The Continued Evolution of the CNCPS-What it means for Dairy Formulation.

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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.

1. 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. Two of the first papers leading to the Cornell Net Carbohydrate and Protein System (CNCPS) are Van Soest et. al. (1982) and Fox et al. (1982) describing the beginnings of the rumen and growth sub-models. 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 increasing 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.

2. Developmental timeline.

The acronyms CNCPS, CPMv1, v4, v5, v6, CPM Dairy ver. 3, CNCPSv6.1, and, AMTS (.Cattle, .Pro), and NDS describe part of the evolution. First published as a system in the Journal of Animal Science (Russell et al., 1992; Sniffen et al., 1992; Fox et al., 1992) CNCPS had been developing for at least 10 years prior to the publications. The first three developments of the CNCPS were as spreadsheets and then in 2000, the first stand-alone version was released. Release dates were: v1: 1991; v2: 1993; v3: 1994; v4: 2000; v5: 2003; v6: limited internal release, 2006; v6.1 beta version first released 2007.

In the late 90s, CNCPSv5, CPM Dairy ver. 2 and 3 were being developed. CNCPSv5 was released in 2003 with a list of updates including: updates to maintenance requirements, impact of environment on animal production, microbial N requirements, tropical cattle formulation, mineral requirements, amino acid ratios, updated amino acid efficiencies, and many others. CPM Dairy ver. 3 included the updated biology introduced in CNCPSv5 plus the fatty acid sub-model, thus representing something akin to CNCPSv5.5. Starting in 1999, the group started a massive undertaking in relation to CNCPS. All previous development began with an existing version as a base with new predictions added, known issues corrected, etc. The new project began a re-engineering process where every equation and sub-model was evaluated, error checked, and validated. Updates to equations, coefficients, and other biological improvements were completed. This process uncovered multiple errors and inconsistencies that were introduced over time. This process also brought about the recognition that we had become more focused on software development than research and that was not a good strategy for an academic unit.

To that point, 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 to research versus software development and support. Currently, three licenses have been issued to AMTS LLC (NY), RUM&N (Italy), and Fabermatica (Italy) and AMTS and RUM&N have licenses for North America. The past four years have resulted in multiple updates and improvements in the prediction capability of the model. The resulting current version (v6.1) has been shown to be quite accurate with a mean prediction bias of less than 1%. Users of either CNCPSv6.1 beta or commercial implementations (from AMTS or RUM&N) typically report actual production to be within +/- 0.2 liters milk per cow.

3. Recent updates to improve accuracy and precision

The changes that resulted in the development of CNCPSv6 were described by Tylutki et. al. (2008). An important point in any modeling evaluation is a discussion regarding predicted versus inputted dry matter intake. During the development of CNCPSv6, it was decided to add a new DMI prediction equation for lactating dairy cows. However; instead of simply replacing the existing equation, it was decided to add the equation from the 2001 Dairy NRC. This provides a range of expected DMI versus a single number. The majority of DMI equations contain no information regarding the diet. The two equations implemented utilize bodyweight and fat corrected milk (they are then adjusted for days in milk and environmental conditions using the same adjustments). Different data-sets were utilized in developing these equations and in general, we find that the CNCPS equation is more accurate in temperate northern environments. The NRC equation tends to be more accurate in the Southwest USA, California, and Southeast USA type environments. Reasons for this have not been investigated; however, it can be hypothesized that forage NDF digestibility related to fill versus meeting caloric requirements plays a large role in the higher DMIs predicted by the NRC equation.

Another fundamental change, primarily affecting growing cattle was to remove the link between the current body condition score (BCS) and maintenance energy requirements. Data from France and 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. With higher BCS the implication that more energy was consumed by the animal and thus the larger the organ mass and the greater the amount of maintenance energy required. Thus, prior to v6.1, as the BCS input was increased, primarily for growing cattle, the greater the maintenance requirement and the less energy was 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 at an average BCS than was truly available.

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 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 came from *in vitro* fermentation studies from Jim Russell's lab using pure cultures of *s. bovis* grown on glucose. To update this, 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). 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. Updates to the changes in degradation rates of the various fractions are found in Table 1. 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 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.

Non-fibre-carbohydrate (NFC) concentration has been decreased (e.g. from 40 to 38.4% DM). This represents another change within the calculations. 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 or amylase, Mertens (2002) AOAC approved NDF assay includes these two reagents. Given that the majority of commercial laboratories routinely use sulfite and amylase to improve filtering ease, we adopted the AOAC NDF method for use within CNCPS. Thus, NFC is now calculated as:

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

The AOAC NDF assay also suggests that NDF should be reported on an organic matter basis (vs. DM basis). This is being further investigated. Feeds such as expellers soy bean meal and other process protein products should still be analyzed in the absence of sodium sulfite and amylase in order to appropriately describe their protein fractions. The net result of this change is that dietary NFC values have all been reduced 2-4 units.

Passage Rates and Pool Assignments

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 recently updated and account for a greater amount of variation in liquid turnover than the equation found in v5.0 (Seo et al. 2006). 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).

As indicated earlier, 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 (Volden et al., 2002; Reynal et al. 2007). 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). In a paper evaluating protein fractionation schemes for models such as the National Research Council Nutrient Requirements of Dairy Cattle (NRC, 2001) and the CNCPS, Lanzas et al., (2007a) pointed out that both protein and carbohydrate soluble pools were assigned the solids passage rate in the CNCPS structure. Given that liquid passage is 5 to 10 times faster than the solids passage rate, combined with fast degradation rates assigned to the soluble protein pools, caused any pool constituents, including the soluble carbohydrates, to be degraded in the rumen. This leads to several over and under estimations. The first over-estimation is the level of rumen ammonia production, because nearly all of the soluble proteins were degraded to ammonia, especially given the digestion rates previously assigned to those pools. Microbial yield will also be over-predicted because almost all of the soluble carbohydrates would be predicted to ferment in the rumen.

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. 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 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 2) (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 all feeds has been adjusted. Where earlier versions utilized 95% NPN as a percent of soluble CP for feeds such as alfalfa silage, 45% has been implemented. 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 3 illustrates this. 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.

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. From a peptide perspective, Chen et. al. (1987) and 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, supports excessive peptide supply. Thus, the CNCPS was adjusted so that CHO A1-A4 and PRO A-B1 flow with the liquid phase, CHO B1 (starch) always flows with the concentrate solid phase. Table 4 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.

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). However, the comparisons described in Figure 1 indicates that when evaluating these data, a static value does reasonably well over a large range in milk production and a dietary CP levels, most likely because the changes in efficiency of use of particular amino acids are within the range covered by the conversion of MP to NP and the individual AA efficiency is hard to detect because the we have little data on AA balancing beyond methionine and lysine. Also, when making comparisons for evaluating AA limitation, the AA in question or MP in general should be at or near limiting through a dose titration to elucidate the optimal efficiency given the ME available for milk and the stage of lactation.

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.

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. An update that can have a significant change in ME available for milk and tissue is the implementation of 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 all of 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 6 and are based on data and reviews from Lock et al. (2006) and Moate et al. (2004).

4. Prediction Impact.

Figure 1 illustrates an evaluation from 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 is less then 1%.

As an example, the CPM ver.3 100 lb cow session file was imported into AMTS.Cattle.Professional ver. 3.0. AMTS.Cattle products are commercialized software platforms implementing CNCPS ver. 6.1 biology. As one of three license holders for the core biology, AMTS and other license holders must ensure that predictions from AMTS products match CNCPSv6.1. Table 7 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 biology and ME allowable milk reduced. In this case, MP allowable milk is 10.8% greater then 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 7. 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 biology.

Using the optimization in AMTS.Cattle.Professional ver. 3.0.18, the diet was reformulated (results not shown). ME allowable milk was able to be increased while decreasing MP allowable milk. Dietary crude protein drops from 18.43 to 16.46% and reducing feed costs 39 cents per cow per day. Amino acid flows and ratios were held within accepted guidelines. This simple exercise illustrates the potential to decrease N feeding while maintaining/improving productivity, environmental impact, and profitability.

Table 4 shows 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. This 192 grams would equate to approximately 15 g lower MP flow, or approximately 1 liter lower MP allowable milk.

Integrating the changes in kd, kp, and PRO A and B1 pool sizes quickly reveals large changes in rumen protein dynamics and the potential for B1 protein escape. Table 5 is an example for Alfalfa Silage, Soybean Meal, and Corn Silage illustrating proportions degraded and escaping. At the diet evaluation level, total MP from microbial yield has been reduced approximately 10% due to these changes.

The latest area Van Amburghs team has been addressing is related to fibre digestibility. Long-term *in vitro* studies (up to 240 hrs) have shown that the fermentable NDF pool is a two-pool system. Furthermore, the 2.4 factor utilized to estimate the indigestible CHO pool (CHO C) is not a fixed constant. Again, this is partially related to improved methods and a larger dataset evaluated. Raffrenato (2010) reported that for BMR corn silage hybrids, the 2.4 value varies between 3 and 5, Conventional hybrids 2 to seven, Alfalfa 1.9 to 3.2 (with 80% between 2.2 and 2.8), grasses 1.5 to 5.5 (with immature grasses varying from 1.9 to 7.5). Additionally, these values tend to vary within forage type depending upon stage of maturity, further complicating matters. Raffrenato has devised a system to estimate a single rate for the two pool model as an intermediate step to implementation of a two-pool NDF system (CHO B3 and CHO B4).

6. Evaluating Diets with CNCPSv6.1 Biology

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 biology:

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 may go as high as 200%.
3. Peptide balance can be ignored.

4. Urea cost can be ignored. 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 fibre 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 liter of each other. 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 6.4% MP (comparable to 6.7 in CPM)
9. LYS:MET ratio to maximize milk protein yield should be between 2.80-2.95:1
10. Unsaturated fatty acid intake should be watched. Values greater then 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 recommendations.

As always, the models predictions are only as good as the inputs. Follow the weak link method for evaluating diets as shown in Figure 2.

7. Future Modeling Work

The overall predictability of CNCPSv6.1 is 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. Excretion predictions will also be improved allowing for more accurate predictions of greenhouse gases.

8. 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.

9. References

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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)	In CPMv3, 0%. Did not exist in other versions.	0%
CHO A2 (Lactic)	Did not exist	7%
CHO A3 (Other Organic Acids)	Did not exist	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)	0%	0%
PRO A (NPN)	10000%	200%
PRO B1 (Soluble True Protein)	130-300%	10-40%
PRO B2 (Moderately Degradable)	3-20%	3-20%
PRO B3 (Slowly Degradable, Bound in NDF)	0.05-2.00%	For forages, same as CHO B3. For concentrates, 0.05-2.00%
PRO C (Unavailable)	0%	0%

Table 2. 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 3. 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%

Table 4. 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%

Table 5. Calculated rumen degraded and undegraded CHO and PRO pools for Alfalfa Silage, Soybean Meal, and Corn Silage comparing CNCPS ver. 6.1 to earlier versions (including CPMv3).

Table 5	**CNCPS v5/CPMv3 and earlier**			**CNCPS v 6.1**		
Component	**Alfalfa SIlage**	**Soybean Meal**	**Corn Silage**	**Alfalfa SIlage**	**Soybean Meal**	**Corn Silage**
Pool Size (% DM)						
CHO A1	7.18	0.00	8.98	1.72	0.00	2.70
CHO A2	N/A	N/A	N/A	5.00	0.00	6.00
CHO A3	N/A	N/A	N/A	0.00	0.00	0.00
CHO A4	3.74	10.88	0.45	3.74	10.88	0.45
CHO B1	1.56	2.18	35.49	1.56	2.18	35.49
CHO B2	18.72	14.15	0.00	15.57	15.94	0.00
CHO B3	20.08	7.70	32.80	23.68	9.40	34.11
CHO C	16.32	0.60	6.89	16.32	0.60	6.89
PRO A	10.80	5.92	4.00	7.80	1.24	2.60
PRO B1	1.20	5.08	0.00	4.20	9.06	1.40
PRO B2	4.40	42.30	2.69	4.40	39.60	2.69
PRO B3	1.20	0.60	0.92	1.20	0.57	0.92
PRO C	2.40	1.10	0.39	2.40	1.03	0.39
kd %/hr						
CHO A1	0%	0%	0%	0%	0%	0%
CHO A2	N/A	N/A	N/A	7%	0%	7%
CHO A3	N/A	N/A	N/A	5%	0%	5%
CHO A4	300%	300%	300%	20%	40%	20%

Table 5	CNCPS v5/CPMv3 and earlier			CNCPS v 6.1		
Component	**Alfalfa SIlage**	**Soybean Meal**	**Corn Silage**	**Alfalfa SIlage**	**Soybean Meal**	**Corn Silage**
CHO B1	30%	25%	35%	30%	25%	35%
CHO B2	30%	25%	35%	35%	30%	30%
CHO B3	6.00%	6.00%	5.95%	6.00%	6.00%	3.60%
CHO C	0%	0%	0%	0%	0%	0%
PRO A	10,000%	10,000%	10,000%	200%	200%	200%
PRO B1	150%	230%	300%	15%	23%	30%
PRO B2	11%	11%	15%	11%	11%	15%
PRO B3	1.75%	0.20%	0.25%	6.00%	0.20%	3.60%
PRO C	0%	0%	0%	0%	0%	0%
kp %/hr	*These kp's are examples only for these calculations.*					
Liquid	11%	11%	11%	11%	11%	11%
Forage	4%	4%	4%	4%	4%	4%
Concentrate	6%	6%	6%	6%	6%	6%
% Degraded						
CHO A1	0.00%	0.00%	0.00%	0.0%	0.0%	0.0%
CHO A2	N/A	N/A	N/A	38.9%	0.0%	38.9%
CHO A3	N/A	N/A	N/A	31.3%	0.0%	31.3%
CHO A4	98.7%	98.0%	98.7%	64.5%	78.4%	64.5%
CHO B1	88.2%	80.6%	89.7%	83.3%	80.6%	85.4%
CHO B2	88.2%	80.6%	89.7%	89.7%	83.3%	88.2%
CHO B3	60.0%	50.0%	59.8%	60.0%	50.0%	47.4%
CHO C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PRO A	100.0%	99.9%	100.0%	94.8%	94.8%	94.8%
PRO B1	97.4%	97.5%	98.7%	57.7%	67.6%	73.2%
PRO B2	73.3%	64.7%	78.9%	73.3%	64.7%	78.9%
PRO B3	30.4%	3.2%	5.9%	60.0%	3.2%	47.4%
PRO C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals						
	CHO Degraded %DM					
CHO A1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHO A2	N/A	N/A	N/A	1.9%	0.0%	2.3%
CHO A3	N/A	N/A	N/A	0.0%	0.0%	0.0%
CHO A4	3.7%	10.7%	0.4%	2.4%	8.5%	0.3%

Table 5	CNCPS v5/CPMv3 and earlier			CNCPS v 6.1		
Component	Alfalfa SIlage	Soybean Meal	Corn Silage	Alfalfa SIlage	Soybean Meal	Corn Silage
CHO B1	1.4%	1.8%	31.9%	1.3%	1.8%	30.3%
CHO B2	16.5%	11.4%	0.0%	14.0%	13.3%	0.0%
CHO B3	12.0%	3.9%	19.6%	14.2%	4.7%	16.2%
CHO C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHO in Feed %DM	67.6%	35.5%	84.6%	67.6%	39.0%	85.6%
CHO Degraded %DM	33.6%	27.7%	51.9%	33.8%	28.3%	49.1%
% CHO Degraded	49.8%	78.0%	61.3%	50.1%	72.5%	57.3%
	PRO Degraded %DM					
PRO A	10.8%	5.9%	4.0%	7.4%	1.2%	2.5%
PRO B1	1.2%	5.0%	0.0%	2.4%	6.1%	1.0%
PRO B2	3.2%	27.4%	2.1%	3.2%	25.6%	2.1%
PRO B3	0.4%	0.0%	0.1%	0.7%	0.0%	0.4%
PRO C	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PRO in Feed %DM	20.0%	55.0%	8.0%	20.0%	51.5%	8.0%
PRO Degraded %DM	15.6%	38.3%	6.2%	13.8%	32.9%	6.0%
% PRO Degraded	77.8%	69.6%	77.2%	68.8%	64.0%	75.6%

Table 6. 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

Table 7. Selected outputs from 100 lb cow session file as predicted by CPM ver. 3.0.10 and AMTS.Cattle.Professional ver. 3.0.18.

Component	CPM ver 3	AMTS (6.1 biology)	% 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%

Component	CPM ver 3	AMTS (6.1 biology)	% Change
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%

Figure 1. Predicted versus observed 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.

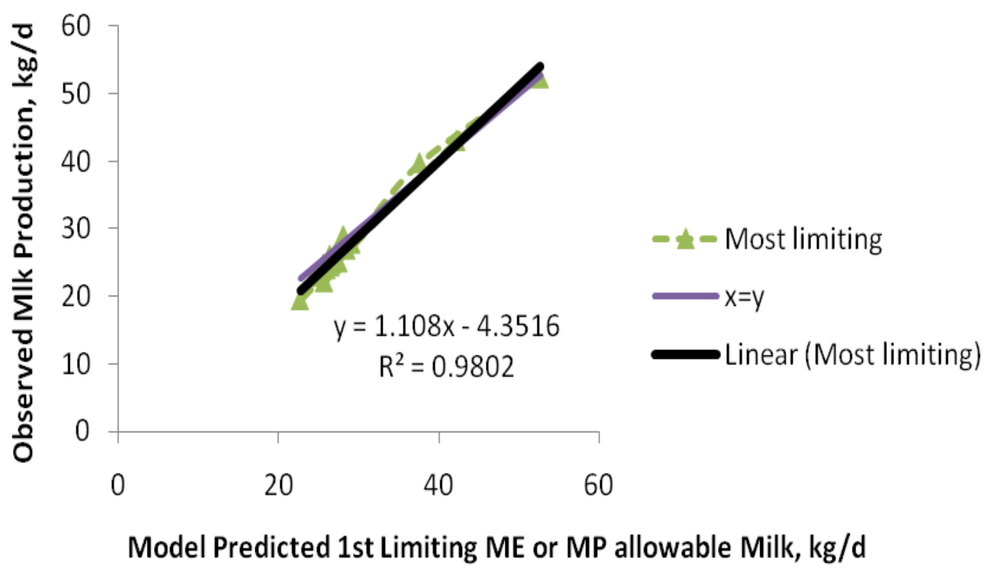

Figure 2. Weak link analysis to be used in evaluating diets regardless of formulation system (Adopted from Roseler, 1993).