Recent Observations in Dairy Cattle:
Dietary Cation-Anion Difference, By-pass Protein, and Supplemental Fats

Charles C. Stallings
Professor of Dairy Science
Virginia Tech, Blacksburg USA
cstallin@vt.edu
Web site: www.vtdairy.dasc.vt.edu

A review of recent research publications provide an update on some areas of emphasis important in the feeding of lactating dairy cows. The areas I will review are dietary-cation anion difference, by-pass or rumen resistant protein, and supplemental fat sources.

Dietary Cation-Anion Difference (DCAD)

Minerals come into consideration when feeding close-up dry cows as well as lactating cows. Generally, excess sodium (Na) and potassium (K) should be avoided in close-up dry cow diets, but these cations are desirable in lactating cow diets. Sulfur (S) and chlorine (Cl) are sometimes added as anionic salts to off-set sodium and potassium and are called anions. The equation that is sometimes used is: milliequivalents (Na + K) – (S + Cl). To get the milliquivalents of each mineral: % of dry matter/constant for mineral based on atomic weight = milliequivalents/100 grams of dry matter.

It is possible to calculate the cation-anion difference for feeds or rations. Below is an example of the calculations for a grass hay and a table with values for other feeds.

Na	.04% /.023 = 2
K	2.44% /.039 = 63
S	.26% /.016 = 16
Cl	.08% /.0355 = 6

Total cation milliequivalents/100 grams = 2 + 63 = 65
Total anion milliequivalents/100 grams = 16 + 6 = 22
Cation-anion difference = 65 – 22 = +43

Feed	Na,%	K,%	S,%	Cl,%	DCAD
Grass	.04	2.44 .	26	.08	+43
Soybean meal	.03	2.14	.47	.08	+25
Alfalfa	.12	1.71	.28	.38	+20
Corn silage	.06	1.00	.14	.08	+18
Barley grain	.02	.61	.15	.18	+3
Corn grain	.02	.37	.14	.05	0

Remember that as the level of potassium increases so does the DCAD as long as the other minerals stay constant. A grass with 3% potassium would have 14 more milliequivalents than the grass used above. When forages with high potassium levels are used in dry cow rations it becomes difficult to add enough anionic salts to be effective because the salts are unpalatable. Dilution of the high potassium forage with feeds containing less potassium becomes necessary. This can be done by using feeds such as corn silage for both far-off and close-up dry cow groups and limiting grass hays and silages. Also, grains that are low in potassium were used in most close-up groups.

A new area of interest is the DCAD level in lactating cow diets. If we take the 2001 NRC requirements for Na, K, S, and Cl as % of dry matter at 45 kg of milk per day we get:

Na = .22%
K = 1.06%
S = .2%
Cl = .28%

If we make the same calculations for these dietary concentrations as we did with the feeds above we get:

Na	.22% /.023 = 10
K	1.06%/.039 = 27
S	.20%/.016 = 13
Cl	.28%/.0355 = 8

Total cation milliequivalents = 10 + 27 = 37
Total anion milliequivalents = 13 + 8 = 21
Cation-anion difference = 37 – 21 = +16

Therefore, the minimal DCAD for lactating dairy cows should be around +22. A recent research report by Chan and others in 2005 looked at DCAD levels of 20, 35, and 50 for early lactation Holstein cows. The feeds consumed in kg dry matter per day were:

DCAD	**20**	**35**	**50**
Corn silage	6.1 kg	6.2kg	5.4
Alfalfa hay	1.7	1.8	1.6
Whole cottonseed	1.5	1.6	1.4
Corn, steam flaked	3.8	3.9	3.5
Mineral/vitamin mix	2.6	2.7	2.4
Soybean meal, 48%	1.4	1.5	1.3
Sodium sesquicarbonate	.13	.20	.24
Potassium carbonate	.05	.17	.26
Magnesium sulfate	.09	.09	.08

The nutrient concentrations in the ration dry matter are below.

DCAD	20	35	50
Crude protein, %	16.7	16.8	16.2
Rumen undegradable protein, % of CP	39	39	39
Net energy, Mcal/kg	1.8	1.7	1.7
Neutral detergent fiber, %	34	33	35
Nonfiber carbohydrates, %	41	40	40
Fat, %	5.0	4.3	4.0
Sodium, %	.45	.49	.63
Potassium, %	1.3	1.6	2.1
Sulfur, %	.33	.31	.29
Chlorine, %	.30	.30	.29

The animal response to the different DCAD diets is below.

DCAD	20	35	50	Sig.
Dry matter intake, kg/day	16.4	17.1	15.3	NS
Dry matter intake, % body weight	3.30	3.38	2.96	*
Milk, kg/day	25.5	24.2	22.4	*
3.5% fat correct milk, kg/day	27.8	25.6	25.7	*
Milk fat, %	4.1	4.0	4.3	NS
Milk protein, %	2.9	3.0	2.9	NS

NS = not significantly different, * = significantly different

The authors conclude that a DCAD between 23 and 33 is probably optimum for lactating cows in cooler weather. Sodium sesquicarbonate (a form of sodium bicarbonate) and potassium carbonate were used in this study to supply sodium and potassium. Certainly the 50 DCAD level was excessive probably because the ration was too alkaline or unpalatable resulting in reduced intake.

Another recent study from France (Apper-Bossard and others) used DACD levels of 0, 15 and 30 to study response to increased cations in rations of lactating dairy cows. They fed these levels with 20 and 40% concentrate in the diet dry matter. Interestingly, they found intake, fat corrected milk, and milk fat percent to increase with increased DCAD but only on the 40% concentrate diet. This indicates that best response would be expected on higher concentrate rations lower in forage. They speculate that the reason for this was a localized rumen buffering effect, along with the ability to maintain blood acid-base status when cows produce acid in the rumen.

The most practical sources of cations are sodium bicarbonate and potassium carbonate. Most of the time sodium bicarbonate is the first choice due to availability and cost. Sodium carbonate and potassium bicarbonate are also available but are more expensive.
Does hot weather make a difference? At this point it appears a DCAD of 37 is needed because the sodium and potassium levels are elevated to be similar to what is recommended under hot conditions. A DCAD of 16, however, would not be adequate. Usually 150 to 250 grams of sodium bicarbonate would be desirable with corn silage based diets and/or high concentrate intakes especially in hot weather.

Rumen Undegradable or By-pass Protein

Nitrogen in the ruminant animal can be converted into microbial protein which in turn can be used as a source of amino acids for milk protein production or other processes. In reverse the protein breakdown process results in nitrogen that is excreted by the animal. Below is the distribution of excreted nitrogen in lactating dairy cows fed three concentrations of crude protein. The units are expressed as grams (g) of nitrogen (N) per cow per day.

	Intake N, g/day	Urine N, g/day	Fecal N, g/day	Total Excreted, g/day	Excreted/Intake, %
12 % protein	359	99	158	257	72
15 % protein	449	138	179	317	71
18% protein	582	228	199	427	73

Source: Tomlinson et al. 1996. American Society of Agricultural Engineers.

As nitrogen intake increases so does excretion in both the urine and feces but the increase is greatest in the urine. At 12% protein in the ration the percent of excreted nitrogen in the urine is 39% compared to 44% at 15% protein and 53% at 18% protein. The bottom line is the majority of the excess fed nitrogen is excreted via the kidney in the urine. In addition much of the nitrogen in urine is in the form of urea which can be broken down to ammonia and be partially volatilized into the atmosphere. It is interesting to note that the efficiency of nitrogen utilization (excreted N divided by N intake) was the same across all three protein levels. In this study the milk production was 20 kg per cow per day and the nitrogen excreted in the milk was approximately 100 grams per cow per day and was not affected by the amount of protein in the ration. The amount retained by the cow however increased with increased protein in the ration going from 16 to 43 to 55 grams at 12%, 15%, and 18% protein.

A recent study from the University of Wisconsin looked at the effect of protein source on nitrogen excretion. Alfalfa and corn silages were fed in equal proportions at 50% of ration dry matter. Solvent (high protein degradability, HD) and expeller (low protein degradability, LD) soybean meals were varied to alter the ratio of rumen degradable to undegradable protein. Both soybean meals were fed in all four diets, only the proportion changed with the HD diets having the majority solvent soybean meal and the LD diets having more of an equal mixture of solvent and expeller.

	DM intake, lbs./day	Milk, kg./day	Milk N, g/day	Milk N, % intake	Milk urea nitrogen, mg/dl
17 % protein (LD)	23	39	177	29	11.9
18 % protein (LD)	24	41	189	27	12.5
17.6 % protein (HD)	21	37	169	28	12.6
18.7 % protein (HD)	24	39	181	25	13.4

Source: Flis and Wattiaux. 2005. Journal of Dairy Science.

Dry matter intake and milk were increased with addition of expeller soybean meal on both the LD and HD diets. Milk nitrogen in grams per day was also increased by addition of expeller soybean meal indicating more amino acids for milk protein synthesis. Milk urea nitrogen was not different but did tend to be higher on higher protein diets. The next table contains information on nitrogen excretion from this experiment.

	Intake N, g/day	Urine N, g/day	Fecal N, g/day	Total Excreted, g/day	Excreted/Intake, %
17 % protein (LD)	618	194	209	403	65
18 % protein (LD)	707	213	232	445	63
17.6 % protein (HD)	596	202	190	392	66
18.7 % protein (HD)	712	223	208	431	61

Source: Flis and Wattiaux. 2005. Journal of Dairy Science.

Clearly more nitrogen consumed results in more nitrogen excreted. This study also demonstrated that as more expeller soybean meal was fed that was lower in rumen degradability than solvent soybean meal, dry matter intake and milk production increased. The opposite was true when solvent soybean meal was fed in excess. Therefore, source of protein is important as is level of ration protein. In addition there were differences in how cows excreted nitrogen based on age or lactation number. First lactation cows excreted additional nitrogen while multiple lactation cows retained more of the nitrogen. The authors concluded that first lactation cows should have rations balanced that are not excessive in protein content especially when containing highly degradable protein sources. A separate first calf heifer group would be needed.

Urea is a small molecule that travels in the aqueous (water) phases of the cow and appears in the blood, urine, and milk. Because milk urea nitrogen (MUN) is a breakdown product of protein, it can be used to monitor protein status of cows. A recent report by Wattiaux (Hoard's Dairyman, 2005) indicates that an MUN of 11.5 to 12 mg/dl would be associated with a ration protein level of 16.5% and this can be an optimal situation that does not reduce milk production while avoiding excess urinary nitrogen. Wattiaux estimates that there is 2 mg/dl change for each one percentage unit change in protein when rations contain 15 to

18.5% protein. Herds with an MUN above 14 would have increased urinary excretion of nitrogen.

How much protein is needed for lactating dairy cows? Certainly the 12% protein in the experiment above would not be adequate for most modern dairy cows. Could we use less than 18% and lose no milk production? In some cases it seems that we can if we have the proper balance of rumen degradable and undegradable protein in combination with adequate rumen available energy. Also it appears age or lactation number should be considered when managing the lactating herd. Keeping first lactation cows apart from the rest of the herd has merit from both a social as well as a nutritional standpoint. A lower protein level is warranted when feeding first lactation cows relative to older cows because they are usually lower producing and do not utilize the nitrogen as efficiently.

Supplemental Fats

Fats in various forms can be fed to dairy cattle up to 7% of ration dry matter. Typical rations including silages, corn, and soybean meal will contain 3% fat without using any high fat feeds. Therefore, it is possible to add another 4% fat to the ration to increase the energy density. To do that we can use oilseeds (soybeans and cottonseeds) and rumen protected fat sources. Some soybean meals contain higher levels of fat such as extruded and expeller. In the following table I have included examples of fat sources with content of fat and energy according to the 2001 National Research Council.

	Fat %	TDN %	Net energy, mcal/kg
Rumen protected sources			
Hydrolyzed fatty acids	99	176	5.41
Calcium soaps of fatty acids	84.5	164	5.02
Whole seeds			
Cottonseeds	19	77	1.94
Soybeans, roasted	19	99	2.75
Soybean meals			
Extruded, full fat	19	99	2.75
Expeller	8	90	2.38
Solvent	2	57	2.13

Usually it is most economical to add 2 % supplemental fat from whole seeds or extruded soybean meal. This results in rations with 5% fat. Anything above this should be added as rumen protected or inert fat (commercial sources are available). The two types of rumen protected fat available are hydrolyzed fatty acids or calcium soaps of fatty acids. Hydrolyzed fatty acids have higher fat content because they are 100% fatty acids and calcium soaps have 18% calcium associated with it which dilutes the fat. That is the reason the energy values are different. There is some research indicated calcium soaps are more digestible, however. Rations should not exceed 7% fat in the overall dry matter from all sources.

To raise the ration fat content by approximately 2 percentage points or .5 kg of fat it would be necessary to feed the following amounts of each feed.

	Amount of feed needed, kg
Rumen protected sources	
Hydrolyzed fatty acids	.51
Calcium soaps of fatty acids	.59
Whole seeds	
Cottonseeds	2.6
Soybeans, roasted	2.6
Soybean meals	
Extruded, full fat	2.6
Expeller	6.3
Solvent	can't be done

Because fatty acids reduce the intestinal absorption of calcium and magnesium requirements for these two increase when fats are fed. Supply .9% calcium and .35% magnesium in the ration when fats are fed. Also avoid feeding excess fat especially in hotter weather. Overfeeding can cause problems with rumen function and reduce dry matter intake.

Literature Cited

Apper-Bossard, E., J. L. Peyraud, P. Faverdin, and F. Meschy. 2006. Changing Dietary Cation-Anion Difference for Dairy Cows Fed with Two Contrasting Levels of Concentrate in Diets. Journal of Dairy Science 88:749-760.

Chan, P. S., J. W. West, J. K. Bernard, and J. M. Fernandez. 2005. Effects of Dietary Cation-Anion Difference on Intake, Milk Yield, and Blood Components of the Early Lactation Cow. Journal of Dairy Science 88:4384-4392.

Flis, S. A. and M. A. Wattiaux. 2005. Effects of Parity and Supply of Rumen-Degraded and Undegraded Protein on Production and Nitrogen Balance in Holsteins. Journal of Dairy Science 88:2096-2106.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. National Academy of Science, Washington D. C.

Tomlinson, A. P., W. J. Powers, H. H. Van Horn, R. A. Nordstedt, and C. J. Wilcox. 1996. Dietary Protein Effects on Nitrogen Excretion and Manure Characteristics of Lactating Cows. Transactions of the American Society of Agricultural Engineers 39:1441-1448.

Wattiaux, M. A. 2005. What Can MUN's Really Tell Us? Hoard's Dairyman, page 697.