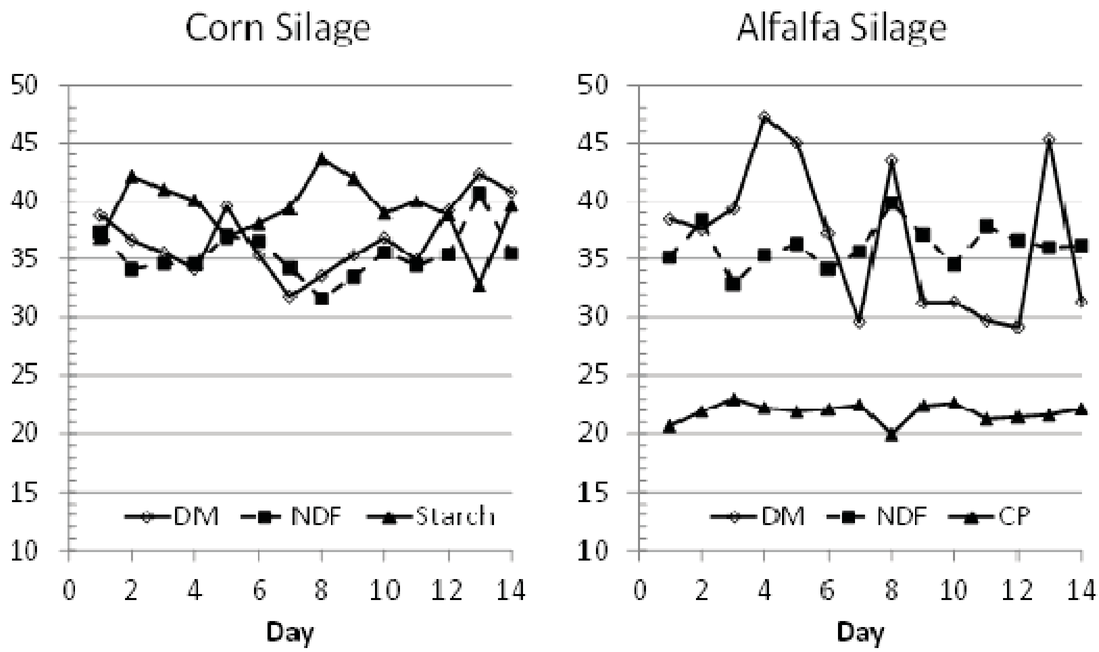

Figure 1. Day to day changes in DM (%) and NDF, CP, and starch (% of DM) of corn silage and haycrop silage on two farms. The farms were chosen because the day to day range in nutrient composition was approximately the average for the data set.

For hay crop silage, DM was most variable, followed by CP and NDF (average CV = 8.5, 5.8, and 5.0, respectively). The range in variation between farms was large (Table 1). The range in DM concentrations within a farm was more than 5 times greater for the least consistent hay crop silage compared with the most consistent. The range in NDF and CP varied about 4-fold between the most and least consistent haycrop silages. Contrary to conventional wisdom, within a farm over a short period of time, haycrop silage was a more consistent source of NDF than was corn silage (5.0 vs. 6.2 for haycrop and corn silage, respectively). Even though day to day variation in corn and haycrop silage was substantial, it was much less than what was observed in the national population. The average standard deviation within a farm was 2 to 3 times less than SD for the national population (DairyOne website).

An obvious question is: Why is corn and haycrop silages so variable over a short period of time? One possible reason is laboratory error; however, all assays were conducted in duplicate, and averaging the duplicate values had essentially no effect on

SD, CV, or ranges when compared to using a single laboratory value for each day (data not shown). Another potential source of variation is sampling error. Averaging the results from the duplicate daily samples reduced variation by 13 to 25% depending on the nutrient and type of silage (data not shown). Sampling error is clearly an important source of variation and it is probably greater than our estimates because the sampling protocol we followed. Even though the cow does not experience sampling error, it can have a significant impact on diet formulation and that will ultimately affect the cows. High sampling error means that you should not have great confidence in the results from a single sample. Rather, multiple samples should be taken over a short period of times (days) and the average of those samples should be used for diet formulation. We used Monte Carlo techniques to randomly select samples from the 14 day to day study and determined that the mean of 3 samples consistently matched the overall mean (over 14 days) for NDF within each farm. A single randomly selected sample was within +/- 5% of the mean only 50% of the time.

Month to Month Variation in Forages

The effect of an ingredient on the variation observed in the TMR is dependent on variation in the ingredient and on the inclusion rate of the ingredient. The effect an ingredient has on the variation of the total diet changes with the square of the inclusion rate. This means that when the inclusion rate of an ingredient is doubled, its effect on total diet variance does not increase by a factor of 2, but by a factor of 4 (i.e., 2 squared). Relying on multiple ingredients, each with a limited inclusion rate can greatly reduce variation in the TMR. This is illustrated in Figure 3. The NDF concentrations of corn silage and hay crop silage from two farms are highly variable day to day; however, if the TMR contained 25% corn silage and 25% haycrop silage, the concentration of forage NDF in the diets is less variable. In Farm A (Figure 3), the CV for corn silage and haycrop silage are 5.3 and 4.3 but the CV for the mix is only 3.7. For farm B, the CV for corn silage is 7.3 and 2.9 for haycrop and for the mix it is 4.3. For both farms, the CV of the mix is much less than the average of the CV for the two forages.

Measures of month to month variation in nutrient composition of forages and concentrates within farms are shown in Tables 2, 3, and 4. Unexpectedly, the relative variation in corn silage NDF over 12 months was essentially the same as observed over a period of 14 days (Tables 1). However, as expected, the average variation in NDF of haycrop silage over a 12 month period was substantially greater than what was observed over a 14 day period (CV = 8.7 vs. 5.0). More important than average within farm variation in forage composition is the range in within-farm variation that was observed (Table 3). Some of the farm to farm differences in variability could be caused by sampling variation (different people sampled at different farms, storage structures differed, etc.) but some is likely real variation. For the forages on the most consistent farms, the range in CP and NDF concentrations were so small as to have little biological and economic importance. On the other hand, for the most variable farms, the range in NDF was 16 to 22 percentage units depending on the forage (8 to 11 percentage unit deviation from the mean). At a 25% inclusion rate, this amount of variation could change forage NDF concentrations of the TMR by 2 to 3 percentage units. The range in

CP concentrations for the least consistent farms is great enough to cause substantial change in CP concentration of the TMR, but for the most consistent farms, repeated sampling of forages would be unnecessary. For the more variable farms, frequent sampling would be needed to quickly identify when forage composition changed.

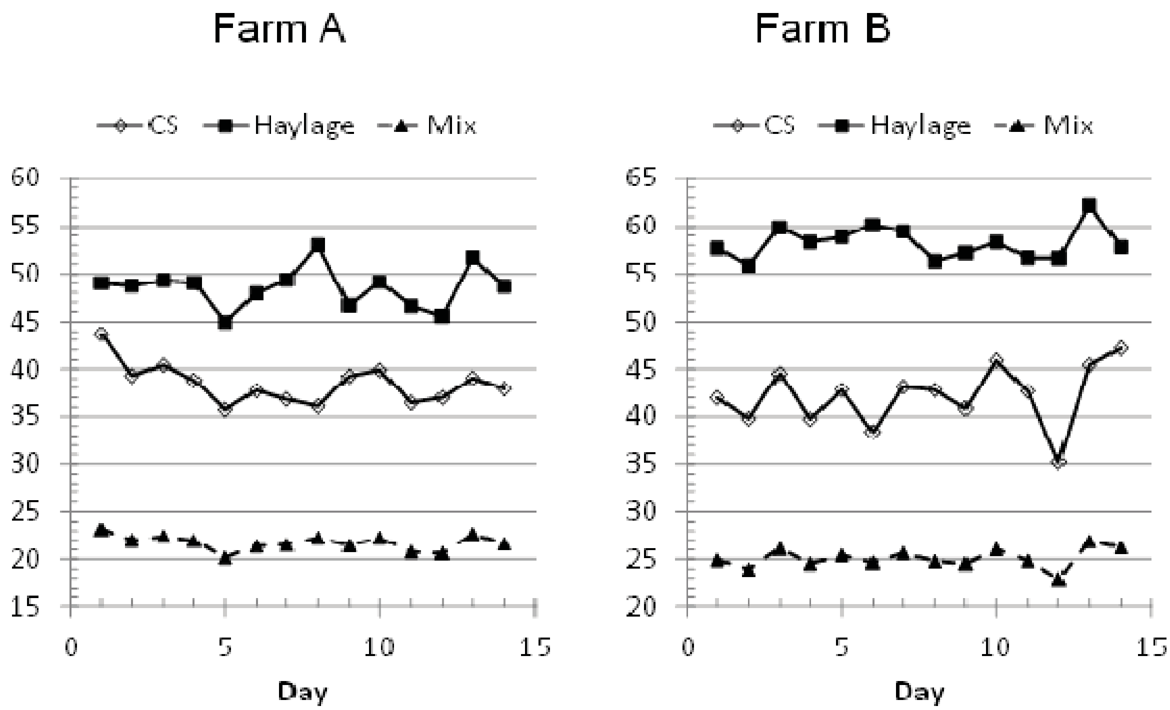

Figure 2. The effect of blending forages on variation in the TMR. Forages were sampled daily for NDF. The line designated as Mix is the concentration of forage NDF in the TMR assuming corn silage and haycrop silage each comprised 25% of the TMR. Data are % of DM of silage or total TMR).

Month to Month Variation in Concentrates

As would be expected, the average variation in DM, CP, and NDF for the concentrates was less than for the forages (Table 2). However, variation in NDF in many of the concentrates was substantial. In most situations, the **average** within farm variation in CP or NDF concentrations would have only minor effects on TMR nutrient composition. The average deviation (range divided by 2) in CP concentration for most of the concentrates would change the CP concentration of the TMR by about 0.3 percentage units with an inclusion rate of 20% (a change of 0.6 units is possible with wet brewers grains). Assuming a 20% inclusion rate and average within farm variation for concentrate NDF, diet NDF could change by 0.3 to 0.8 percentage units (a change that likely would have little effect on the cow).

The range in variation among farms for the concentrates (Table 4) is more important than the average variation (Table 2). For example, the DM concentration for high moisture corn from one farm varied by 19 percentage units over the year which is enough to substantially affect the amount of corn DM fed in a diet. The largest month to month range in DM concentration of wet brewers could also affect the TMR. For most of the concentrates (the exception is wet brewers), even for the most inconsistent farm, the variation in CP probably would not cause major issues. The most inconsistent wet brewers with respect to CP could cause important changes in CP concentrations of the TMR. On farms that experienced the greatest range in NDF concentrations for high moisture corn, distillers, and wet brewers grains, the NDF concentration of the TMR could be altered enough to affect cows. The NDF concentration of soybean meal could vary tremendously, however inclusion rate for soybean meal is usually <10% and some of that variation is likely a result of not identifying low and high protein soybean meal as separate feeds. The assumption that concentrate feeds within a farm do not vary enough to justify sampling is clearly wrong at least for NDF. The NDF concentration of high moisture corn, brewers grains and distillers grains should be monitored. An often stated complaint about distillers grains is that it is too variable. Based on data in Table 2 and 4, distillers and brewers grains have similar variation and for NDF, distillers grains are actually more consistent than high moisture corn.

IMPLICATIONS

1. Within farm variation for feeds differs widely among farms, therefore sampling schedules should be tailored to individual farms (increased sampling for farms with greater variability).

2. Day to day variability in corn silage and haycrop silage is large and often as great as month to month variation. **Single samples should not be relied upon to provide an accurate description of the feed**. Results from 2 or 3 samples taken within a short period of time should be averaged and the average used in diet formulation. Duplicate samples taken on a single day reduced day to day variation but probably not enough to justify the added costs, at least for smaller farms.

3. Multiple sources of nutrients, even highly variable sources, greatly reduce the variation in the nutrient composition of the TMR.

4. For many concentrates, the CP and NDF concentration (and DM for wet feeds) vary substantially and was large enough to justify routine sampling. Changes in nutrient composition were great enough to affect ration formulation.

5. A month to month or day to day change in nutrient composition of a feed could substantially alter its inclusion rates when linear programming is used for diet formulation. If the change in nutrient composition was not ‘real’ (e.g., sampling variation), multiple sampling of ingredients could actually increase variation in TMR. Averaging sample results should reduce this effect.

Table 2. Variability in composition of feeds within farms over a 12 month period[a].

Dry Matter, %			Crude Protein, %			NDF, %		
Mean	SD	Range[b]	Mean	SD	Range[b]	Mean	SD	Range[b]
			Corn silage (data from 48 farms)					
34.1	2.67	9.1	7.9	0.55	2.0	40.8	2.60	8.8
			Legume silage (38 farms)					
42.8	6.29	20.7	21.5	1.64	5.2	39.9	3.47	10.9
			Legume hay (21 farms					
87.8	2.46	8.2	21.2	2.01	6.3	37.5	4.20	13.2
			Small grain silage (9 farms)					
37.3	3.27	10.6	13.0	1.46	4.6	53.6	3.29	9.5
			Straw (15 farms)					
87.8	3.78	11.7	4.7	1.16	3.4	79.8	2.41	7.3
			Dry shelled corn (27 farms)					
85.3	1.67	4.6	8.4	0.43	1.2	11.3	1.30	3.7
			High moisture shelled corn (23 farms)					
68.8	3.04	9.5	8.1	0.58	1.8	11.6	1.87	5.9
			Dried distiller grains with solubles (11 farms)					
89.9	1.31	3.6	30.4	1.02	2.9	32.6	2.25	6.4
			Soybean meal (18 farms)					
88.3	0.91	2.5	52.4	1.05	2.3	8.7	0.95	3.1
			Wet brewers grains (11 farms)					
22.9	1.70	5.5	31.3	2.03	6.3	49.1	2.60	8.1

[a] Samples were taken monthly if the feed was fed (not all feeds were fed for 12 months on all farms). The statistics were calculated for each farm and then averaged across farms.

[b] Range = maximum monthly value minus minimum monthly value (within a farm).

Table 3. Ranges for within- farm forage composition statistics (over a maximum 12 month period) across farms[a]

	DM, %	CP, %	NDF, %
Corn silage (data from 48 farms)			
Mean	29.9 - 43.1	6.8 - 11.8	35.1 - 51.2
SD	0.80 - 5.00	0.24 - 1.27	1.16 - 6.52
Range	2.5 - 17.9	0.8 - 4.7	4.1 - 22.1
Legume hay (data from 21 farms)			
Mean	72.3 - 88.5	18.3 - 24.6	30.9 - 43.9
SD	1.17 - 9.79	1.18 - 3.62	0.68 - 7.32
Range	2.1 - 20.7	3.7 - 11.1	1.6 - 16.6
Legume silage (data from from 38 farms)			
Mean	27.2 - 49.9	17.8 - 23.8	32.1 - 47.3
SD	2.93 - 11.1	0.33 - 2.64	1.21 - 6.01
Range	8.6 - 41.3	0.9 - 9.1	2.6 - 19.0
Small grain silage (data from 9 farms)			
Mean	31.4 - 61.7	10.3 - 17.1	42.2 - 64.0
SD	1.67 - 4.62	0.59 - 3.76	1.36 - 6.88
Range	4.4 - 17.1	1.6 - 13.6	4.0 - 17.2
Straw (data from 15 farms)			
Mean	82.3 - 90.8	3.7 - 5.8	72.4 - 82.6
SD	0.76 - 13.40	0.27 - 2.73	1.21 - 4.59
Range	1.4 - 42.5	0.8 - 8.9	2.8 - 15.5

[a] Samples were taken once monthly if the forage was fed (not all forages were fed for 12 months on all farms). Statistics were calculated for each farm and then the minimum and maximum among farms for each statistic were determined.

Table 4. Ranges for within-farm concentrate composition statistics (over a maximum 12 month period) across farms[a]

	DM, %	CP, %	NDF, %
Corn grain (data from 27 farms)			
Mean	83.0 - 86.5	7.8 - 9.2	9.9 - 13.3
SD	0.39- 4.50	0.18 - 1.14	0.40 - 2.70
Range	1.0 - 10.0	0.5 - 2.7	1.2 - 7.7
High moisture corn grain (data from 23 farms)			
Mean	57.3 - 77.6	6.9 - 9.1	7.9 - 23.6
SD	0.69 - 5.76	0.24 - 0.89	0.64 - 5.85
Range	1.5 - 19.4	0.8 - 3.2	1.9 - 18.9
Dried distillers grains with solubles (data from 12 farms)			
Mean	86.9 - 91.8	28.1 - 39.6	31.2 - 34.5
SD	0.58 - 2.22	0.64 - 1.97	1.12 - 5.05
Range	1.7 - 5.4	1.5 - 6.2	3.1 - 11.9
Soybean meal (data from 18 farms)			
Mean	87.2 - 91.2	49.6 - 53.6	8.0 - 11.0
SD	0.29 - 3.25	0.29 - 3.69	0.22 - 3.16
Range	0.7 - 8.6	0.6 - 4.4	0.5 - 14.9
Wet brewers grains (data from 11 farms)			
Mean	21.0 - 24.8	25.0 - 34.3	45.8 - 54.4
SD	1.15 - 2.58	1.47 - 3.15	1.41 - 3.66
Range	3.7 - 9.2	4.7 - 10.0	3.0 - 12.0

[a] Samples were taken monthly if the concentrate was fed (not all feeds were fed for 12 months on all farms). The statistics were calculated within each farm and then the minimum and maximum among farms for each statistic were determined.