Updates to the Cornell Net Carbohydrate and Protein System v6.1 and implications for ration formulation

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INTRODUCTION

The Cornell Net Carbohydrate and Protein System (CNCPS) has been in development for nearly 30 years, and various versions of the CNCPS or implementations of the program (CPM Dairy, AMTS.Cattle, NDS, DinaMilk) have been used in the dairy industry to evaluate and formulate rations for more than 10 years. The long-term objective of the CNCPS modeling effort has been to provide a field usable model that accounts for a large proportion of the variation in ration formulation and animal performance and is based on a functional mathematical description of the biology of both growing and lactating cattle and their diet and management. Models such as the CNCPS are evolutionary in that as research progresses, model improvements and enhancements occur, provided adequate resources are available for programming and evaluation. This process is similar to the process that occurs when a new Nutrient Requirements of Dairy Cattle publication is produced. Unlike the NRC publications, historically published every 10 years, the CNCPS has been updated on a somewhat continuous basis. Each update has allowed us to predict performance with increased accuracy. However, these updates have at times, caused confusion in the field. This confusion is a combination of changing guidelines and a lack of awareness as to what the changes were and why/how they impact predictions. The objective of this paper is to describe recent updates and explain what impact they have on predictions.

The changes that resulted in the development of CNCPSv6 were described by Tylutki et al. (2008). This paper will focus primarily on the changes that have occurred since the publication by Tylutki et al. (2008) with references to v6.1 but more substantive changes will be highlighted here. The changes will be listed in order of calculation such as maintenance, then growth or lactation or submodel impacting such calculations.

MAINTENANCE

The first change primarily affects growing cattle and the update was to remove the link between the current body condition score (BCS) and maintenance energy requirements. Data from France that was used in the INRA system for lactating beef cattle on pasture made an association between previous level of nutrient intake and BCS and maintenance requirements. As cattle achieved greater BCS theoretically they consumed more energy and thus had larger organ mass and with larger organ mass, more energy was partitioned to maintenance and away from growth. Thus, prior to v6.1, as the BCS input was increased in growing cattle, the greater the maintenance requirement and the less energy available for growth. The outcome was a difference of almost 0.4 kg/d in ME allowable growth as the score ranged from 1 to 5. This resulted in the potential to overfeed energy to heifers since the model would predict less ME allowable gain than was truly available at an average BCS. This is also true for CPM Dairy.

Another update that impacts the maintenance requirement of all cattle is the calculation of surface area. The equation to calculate surface area used in the CNCPS up to v6.0 was from Mitchell (1928) and that equation (0.09 x $W^{0.67}$) was derived from sheep weighing from 14, 24 to 38 kg (Berman, 1998). Another equation by Brody (1945) was developed on 50 Holstein cattle from 41 to 617 kg (0.14 x $W^{0.57}$) and this equation was validated using body measurement data of Holsteins from Heinrichs et al., 1992 by Berman (1998) and adopted for use in the model. The Mitchell equation will under-estimate surface area by 7-10% at 30 to 50 kg (65-110 lb) BW and thus heat loss, and will over-estimate surface area by 23% at 650 kg (1,450 lb) BW at maturity, thus decreasing the effect of evaporative heat loss due to smaller surface area (Berman, 1998)

FEED FRACTIONS AND POOL ASSIGNMENTS, PASSAGE RATES AND RATES OF DIGESTION

Multiple changes were made to correct errors and prepare the model for future development, especially consideration for a VFA submodel. The first step was to expand the CHO pools to four A fractions (VFAs, Lactic, other organic acids, e.g. malate, sugar) as well adjusted CHO kd values downward based on gas production data from Dr. Pell's group. Previous versions utilized a 200-300% per hour kd for sugar. A 300% per hour kd implies rumen retention time of 0.2 hours (12 minutes); a value greater than the mean growth rate of rumen bacteria. The original value for sugar rates came from *in vitro* fermentation studies from Jim Russell's lab using pure cultures of *s. bovis* grown on glucose. To update this, Dr. Pell's graduate students measured mixed sugar fermentation by mixed rumen bacteria using the gas production technique to vary between 40 and 60% per hour (rumen retention time of 100 to 150 min) (Molina, 2002). Updates to the changes in degradation rates of the various fractions are found in Table 1.

Based on the changes in rates of degradation and passage there is a significant impact on soluble pool movement out of the rumen. As an example, the data in Table 2 demonstrates a 16% reduction in sugar (CHO A4) degradability. If a lactating dairy diet fed at 24 kg contains 5% sugar, this results in 192 g less sugar degraded. The 192 grams would equate to approximately 15 g lower MP flow, or approximately 1 liter lower MP allowable milk.

Further, it was assumed PRO A utilization was instantaneous with a kd of 10,000%/hr implying a rumen retention time of 0.6 min. This would imply that any addition of urea would be dissolved and captured by rumen bacteria in 36 seconds, an unrealistic expectation. This value was generated to represent the rate of solubilization and not necessarily microbial uptake. With these changes rates for pools like PRO A kd were reduced to 200%/hr. There were many other updates to the version including: new

Table 1. Feed degradation rates (%/hr) used for CHO and PRO pools in CNCPSv6 and prior to version 6.1

Component	Prior to v6	V6.1
CHO A1 (VFA)	Not modeled	0%
CHO A2 (lactic acid)	Not modeled	7%
CHO A3 (other organic acids)	Not modeled	5%
CHO A4 (sugar)	300-500%	40-60%
CHO B1 (starch)	20-40%	20-40%
CHO B2 (soluble fiber)	20-40%	20-40%
CHO B3 (available NDF)	4-9%	4-9%
CHO C (unavailable NDF)	0%	0%
Pro A (NPN)	10,000%	200%
Pro B1 (soluble true protein)	130-300%	10-40%
Pro B2 (moderately degraded protein)	3-20%	3-20%
Pro B3 (slowly degraded protein, bound in NDF)	0.05-2.0%	For forages, same as the CHO B3
Pro C (unavailable protein)	0%	0%

Table 2. Calculated rumen degradability of several pools using previous and current kd and kp phases.

	Prior to v6			V6.1		
Pool	Kd, %/hr	Kp, %/hr	% degraded	Kd, %/hr	Kp, %/hr	% degraded
CHO A4	500	4	99	60	12	83
CHO B1	20	4	83	20	6	77
Pro A	10,000	4	100	200	12	94

passage rate equations, maintenance requirements for heifers were updated, and error corrections to more appropriately account for microbial ash accumulation, rumen ammonia flow, and updating DMI equations. These changes reduced predicted microbial protein flow approximately 5-7% compared with previous versions.

Historically, NFC was calculated as:

$$NFC = 100 - (CP + Fat + Ash + (NDF - NDIP))$$

This assumed that the protein within NDF remained during the NDF extraction. While true when the NDF assay does not include sodium sulfite, Mertens (2002) AOAC approved NDF assay includes this reagent and we support the use of it as we move forward. Given that the majority of commercial laboratories routinely use sodium sulfite and amylase to improve filteration, we adopted the AOAC NDF method for use within CNCPS. Thus, NFC is now calculated as:

$$NFC = 100 - (CP + Fat + Ash + NDF)$$

The non-fiber-carbohydrate (NFC) concentration has been decreased (e.g. from 40 to 38.4% DM). This represents another change within the calculations.

The AOAC NDF assay also suggests that NDF should be reported on an organic matter basis (vs. DM basis). This is being further investigated but is expected to be implemented in the near future. There will be an exception list of feeds that will be analyzed either without sodium sulfite (commercial soybean products and animal protein products are the primary feeds affected by this) or we will use another measure to generate an NDF value and associated protein. Since animal proteins do not contain fiber, the use of NDF is not appropriate to begin with and this is under consideration as we move forward. Overall, the net result of these changes are dietary NFC values will be reduced 2-4 units if this change is implemented.

In CNCPS v6.1 the soluble pools, carbohydrate (CHO A) and protein (A and B1), have been re-assigned to the liquid passage rate equation to more appropriately reflect the biology of the cow. Both the solid and liquid passage rate equations were updated and account for a greater amount of variation in liquid turnover than the equation found in v5.0 (Seo et al. 2006). Prior to v6.1 the soluble pools were predicted to flow out of the rumen with the solids passage rate, thus with the high digestion rates and the slow passage rates, all of the soluble fractions were degraded in the rumen. This change in passage rate assignment increases the predicted outflow of soluble components, thus reducing microbial yield and estimated ammonia production and rumen N balance. These changes improve the sensitivity of the model to changes in feeds high in soluble carbohydrates and protein and reduce, but don't eliminate, the under-prediction bias observed in a previous evaluation of the model (Tylutki et al. 2008).

METABOLIZABLE ENERGY

Overall, the model predicts ME allowable milk with reasonable accuracy. An evaluation by Huhtanen using a research dataset indicated an $R^2 = 0.99$ for predicted vs observed ME allowable when evaluated with diets ranging from 12 to 18% CP and milk yields from 15 to 40 kg/cow/d. Our own internal data sets provided similar predicted versus observed relationships when evaluated on a per cow basis among data sets (Tylutki et al., 2008). However, an update that can have a significant change in ME available for milk and tissue is the implementation of the digestibility of fatty acids on an individual fatty acid basis. Previously, the CNCPS used a global intestinal fat digestion coefficient, 95%, for all ether extract appearing at the small intestine. With the work that has been conducted to better estimate fatty acid digestibility, along with the development of the fatty acid submodel in CPM Dairy, we determined the model was more accurate in predicting ME allowable milk if the digestibility of individual fatty acids were used in place of the global coefficient. The digestibility values used are found in Table 3 and are based on data and reviews from Lock et al. (2006) and Moate et al. (2004).

Table 3. Post-ruminal fatty acid digestibility used in the CNCPS v6.1.

Fatty acid	Post-ruminal digestibility, %
C12	95.4
C14	75.1
C16:0	75.0
C16:1	64.0
C18:0	72.0
C18:1	90.0
C18:2	78.0
C18:3	77.0
Other	58.7

PROTEIN FRACTIONS AND METABOLIZABLE PROTEIN

The first step in this process is to ensure that the model is capable of predicting the MP allowable and the most limiting nutrient MP or ME allowable milk with good accuracy and precision. The current CNCPS/CPM Dairy balances for amino acids using a factorial approach based on the amino acid content of the predicted metabolizable protein (MP) supply and the amino acid profile of the tissue and milk. The approach is identical to that described by O'Connor et al. (1993) with many upgrades and modifications to the prediction of MP supply (Fox et al., 2004; Seo et al., 2006; Lanzas et al., 2007a,b; Tylutki et al., 2008). In order to have confidence in the ability of the model to predict AA accurately, the model needs to be able to account for the MP allowable milk with reasonable accuracy and precision. During the development of CNCPS v6.1 (Tylutki et al., 2008; Van Amburgh et al. 2007), we have refined the model to be more sensitive to MP supply and thus more robust in evaluating the most limiting nutrient under field conditions. This has allowed current users to balance diets at crude protein levels below 16% and maintain milk yield to increase overall efficiency of use and in many cases enhance milk protein output.

Proteins, peptides and free amino acids in the soluble pool can be rapidly degraded, but because they are in the soluble pool, they move with the liquid phase from the rumen to the small intestine and supply the cow with AA. There are now several data sets that demonstrate that the soluble pool of feeds contributes between 5 and 15% of the total amino acid flow to the duodenum of the cow (Hristov et al. 2001; Volden et al., 2002; Choi et al. 2002a,b; Reynal et al. 2007). The pool sizes of the NPN and soluble true protein have been updated to reflect the presence of small peptides in what was previously considered the NPN fraction (Table 4) (Ross and Van Amburgh, unpublished).

As the data illustrates, regardless of protein precipitating agent, as filter paper pore size is decreased, the amount of true protein recovered increases. Thus, what historically has been defined as PRO A was severely over-estimating true NPN supply.

Additionally, peptide length does not vary based upon pore size. Based upon these findings, NPN as a percent of soluble protein for forages has been adjusted and this will most likely occur for all of the remaining feeds in the feed library. In earlier versions of the model, the library described the soluble CP fraction of fermented forages as 95% NPN for feeds such as alfalfa silage, 45% has been implemented in the current version. This does not mean that all alfalfa silages fall into this range, but without a functional field applicable assay and given the values we derived, it was a reasonable compromise for this release. Feeds such as soybean meal have been reduced from 25 to 5% NPN % soluble protein. This greatly impacts protein A and B1 pool sizes (Table 5). These shifts in pool sizes, coupled with reduced microbial yield predictions, results in excessive peptide supply for the rumen. Therefore, reductions in dietary RDP requirements (and crude protein) are achievable.

Table 4. Precipitable true protein of trypticase with varying protein precipitating agents and filter paper pore size. The 20 µm pore size represents Whatman 54 filter paper.

PPT Agent	Filter pore, µm	True protein	Filtrate peptide chain length	True Protein, % of largest pore
Tungstic acid	1	34.4	3	1,911%
	6	23.1	4.3	1,283%
	20	1.8	4.2	
Stabilized TA	1	31	3.3	705%
	6	28.5	3.4	648%
	20	4.4	3.6	
TCA	1	2.57	3.4	612%
	6	0.78	4.3	186%
	20	0.42	5	

Table 5. Calculated Protein A and B1 pool sizes using original and updated NPN % soluble protein values using an alfalfa silage as an example.

Component	prior to v6	v6.1
CP % DM	20%	20%
SP % CP	55%	55%
NPN % SP	95%	45%
PRO A + B1 (% DM)	11.00%	11.00%
PRO A (% DM)	10.45%	4.95%
PRO B1 (% DM)	0.55%	6.05%

The soluble proteins and peptides move with the liquid phase from the rumen to the small intestine and supply the cow with AA (Choi et al. 2002; Volden et al., 2002; Hedvquist and Uden, 2006; Reynal et al. 2007), thus, to account for the AA profile of these peptides, we need to provide an AA profile for the soluble pool and as the model moves forward we will be adopting whole feed amino acid values, not the insoluble residue (Sniffen et al. 1992). Thus, the CNCPS was adjusted so that CHO A1-A4 and PRO A-B1 flow with the liquid phase and CHO B1 (starch) always flows with the concentrate solid phase. Table 5 provides an example of integrating the pool phase flow and kd changes. This is currently being done by mathematical manipulation of the pools and rates but a more robust approach is needed to account for more variation in the predicted AA flow.

Further, relative to ruminal N requirements, the previously described peptide requirement was developed from in vitro data from Chen et. al. (1987) and related papers. Data from Broderick and Wallace (1988) reported that peptide uptake by the microbes is a rate limiting step versus peptide formation. This, coupled with PRO B1 being a component of soluble protein, indicates that peptide supply is probably never limiting in the rumen as we have calculated. Also, peptides from endogenous protein flow (Ouellet et al. 2004) are used by the microbes with good efficiency and with ruminal microbial protein turnover there are many sources of peptides not considered when the model was developed. This suggests that feeding to supply peptides for ruminal requirements as has been done for many years causes us to overfeed protein and that the rumen is rarely short on peptides for microbial utilization.

This version of the CNCPS uses an overall efficiency of use of MP to net protein (NP) of 0.67, the same value utilized in the 2001 Dairy NRC (Tylutki et al., 2008; National Research Council, 2001). In addition each amino acid has individual efficiencies for maintenance, growth and lactation and the efficiencies are currently static. Data from recent studies in lactating cattle call into question the use of static efficiencies for either overall MP or specific AA and this makes sense given the possible roles certain AA have in metabolism (Doepel et al., 2004; Pacheco et al., 2006; Wang et al. 2007; Metcalf et al., 2008).

Metcalf et al. (2008) challenged the use of a static efficiency and observed a range in efficiency of use of 0.77 to 0.50 as MP supply was increased. They further determined using a best fit of data that the optimal efficiency of use of MP to NP was between 0.62 and 0.64 for the average cow. This is quite a bit lower than our current value but is consistent with the data of Doepel et al. (2004). Taking the simple mean of the efficiencies from the Doepel et al. (2004) publication, the average efficiency of use of the essential AA is 62.2%, again lower than the value we are currently using in the model but consistent with the data of Metcalf et al. (2008). Most likely, any change in efficiency of use of MP or amino acids will be associated in a change in ME utilization, thus the absolute differences within one nutrient will be hard to detect or manipulate.

Additional changes have been made to the calculations for metabolic fecal nitrogen. This was a double-accounting error that resulted in under-estimating endogenous protein losses. As this directly impacts maintenance protein requirements, MP maintenance has increased slightly.

PREDICTED N EXCRETION

The CNCPS is designed to be used in the field to predict nutrient excretion as part of a nutrient management decision making process. Through evaluation, the partitioning of urine and fecal N excretion was determined to be inconsistent with total collection studies, thus a study was undertaken to improve this partitioning. In part this was done to help us refine N feeding and excretion in relation to milk. Since urinary urea N is the most volatile form of excreted N and also represents the true excess N, better predictions of urinary N would help nutritionists formulate to decrease this form of N excretion. Data to evaluate model predictions were compiled from published studies (n=32) that reported total collection N balance results. Considerable care was taken to ensure that the treatments included in the data set (n=104) accounted for >90% of the N intake (NI). Unaccounted N for the compiled data set was 1.47% ± 4.60% (mean ± SD). The results showed FN predictions could be improved by using a derivative of an equation proposed by Marini et al. (2008): FN (g/day) = (((NI (g/kg organic matter) × (1 – 0.842)) + 4.3) × organic matter intake (kg/day)) × 1.20, which, when evaluated against the compiled N balance data, had a squared coefficient of determination based on a mean study effect (R^2_{MP}) of 0.73, concurrent correlation coefficient (CCC) of 0.83 and a mean square prediction error (MSPE) of 781. Prior to this, urinary N was being over-predicted by the CNCPS due to inconsistencies in N accounting within the model. Incorporating the more accurate FN prediction into the current CNCPS framework and correcting the endogenous protein calculation error considerably improved UN predictions (MSPE = 970, R^2_{MP} = 0.86, CCC = 0.90). The changes to FN and UN translate into an improved prediction of total manure N (MSPE = 623, R^2_{MP} = 0.96, CCC = 0.97) and were incorporated into the latest version of the CNCPS v6.1.

METHANE PRODUCTION

Due to the pressure being put on the dairy industry to be more environmentally friendly, and due to sporadic requests from groups for predictions, we decided to identify an equation that would provide robust predictions of methane production with inputs currently available in the CNCPS for both beef and dairy cattle. A review of the literature was conducted and several equations were identified. There are many extant equations available for predicting methane and a couple recent evaluations of new prediction equations (Ellis et al., 2007; Mills et al. 2003). We adopted two equations for used in the model, the first equation we adopted was from Mills et al. (2003) (non-linear equation 3, "Mitschelich 3") that included an exponential function describing the increasing effect of ME intake on methane production with an additional ratio for starch/ADF relationships. This equation is specifically for dairy cattle, both lactating and dry, and somewhat complex due to the number of variables requiring quantities of dietary components but easily available within the structure of the CNCPS. The equation is: CH_4 (MJ/d) = $45.98 – (45.98e^{(-1*(((-0.0011*starch/ADF)+0.0045*MEintake,}$ where starch and ADF are kg of dry matter consumed and ME intake is in megajoules. The equation adopted for beef cattle was from Ellis et al. (2007) and is equation 14b. The equation was chosen because it had the lowest RMSPE (14.4%) and the highest R^2 of the evaluated equations, 0.85. Again, it is a fairly complex equation requiring ME intake, ADF and lignin, but all factors utilized in the CNCPS. The equation is: CH_4 (MJ/d) = 2.94 + 0.0585 * ME intake (MJ/d) + 1.44 * ADF (kg/d) – 4.16 * lignin (kg/d).

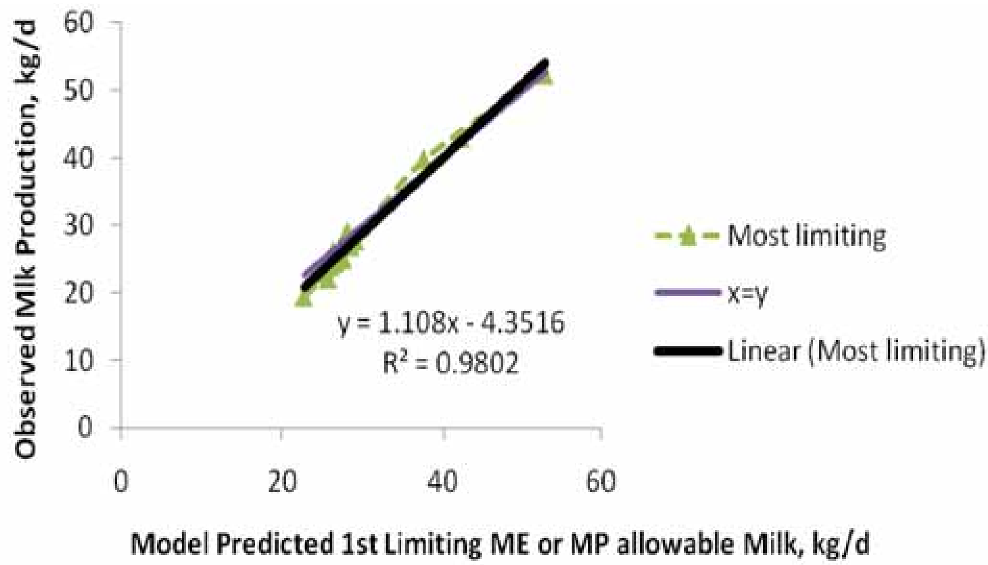
AMMONIA POTENTIAL

The calculation of the ammonia potential of the total N excretion is based on the amount of volatilization of urinary urea N that can occur given the amount of urinary urea excreted daily. This calculation was provided to help guide assessments of the amount of ammonia that could be emitted under typical environmental conditions and requires refining but provides a beginning basis for predicting ammonia volatilization. The calculation assumes 65% of the N in urine has the potential to volatilize under normal circumstances and is sensitive to the amount of N excreted in the urine.

PREDICTION OUTCOME

An evaluation of most limiting (ME or MP) milk is found in Figure 1. Studies and actual farm data are contained in these comparisons and demonstrate that the model is doing a reasonable job in predicting the most limiting nutrient supply, thus this provides us with a reasonable platform from which to start making changes. The evaluation was made from both research and on-farm datasets for lactating dairy cows. The dataset represents cows producing 21 to 52 liters of milk per day fed diets ranging from 12.7 to 17.4% crude protein. Model predicted milk reported is the lower of ME or MP allowable milk. The intercept was not different from zero and the mean prediction bias was less than 1%.

Figure 1. Observed versus predicted milk production as predicted by CNCPSv6.1. Diets range in crude protein from 12.7 to 17.4% DM with milk yields ranging from 21 to 52 liters per day.



As an example, the CPM ver.3 100 lb cow session file was inputted into CNCPSv6.1. Table 6 lists selected output variables from the two programs. In almost all cases, MP allowable production (milk or gain) will be predicted to be higher in CNCPSv6.1 and ME allowable milk reduced. In this case, MP allowable milk is 10.8% greater than in CPMv3 while ME allowable milk is decreased 6.2%. This example in CPMv3 is perfectly balanced for ME and MP while v6.1 suggests opportunity for reformulation. MP from bacterial sources was reduced 6.8% while MP from feed increased 23.8%. This shift changes MP from bacteria from 52% of total MP supply to 44%. As can be expected, these shifts impact amino acid flows and ratios. Microbial protein has a near perfect amino pattern for milk protein production. Thus, reducing microbial yield introduces altered ratios and potentially more variability in ratios as RUP LYS from feed is more variable in composition.

Flows for all amino acids changed as represented by the amino acid balances illustrated in Table 6. LEU and ILE balances changed over 100% while MET and LYS balances increased nearly 50%. These, coupled with the MP balance, suggest reformulation to decrease MP supply, while maintaining AA balance (and ratio) is possible. The LYS ratio (% MP) dropped from 6.9 to 6.6% (a 10% reduction) while the LYS:MET ratio shifts from 3.1 to 3.3:1. In general, we have found that LYS %MP has a larger shift in going from CPMv3 to CNCPSv6.1.

EVALUATING DIETS WITH CNCPSV6.1

Given that the evaluation guidelines nutritionists routinely use when formulating with CPMv3 have changed, the following is an updated list for evaluating diets with CNCPSv6.1:

1. Dry matter intake: Inputted DMI should be within the range of CNCPS and NRC predictions. If it is not, review inputs for bodyweight, environment, and feed amounts.
2. Rumen ammonia should be between 100 and 150%. Diets high in hay silage, or given ingredient availability limitations might be as high as 200%, and although unacceptable from an efficiency perspective, realistic depending on the total forage availability.
3. Peptide balance can be ignored.
4. The considerations given to urea cost can be minimized. However, you can target a urea cost of less than 0.25 Mcal/d.
5. NFC for lactating dairy cow diets can vary between 30 and 42% depending upon sources.
    a. Sugar versus starch versus soluble fiber is user preference in our opinion. Given that cattle require fermentable CHO, sources of fermentable CHO should rely upon local availability and pricing.
6. ME and MP allowable milk should be within 1 kg of each other and should match the observed milk before any ration changes are made. For growing cattle, MP allowable gain should be 0 to 250 grams greater then ME allowable gain.
    a. For replacement heifers, keep lactic acid less than 3% DM. Data from the 1980s suggests a direct link between lactic acid intake and empty body fat composition in growing cattle.
7. peNDF should be greater than 22% DM for lactating dairy cows (8-10% for feedlot cattle).
8. Lysine should be greater than 6.5% MP and Methionine greater than 2.2% MP
9. LYS:MET ratio to maximize milk protein yield should be between 2.80-2.95:1
10. Total unsaturated fatty acid intake should be monitored. Values greater than 500 g/d are a risk factor coupled with quantity and quality of forage NDF (lower quality forages and/or lower quantities of forage NDF fed increase the risk of milk fat depression).
11. Minerals and vitamins. Given that CNCPSv6.1 has implemented the Dairy NRC recommendations for minerals and vitamins (as a dietary supply including bioavailability), we suggest following NRC recommendations.

Table 6. Selected outputs from 100 lb cow session file as predicted by CPM ver. 3.0.10 and CNCPSv6.1.

Component	CPM ver 3	CNCPS v6.1	% Change
Predicted DMI	24.5 kg	24.6 to 27.6 kg	0 to 12%
ME Supply (Mcal)	69.2	64.9	-6.2%
ME Required (Mcal)	66.8	66.3	-0.7%
MP Supply (g)	2,887	3,093	7.1%
MP Required (g)	2,887	2,875	-0.4%
ME allowable milk (kg)	47.6	44.1	-7.4%
MP allowable milk (kg)	45.4	50.3	10.8%
MP Bacteria (g)	1,499	1,374	-8.3%
MP RUP (g)	1,388	1,719	23.8%
MP Bacteria, % Total MP	52%	44%	-14.4%
Ammonia balance (g)	122	100	-18.0%
RDP %DM	11.5	10.0	-13.1%
MP LYS g	199.3	204.1	2.4%
LYS %MP	6.90	6.60	-4.3%
MP MET g	63.5	62.7	-1.3%
MET %MP	2.20	2.03	-7.7%
LYS:MET	3.1	3.3	3.7%
LYS balance g	32.2	48.0	49.1%
MET balance g	10.7	15.6	45.8%
ARG balance g	26.3	25.9	-1.5%
THR balance g	39.7	48.2	21.4%
LEU balance g	2.4	28.1	1,070.8%
ILE balance g	-15.8	3.4	121.5%
VAL balance g	20.4	18.2	-10.8%
HIS balance g	22.2	33.3	50.0%
PHE balance g	52.8	66.3	25.6%
TRP balance g	15.8	14.9	-5.7%
NFC %	40.0	38.4	-4.0%
Diet ME Mcal/kg	2.82	2.65	-6.0%

FUTURE MODELING WORK

The overall ME and MP allowable milk predictions of the CNCPSv6.1 are very good. However; much remains to be done. Efforts are underway to improve the rumen sub-model to include protozoa, nitrogen recycling, a two-pool NDF and two-pool starch fermentation representation, as well as being able to model additives such as monensin. These components are critical in order for the model to then include a more mechanistic lower-tract component to allow predictions of milk components and body composition. Further, excretion predictions will also be improved allowing for more accurate predictions of greenhouse gases.

In 2006, Cornell began offering a licensing program for the integrated model equations. This was done in an effort to allow commercialization of the CNCPS, and to refocus the modeling group towards research activities versus software development and support. Currently, three licenses have been issued to AMTS LLC (NY), RUM&N (Italy), and Fabermatica (Italy). AMTS and RUM&N have licenses for North America. We hope the result is a positive outcome for the end user since it provides them with more professional software and hopefully better software support. This allows researchers to focus on our core strength of research and development of equations and systems and then implement them into the commercially available software.

SUMMARY

Nutritional models are evolutionary. CNCPSv6.1 is the latest evolutionary generation in the CNCPS/CPM path. Between analytical improvements, error corrections, and new research being implemented within the CNCPS framework, model accuracy has been improved. These changes allow the nutrition professional to reduce dietary crude protein levels while maintaining or improving production and profitability. Economics and environmental issues require us to adopt more accurate predictions for the survival of the dairy and beef industries.

Take Home Messages

- Nutrition models are evolutionary should be expected to change with improved understanding of and continue to change as new research is published
- The current version of CNCPS has improved passage rates, feed chemistry and error corrections and will predict greater metabolizable protein supply from feed protein
- Evaluations of herd level nutritional management, when the actual feed chemistry and inputs are used and all other factors are properly characterized, the CNCPS v6.1 is more accurate and precise in estimating ME and MP allowable milk with a lower prediction bias.
- Future model improvements will include the incorporation of protozoa into the rumen submodel, improved predictions of N metabolism on a whole animal basis, the application of a three pool model for NDF digestion and passage, the development

of a VFA submodel and an improved approach for predicting amino acid requirements and supply.

REFERENCES

Berman, A. 2003. Effects of body surface estimates on predicted energy requirements and heat stress. J. Dairy Sci. 86:3605-3610.

Broderick, G.A. and R.J. Wallace. 1988. Effects of dietary nitrogen source on concentrations of ammonia, free amino acids and fluorescaminereactive peptides in the sheep rumen. J. Ani. Sci. 66:2233.

Chen, G., J. B. Russell, and C. J. Sniffen. 1987. A procedure for measuring peptides in rumen fluid and evidence that peptide uptake can be a rate-limiting step in ruminal protein degradation. J. Dairy Sci. 70:12

Choi, C. W., A. Vanhatalo, S. Ahvenjärvi, P. Huhtanen. 2002a. Effects of several protein supplements on flow of soluble non-ammonia nitrogen from the forestomach and milk production in dairy cows. Anim. Feed Sci. Technol.102:15–33.

Choi, C. W., S. Ahvenjarvi, A. Vanhatalo, V. Toivonen, and P. Huhtanen. 2002b. Quantification of the flow of soluble non-ammonia nitrogen entering the omasal cannula of dairy cows fed grass silage based diets. Anim. Feed Sci. Technol. 96:203-220.

Doepel, L, D. Pacheco, J.J. Kennelly, M. D. Hannigan, I. F. Lopez, and H. Lapierre. 2004. Milk protein synthesis as a function of amino acid supply. J. Dairy Sci. 87: 1279-1297.

Ellis, J. L., E. Kebreab, N. E. Odongo, B. W. McBride, E. K. Okine, and J. France. 2007. Prediction of methane production from dairy and beef cattle. J. Dairy Sci. 90:3456-3467.

Fox, D.G., Tedeschi, L.O., Tylutki, T.P., Russell, J.B., Van Amburgh, M.E. , Chase, L.E., Pell, A.N., Overton, T.R., 2004. The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion. Anim. Feed Sci. Technol. 112, 29-78.

Fox, D. G., C. J. Sniffen and P. J. Van Soest. 1980. A net protein system for cattle: meeting protein requirements of cattle. Protein Requirements for Cattle: Symposium. MP-109. Division of Agriculture, Oklahoma State University. Published January, 1982.

Fox, D.G., C.J. Sniffen, J.D. O'Connor, P.J. Van Soest, and J.B. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets. III. Cattle requirements and diet adequacy. J. Anim. Sci. 70:3578.

Hristov, A. N., P. Huhtanen, L. M. Rode, S. N. Acharya, and T. A. McAllister. 2001. Comparison of the ruminal metabolism of nitrogen from ^{15}N-labelled alfalfa preserved as hay or as silage. J. Dairy Sci. 84, 2738-2750.

Lanzas, C., L. O. Tedeschi, S. Seo, and D. G. Fox. 2007b. Evaluation of protein fractionation systems used in formulating rations for dairy cattle. J Dairy Sci. 90:507-521.

Lanzas, C., Sniffen, C.J., Seo, S., Tedeschi, L.O., Fox, D.G. 2007a. A feed carbohydrate fractionation scheme for formulating rations for ruminants. Anim. Feed Sci. Technol. 136, 167-190.

Lock, A. L. K. J. Harvatine, I. Ipharraguerre, M. E Van Amburgh, J. K. Drackley and D. E. Bauman. 2005. The dynamics of fat digestion in lactating dairy cows: what does the literature tell us? Proc. Cornell Nutr. Conf. Pp. 83-94. Syracuse, NY.

Lock, A.L., K.J. Harvatine, J.K. Drackley, and D.E. Bauman. 2006. Concepts in fat and fatty acid digestion in ruminants. Proc. Intermountain Nutr. Conf. pp. 85-100.

Mertens, D.R. 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. J. AOAC International 85:1217.

Metcalf, J. A., R. J. Mansbridge, J.S. Blake, J. D. Oldham, and J. R. Newbold. 2008. The efficnecy of conversion of metabolisable protein into milk true protein over a range of metabolisable protein intakes. Animal. 8:1193-1202.

Mills, J. A. N., E. Kebreab, C. M. Yates, L. A. Crompton, S. B. Cammell, M. S. Dhanoa, R. E. Agnew, and J. France. 2003. Alternative approaches to predicting methane emissions from dairy cows. J. Anim. Sci. 81:3141-3150.

Moate, P.J., Chalupa, W., Jenkins, T.G., Boston, R.C., 2004. A model to describe ruminal metabolism and intestinal absorption of long chain fatty acids. Anim. Feed Sci. Technol. 112: 79-105.

Molina, D.O. 2002. Prediction in intake of lactating cows in the tropics and of the energy value of organic acids. Ph.D. Dissertation, Cornell University, Ithaca, NY.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle (7th ed.). National Academy Press, Washington, DC.

O'Connor, J. D., C. J. Sniffen, D. G. Fox, and W. Chalupa.1993. A net carbohydrate and protein system for evaluating cattle diets: IV. Predicting amino acid adequacy. J Anim Sci. 71: 1298-1311.

Pacheco, D., C. G. Schwab, R. Berthiaume, G. Raggio, and H. Lapierre. 2006.Comparison of net portal absorption with predicted flow of digestible amino acids: Scope for improving current models? J Dairy Sci 89: 4747-4757.

Reynal, S. M., I. R. Ipharraguerre, M. Liñeiro, A. F. Brito, G. A. Broderick, and J. H. Clark. 2007. Omasal flow of soluble proteins, peptides, and free amino acids in dairy cows fed diets supplemented with proteins of varying ruminal degradabilities. J. Dairy Sci. 90: 1887-1903.

Russell, J.B., J.D. O'Connor, D.G. Fox, P.J. Van Soest, and C.J. Sniffen. 1992. A net carbohydrate and protein system for evaluating cattle diets. I. Ruminal fermentation. J. Anim. Sci. 70:3551.

Seo, S., L. O. Tedeschi, C. G. Schwab, B. D. Garthwaite, and D. G. Fox. 2006.Evaluation of the passage rate equations in the 2001 dairy NRC model J Dairy Sci 89: 2327-2342.

Sniffen, C. J., J. D. O'Connor, P. J. Van Soest, D. G. Fox, and J. B. Russell. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J Anim Sci. 70: 3562-3577.

Tylutki, T.P., D.G. Fox , V.M. Durbal, L.O. Tedeschi, J.B. Russell, M.E. VanAmburgh, T.R. Overton, L.E. Chase, A.N. Pell. 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed. Sci. Tech. 143:174.

Van Amburgh, M. E., E. B. Recktenwald, D. A. Ross, T. R. Overton, and L. E. Chase. 2007. Achieving better nitrogen effiency in lactating dairy cattle:Updating field

usable tools to improve nitrogen efficiency. Proc. Cornell Nutr. Conf. Pp 25-37. Dept. of Animal Sci. Cornell Univ., Syracuse, NY.
Van Soest, P. J., C.J. Sniffen, D. R. Mertens, D. G. Fox, P. H> Robinson, and U. Krishnamoorthy. 1980. A net protein system for cattle: The rumen submodel for nitrogen. Protein Requirements for Cattle: Symposium. MP-109. Division of Agriculture, Oklahoma State University. Published January, 1982.
Volden, H., L. T. Mydland, and V. Olaisen. 2002. Apparent ruminal degradation and rumen escape of soluble nitrogen fractions in grass and grass silage administered intraruminally to lactating dairy cows. J. Animal Sci. 80: 2704-2716.
Wang, C., J. X. Liu, Z. P. Yuan, Y. M. Wu, S. W. Zhai, and H. W. Ye. 2007. Effect of level of metabolizable protein on milk production and nitrogen utilization in lactating dairy cows. J Dairy Sci.90: 2960-2965.