FIELD APPLICATION OF THE CORNELL NET CARBOHYDRATE AND PROTEIN SYSTEM MODEL IN A PROGRESSIVE DAIRY HERD

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The Cornell Net Carbohydrate and Protein System (CNCPS) (1) has been discussed for years (2,3,4,5,6,7,8,9). But does it work on a real dairy farm? To answer this question, the model was taken to a 280 cow central New York Holstein dairy farm with a RHA of 24,057 pounds of milk. This progressive, carefully managed farm was selected to enhance the accuracy of the field-collected data.

Materials and Methods

The herd consists of four lactation groups. Although the model was used for all groups, this paper will focus on the results pertaining to string 4, the early lactation older cows. The evaluation commenced in June, 1991. Dry matter intakes, body condition scores, body weights, environmental temperatures and other inputs were collected within two days of the monthly DHIA sample day. Dry matter intakes were calculated over a one day period in June and August, and over a two day period beginning in September. Ration ingredient dry matters were calculated on or close to the time that intakes were determined. All lactating cows were body taped for the first three evaluations in order to accurately estimate each string's average cow weight. Beginning in October, the string's average weight was adjusted according to the average body condition score. An adjustment of 60 lb. per condition score (1-9 scale) (1) was used (10). Nearly all cows were body condition scored each month. DHIA records were used to obtain other animal inputs. Temperature inputs were obtained from thermometers located inside the barn. Ithaca's average temperature was used if farm measurements were not available or incomplete. Hair depth was estimated each month.

Forages were analyzed for dry matter, neutral detergent fiber (NDF), crude protein (CP), soluble protein, acid detergent insoluble nitrogen (ADIN), neutral detergent insoluble nitrogen (NDIN), and minerals every two months, or sooner if the forages appeared to change. Concentrates were analyzed for the same feed fractions approximately every three months.

Diets were evaluated in June, 1991, to establish baselines for both milk production and feed costs per hundredweight of milk. The CNCPS was used monthly to evaluate and then reformulate rations from August, 1991, through July, 1992. Reformulation was based on cow performance, body condition score, feed analysis, feed cost, manure and feed appearance, and feed inventory.

Results and Discussion

The initial June ration is contained in Table 1. The CNCPS evaluation (Table 2) indicated an excess of rumen ammonia and peptides (62.5% and 65.7% over requirements, respectively). Excessive amounts of rumen available nitrogen will cross the rumen wall and be converted by the liver to urea. The energy expended to complete this process (11) (the urea cost) in this ration was estimated to be 2.3 Mcal/day. Despite the abundance of rumen available nitrogen, metabolizable protein

Table 1. Evaluated monthly rations (lb. dry matter).

Feed	$/Ton As Fed	June	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
Corn Silage	25	12.7	14.7	12.2	17.3	16.6	13.3	13.8	16.2	16.7	18.2	14.5	14.2	11.5
Legume Silage	45	5.3	5.6	6.9	7.9	8.7	6.5	5.2	6.7	6.5	6.8	7.1	8.4	10
HMEC[a]	75	10.9	9.3	8.9	5.8	13.9	11.9	14.5	14.8	16.4	13.5	17.7	13.8	12.7
Corn meal	100	4.6	3.7	6.5	3.8								5.4	5.3
WCS[b]	206	5.6	1.9	5.7	5.1	6.0	5.0	5.5	5.6	5.8	5.1	5.6	5.9	5.9
SBM[c]	206		1.6		3.1	3.4	3.1	3.3	2.0	2.9	3.2	.90	1.9	2.5
Heated SBM	240		5.2	9.3	6.1	5.9	5.8	5.8	8.5	7.2	7.5	7.7	4.8	2.5
Protein Mix[d]	236	10.4												
Animal Prot.[e]	(h)	1.0											2.4	2.1
Tallow[f]	(i)	.50					.9	.5						
Beet pulp	134					3.1	2.3	2.1						
Soyhulls	105				3.6									
Granola[g]	96										2.6			
Minerals	(j)	.70	1.8	1.9	1.9	2.2	2.0	1.9	2.2	2.0	2.1	2.2	2.3	1.9
Total (lbs)		51.7	43.8	51.4	54.6	59.8	50.8	52.6	56.1	57.5	59.0	55.7	59.1	54.4
Ration Cost($)		4.58	3.07	3.93	3.93	4.31	4.16	4.06	4.08	4.16	4.11	4.04	4.44	4.23

a = High moisture ear corn, b = Whole cottonseed, c = Soybean meal, d = Mixture of soybean meal, soyplus, distillers grains, corn gluten meal, and minerals, e = Mixture of hydrolyzed feather meal and bloodmeal in June, 1991; mixture of animal protein products, fishmeal, and plant protein products in June & July, 1992, f = Rumen inert fat, g = Mixture of granola bars and cereal, h = $425 in June 1991, $395 in June 1992, i = $750 in June 1991, $880 in Dec, Jan, j = $546 in June 1991, $338 all other months.

Table 2. Ration and Cow Evaluations

Ration	June'91	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June'92	July
ME Balance[a]	1.0	-6.9	1.1	-1.9	4.2	-4.3	-2.3	-1.3	-.9	5.0	2.5	3.8	-1.5
MP Balance[b]	97	-245	171	43	264	-107	-140	319	54	317	215	544	95
Urea Cost[c]	2.3	0.0	1.2	1.5	2.3	.8	.9	1.8	2.0	3.1	1.3	3.1	1.3
MP-Bact[d]	1255	1184	1223	1255	1400	1223	1253	1346	1349	1375	1367	1388	1385
MP-UIP[d]	1533	1071	1754	1734	1795	1457	1535	1871	1762	1858	1596	2034	1614
CP	20.2	16	18.3	18.3	18.2	17.6	17.6	18.7	18.6	19.2	17.0	19.3	18.3
Prot. deg[e]	60.5	62	54.5	57.9	60.1	57.3	57.8	55.6	60.9	61.5	59.7	56.9	60.0
N-Balance[f]	62.5	19.7	35.1	47.9	49.1	35.2	37.3	39.3	53.6	61.4	33.2	50.7	37.1
Peptide Bal[f]	65.7	-5.2	17.2	39.5	39.9	21.2	26.8	18.3	37.5	43	15	28.4	21.9
Cow													
Milk (lb.)	95.7	90.1	99.4	99.9	97	98	104.1	104.4	108.3	99.3	95.4	103.9	102.6
BF	3.28	3.65	3.24	3.56	3.61	3.70	3.47	3.68	3.59	3.62	3.80	3.55	3.67
Protein	2.90	2.94	2.94	2.95	2.94	2.90	2.96	2.86	2.94	3.01	2.90	2.80	2.92
BCS[g]	4.2	5.3	4.9	4.3	4.5	4.3	4.3	4.3	4.3	4.9	5.2	4.9	5.0
DIM	132	103	90	92	104	108	109	96	104	114	104	114	111

a. Metabolizable energy balance (Mcal).
b. Metabolizable protein balance (grams).
c. Urea cost, Mcal/day
d. Metabolizable protein from bacteria and undegraded feed (grams).
e. Model calculated protein degradability based on feed analysis and passage rates.
f. Rumen NH_3 and peptide balance, as percent above or below requirement.
g. Body condition score, 1-9 scale.

(MP) was in excess by only 3.6% (97 grams). The ration was reformulated, with the animal fat, protein concentrates, and whole cottonseed being removed or reduced and replaced with more corn silage, corn, soybean meal and heated soybean meal. The ration was changed to decrease cost and increase rumen microbial output.

The August evaluation detected an apparent 7.4 lb. difference between observed and predicted intakes (Fig. 1), and a 5.0 lb. drop in production since June (Fig. 2). The large intake discrepancy resulted in the model predicting a large deficiency of both metabolizable energy (ME) and metabolizable protein (MP) (Table 2). It was imperative to determine why intakes appeared to be lower than expected. First, the dry matters of the forages were rechecked. The dry matter of the corn silage was accurate while that of the haylage varied by over 15 percentage points between the upper and lower regions of the bunker silo. This discrepancy accounted for a maximum of 3 lb. of the intake difference. Next, it was verified that cow numbers were correct, that there had not been any feed added from another string, and that the orts had been properly weighed. Lastly, the distribution of cows by days in milk was examined. It was found that 25% had freshened in the last 40 days, many in hot weather. Fresh cows and cows that freshen in hot weather often have intakes lower than predicted by most dry matter intake equations. For example, it has been shown that dry matter intake only reaches 67% of maximum during the first week of lactation, and does not approach its apex until 8-10 weeks post- calving. Intake appears to increase curvilinearly until the maximum level is obtained (12). It is very likely that the skewed cow distribution was largely responsible for the intake discrepancy. The potential for this problem to occur will exist until there is an accurate multivariate dry matter intake prediction equation which utilizes variables including days in milk and environmental temperature. The equation would then be run on each member of a string to give an accurate estimation of the string's intake. Production and intake may also have been lowered by the use of feed analyses which were not current and thus did not accurately represent the crude protein values of the forages being fed.

The spike in intakes in November was believed to be due to the corn silage having both a low NDF level (39.4%) and a high proportion (about 45%) of very hard corn kernels. Many of these corn kernels were not digested by the cow and hence did not contribute to the animal's energy requirement. The model could account for this by lowering the ruminal and intestinal digestion rate of the starch in the corn silage until the ME and days to condition change were as they appeared to be in the herd. Calibration of the model in this manner is only recommended after the situation has been carefully evaluated and the change made makes good biological sense. A rumen inert fat was added to the ration in December and January in an attempt to compensate for excessive condition loss occurring in cows less than sixty days in milk. Historically, supplemental fat has depressed intakes in this herd. It is suspected that the added fat caused some intake depression, since when it was removed in February intakes again approached predicted values.

Milk production was adjusted for milk fat (3.5%) and corrected for days in milk (100 days) (Figure 2). Although many variables are involved, it appeared that the rise in production seen throughout the winter months, followed by a herd record in March, was at least partly due to the CNCPS model. The drop in production in April coincided with the addition of a cereal byproduct. It appeared that when this product was fed, energy partitioning was shifted so that more was partitioned to energy reserves and less to production (Table 2). It has been proposed (13) that when a diet is fed which causes a high propionate production that insulin levels may increase. The increased insulin level stimulates nutrient uptake by tissues, resulting in decreased lipolysis, milk

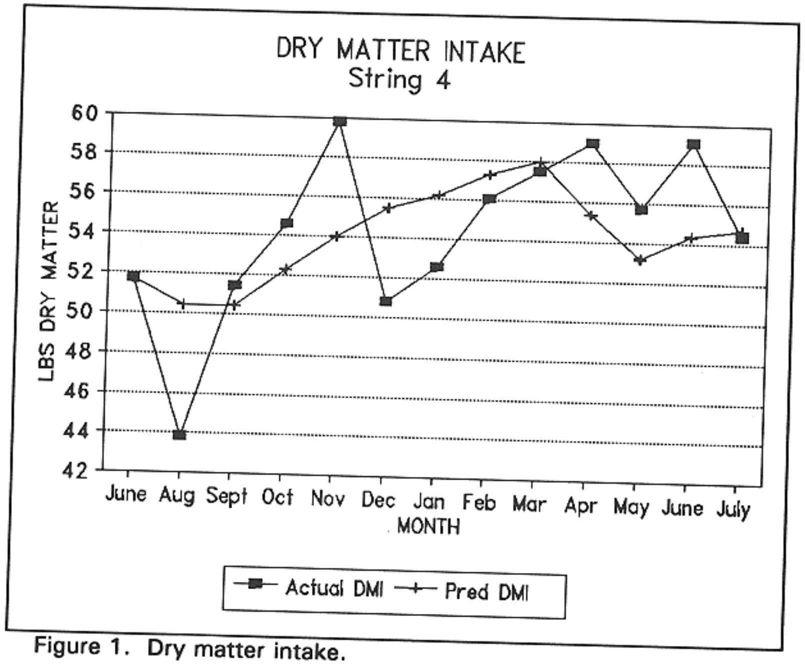

Figure 1. Dry matter intake.

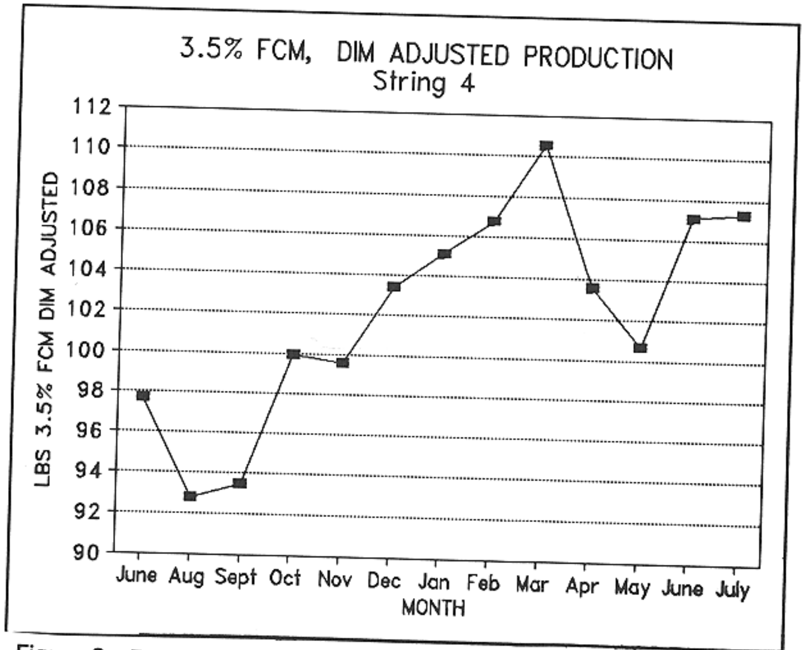

Figure 2. Fat corrected and 100 DIM adjusted milk production.

production, and fat yield. The byproduct was removed from the ration in May, yet production did not appear to respond until protein was increased in the June ration.

Economic Considerations

As stated previously, June of 1991 was used as a baseline for both milk production and feed costs per hundredweight of milk. Although it would have been better to have tracked the herd for several months prior to instituting any changes, using June as a base month should be valid since that or a similar ration had been fed for at least the previous year, and since actual and predicted intakes were exactly equal for that month. The feed prices used were held constant throughout the entire year (Table 1). Feed costs per lb. of dry matter were reduced from the base month (Fig. 3). The sharp drop from June to August was due to the removal of both a fat product and excessive and expensive protein sources. The rise seen in December and January was from a rumen inert fat being brought into the ration. The increased cost starting in May was due primarily to haylage being substituted for corn silage for inventory reasons.

Feed costs per hundredweight of 3.5% FCM reflect ration cost, dry matter intake, and milk production (Fig. 4). The large drop in August and spike in November were due to very low and high dry matter intakes, respectively. The downward trend from November to March was due primarily to a steady rise in production, while the higher costs from April through July were due to a combination of slightly lower milk production, higher dry matter intakes, and increased ration costs. Figure 4 also indicates what feed costs would have been if the base month ration had been fed for each subsequent month. The area between the two curves represents a savings of $21,000. A calculated herd savings of $74,600 was realized when the same technique was applied across all four strings. This procedure is not completely valid, however, since the base month ration was not altered with changing dry matter intakes or milk production. As noted previously, though, the base month or a very similar ration had been fed for at least a year prior to the onset of the study.

Recommendations on field applications of the CNCPS

This field trial indicates that the CNCPS model can be used to both more accurately predict animal requirements and the supply of nutrients needed to meet these requirements. The following summarizes what is required to obtain the potential benefits from using the CNCPS.

A. Animal and environmental inputs

Table 3 lists the necessary animal and environmental inputs and their relative sensitivities. All * inputs can be obtained from a DHIA AIM7-S1-EXTS0043 report. Age and frame size affect the model predicted requirement for growth. This requirement is highly sensitive in young lactating animals. Errors in estimating body weight and condition score are of relatively low sensitivity. Every 55 pounds of bodyweight makes about a one lb. difference in model predicted intake. We recommend body taping about 25% of each first, second, and third or greater lactation cows for the initial evaluation. The value used for body weight in future evaluations should be obtained by adjusting the initial body weight for changes in body condition score. An average of 60 pounds body weight per CNCPS condition

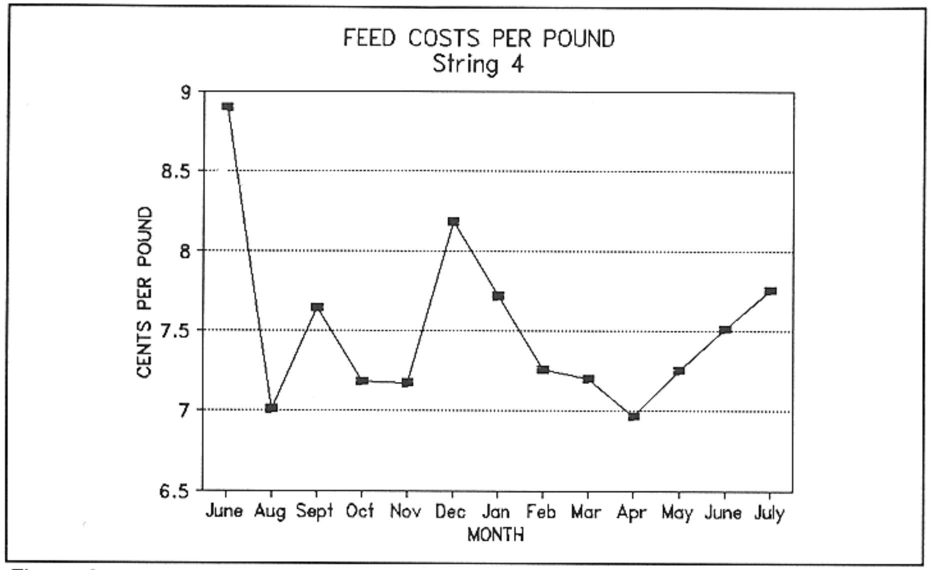

Figure 3. Feed costs per pound of dry matter.

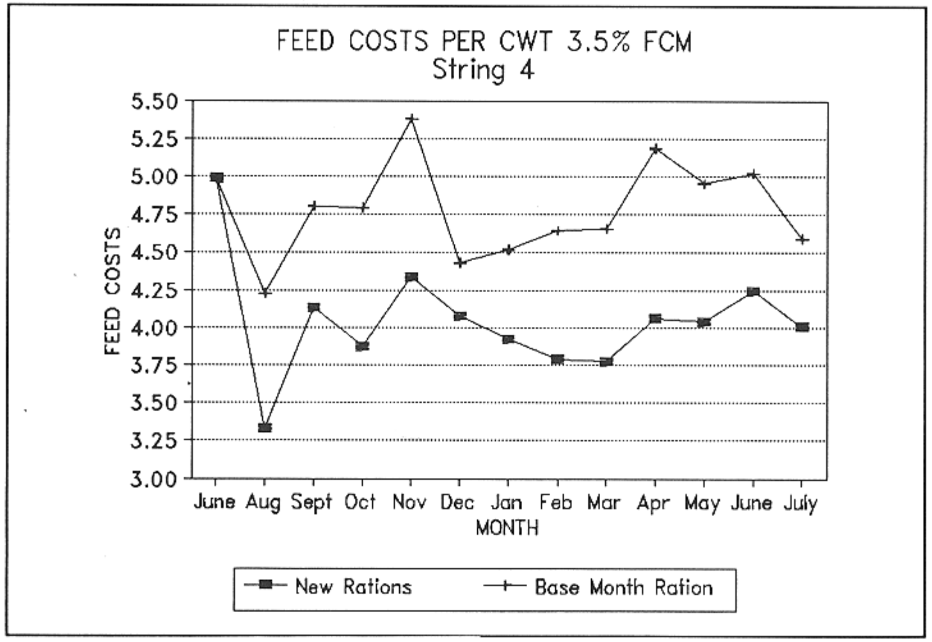

Figure 4. Feed costs per cwt 3.5% FCM.

Table 3. Relative sensitivity of animal and environmental inputs.

	Relative Sensitivity			
Animal Inputs	High	Medium	Low	Variable
Age*[1]	Young		Old	
Frame size				X
Body weight			X	
Flesh condition			X	
Days pregnant*	> 150	100-150	< 100	X
Days In Milk*	DIM, lactation number, and RHA are used to calculate model lactation, fat, and protein curves.			
Lactation #*				
RHA*				
Milk yield*	X			
Butterfat*	X			
Protein*	X			
Ave. daily gain	Young		Old	X
Calf weight				X
Environmental				
Wind speed				X
Previous temp	X			
Current temp	X			
Rel. humidity	Currently inactive			
Storm exposure				X
Night cooling				X
Hair depth				X
Hide thickness				X
Hair coat				X
Heat stress				X

1. All * values can be obtained from DHIA report AIM7-S1-EXTS0043.

score (1-9 scale) should be used (10). Predicted days to change a condition score varies only slightly over the range in body condition scores typically observed in a well managed herd (2.5-3.75, 1-5 scale). The percentage of cows that must be condition scored will depend on the homogeneity of the group. In most situations, 25% of the animals should be adequate. The risk of use in estimating a condition score is relatively low as long as the user is consistent in monitoring monthly changes. It is extremely important to monitor condition scores on a monthly basis in order to appropriately assess how well the energy balance was predicted and to reformulate the ration as needed.

Days pregnant can be estimated from either farm or DHIA records. The input is relatively insensitive at less than 100 days; moderate at 100 to 150 days; and highly sensitive when pregnancy is beyond 150 days. Lactation number, days in milk, and RHA are used to predict milk, fat, and protein values. These inputs are obviously of high sensitivity and have a large impact on predicted DMI and required ME and MP. Expected calf birthweight should be obtained from farm records. The input becomes relatively more sensitive at advanced stages of pregnancy.

Management factors are not currently operational for the dairy submodel. Previous and current temperatures are two environmental inputs with high sensitivity. Every 10°F increase in the previous temperature input results in approximately 0.6 Mcal less ME needed for maintenance. The thermoneutral temperature for the current temperature variable is 68°F. Every 10°F increase in the current temperature above 68°F results in a 1.1 pound decrease in predicted intakes, while every 10°F change below the thermoneutral temperature increases intake by 1.1 lb. Hair depth is not the length of the hair, but rather the depth of the coat. Hide thickness values are obtained from the CNCPS manual (Holstein = 1). Both of these variables alter the amount of ME needed for maintenance. Their relative sensitivity is related to wind speed, coat condition, and environmental temperature. All of these inputs become active at environmental extremes to which dairy cattle are not usually exposed to for prolonged periods of time.

B. Feed inputs

Feed analysis values required are DM, NDF, CP, soluble protein, ADIN, and NDIN. Effective NDF (ENDF) can be estimated from the CNCPS manual, the feed library, and personal experience. One should determine the specific ENDF level which appears to minimize rumen disorders and to optimize production, dry matter intake, and fat percent on a farm with its feeds. Be certain to keep that level in mind when reformulating rations. The model is highly sensitive to ENDF levels. Microbial yield is reduced 2.5% for every 1% decrease in ENDF below 20% of ration dry matter.

All available feed analyses with the analytical values required by the CNCPS were collected in order to evaluate the model's sensitivity to the various feed fractions. Table 4, although somewhat preliminary, indicates which feed analyses are necessary when several common feedstuffs are fed at normal levels. Suggested compositional values for these and other feedstuffs are found in P.J. Van Soest's paper in this proceedings. Laboratories usually report ADIN and NDIN results as a percent of dry matter. These values need to be divided by the percent crude protein for use in the model. Assuming minimal variation in harvest dates and among corn varieties, one or at the most two representative analyses of corn silage and HMEC per crop should be sufficient. Haylage should be analyzed as it appears to change or as different crops are fed. One NDIN per crop should be sufficient. Analysis for crude and soluble protein should suffice for shelled corn. Soybean meal and Soyplus were generally very consistent. One may consider determining protein solubility on soybean meal and NDIN on Soyplus if the same load of feed is going to fed for a sufficient length of time. That length of time will vary with the farm size, but a general recommendation is one month. Analytical results of whole cottonseed are often quite variable, probably due more to problems with grinding and representative sampling of the ground sample than to true variation in the feed. Consider analyzing whole cottonseed for crude and soluble protein if the supply will last for a sufficient length of time. Animal proteins do not contain cellulose, hemicellulose, or lignin, thus analyzing for NDF, ADIN, and NDIN is not necessary. These feeds should be analyzed

for crude and soluble protein if experience dictates that much variability exists. In addition, the digestion rates for the B2 and B3 protein fractions of animal proteins should be set at .05% per hour.

Table 4. Recommended minimum analysis of selected feeds for use by the CNCPS.

Feedstuff	CP	Sol Prot	ADIN	NDIN	NDF
Corn silage[1]	Y	Y	V	V	Y
Alfalfa silage[2]	Y	Y	Y	V	Y
HMEC[1]	Y	Y	V	V	Y
Shelled corn	Y	Y	N	N	N
Soybean meal	M	M	N	N	N
Soyplus	M	N	N	M	N
Animal byproducts	M	M	N	N	N
Whole cottonseed	M	M	N	N	N

Y = Perform at least once per crop (1) or cutting (2), or whenever feed is analyzed.
N = Analysis not necessary, use CNCPS dictionary value.
V = Perform once per crop (1) or cutting (2), assuming minimal variation in harvest dates and among varieties.
M = Perform only if that load of feed will be in inventory for a sufficient length of time (e.g. one month).

Formulating rations

The following sequence of steps should be followed when evaluating or formulating a ration using the CNCPS (8,14).

1. Compare predicted versus actual intake. This is the most important step, since an inaccurate intake value introduces error into all other predictions. Determining intake and some common errors encountered therein have already been discussed earlier in this paper.

2. Compare energy allowable to actual milk production and days to condition change. Do the predictions agree with what has been observed on the farm? Adjust the ration so that the desired level of milk production is supported and days to condition change is appropriate for cows in that stage of lactation.

3. The next step is to balance for ENDF. Remember to consider past ENDF levels and what level appeared to minimize health disorders and maximize production and dry matter intake on this farm. Recall that microbial yield is reduced by 2.5% for every 1% decrease in ENDF levels below 20% of ration dry matter.

4. Balance for rumen bacterial nitrogen and peptide requirements. First, add or subtract feeds such as soybean meal that are high in degradable true protein until peptide needs are met; they are required for optimal fermentation of nonstructural carbohydrates. Then add or subtract feeds high in NPN or soluble protein until ammonia needs are met. Ammonia is required for fermentation of structural carbohydrates. It is probably wise to allow a 10-15% safety margin for rumen nitrogen and peptides.

5. Review the energy cost of urea synthesis. A urea cost of 1.0 Mcal/day or less is a goal. It is often difficult to have a urea cost lower than this when a ration is fed that is high in fermented feeds and soluble protein.

6. Balance the animal's MP requirement with the addition of feeds high in undegraded protein. About 45% of the MP should come from bacteria in early lactation cows, and about 55% in later lactation cows (15). Allow for a 3-5% safety margin when balancing for metabolizable protein.

7. Iterate! Look at the entire ration when a change is made, and increase or decrease a feed that will help out in more than one deficient area. For example, if ME and ENDF levels are low and peptide and nitrogen levels are high, increase corn silage and decrease soybean meal.

8. Compare essential amino acids supplied to requirements. Rations are considered acceptable if supply is at least 90% of requirement.

7. Use your nutritional knowledge to evaluate the ration. Does it make sense? The response of the cows will indicate if the inputs are correct. Remember that this is a model, and it is highly dependent on judgements in choosing inputs. Additionally, it is under continuous refinement since completely accurate equations for all variables are not yet available.

Conclusions

1. The CNCPS model can provide a more accurate and complete accounting of a cow's nutritional requirements and how feeds can be used to economically and efficiently meet them. The model was used to reduce feed costs and nitrogen wastage and increase production on a particular farm.

2. The CNCPS model requires more information than traditional ration balancing programs, including feed carbohydrate and protein fractions, body condition scores, and accurate dry matter intakes.

3. More nutritional knowledge is required by the user since more judgements are necessary in choosing inputs, evaluating results, and in making adjustments in inputs. Also, additional time is required of the user because of the number of inputs requested by the model and because of the iterative approach used to balance a ration.

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