BALANCING DIETS WITH THE CNCPS v6.5 – WHAT'S CHANGED AND IMPLICATIONS FOR USE

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INTRODUCTION

With the release of CNCPS v6.5, there are changes to the predictions and requirements for energy, protein and amino acids and subsequently, some of the values that have been used to evaluate diets have changed or require review. Of particular interest are the amino acid requirements and supply with the updated library values and new post-absorptive efficiencies. Also, nutrient supply in dry cows, heifers and pasture fed or high forage fed cattle have to some degree been under-predicted and a new evaluation of passage rate equations for forages has been conducted and updated passage rate equations are being incorporated where needed.

Amino acids

With the update to the feed library (Higgs et al. 2015) one of the primary outcomes was the significant increase in the feed values for methionine (Met) content due to the updated chemistry that allowed for better recovery of the sulfur amino acids (AA) in feeds and the application of AA to the whole feed and not the insoluble residue. Other AA values changed with the update, but none as dramatic as Met. With the composition updates, the supply of Met in most cases doubled, thus efficiencies of use also were updated as one of the downstream offsets to the increased supply was to develop or adopt efficiencies that more closely reflect the post-absorptive metabolism of AA. The approach was to test and adopt the efficiencies described by Doepel et al. (2004) as re-evaluated by Lapierre et al. (2007). The efficiencies developed by Lapierre et al. (2007) were described as a function of MP supply, however, we have data that suggests the efficiencies should be described on an energy basis (Higgs, 2014). Therefore, to accommodate energy in the prediction, the efficiencies adopted were from the calculations where 100% of MP allowable AA were supplied. The assumption was that the AA supply at that point was at 100% of the MP allowable requirement which should be energy neutral, thus neither under or oversupplied and would represent the values consistent with routine formulation where energy should not be first limiting and protein and AA should not be under or overfed (Van Amburgh et al., 2015) (Table 1).

For comparison, the efficiencies developed by Higgs (2014) from the same dataset but using ME allowable energy as the basis for the AA efficiencies are also shown in Table 1. The efficiency of use of many of the AA developed for v7 are similar to those adopted from Lapierre et al. (2007) for use in v6.5 and provide some insight into the differences among models and also that within model structures, the efficiencies are model specific.

Table 1. The original efficiencies of amino acid utilization as published by O'Connor et al. (1993) and the combined efficiencies (%) of amino acid utilization for both maintenance and lactation adapted from Doepel et al. (2004) and Lapierre et al. (2007) and for comparison, the efficiencies from Higgs (2014) developed on an metabolizable energy allowable basis.

	CNCPS v6.0		CNCPS v6.5	CNCPS v7
Amino acids	Maintenance	Lactation	Combined Efficiency[1]	Efficiencies developed on an ME allowable basis[2]
Met	85	100	66	57
Lys	85	82	69	67
Arg	85	35	58	61
Thr	85	78	66	59
Leu	66	72	61	73
Ile	66	66	67	67
Val	66	62	66	68
His	85	96	76	77
Phe	85	98	57	58
Trp	85	85	65	65

[1]From Doepel et al., 2004 and Lapierre et al., 2007. [2]From Higgs 2014.

It is important to recognize that the efficiencies and breakpoints for AA supply, requirements and utilization are all going to be model specific and that applying the same ratios or grams for all versions of the CNCPS or the 2001 NRC are not appropriate and should not be expected to work effectively. All models are developed to be internally consistent and have particular offsets that allow them to be useful, and will provide different relationships that are not transferable among models.

Based on evaluations of AA supply and requirements, some relationships were developed that allow for formulation of the most limiting AA on an energy basis as a reference point. For example, the current formulation goal for Met (digestible Met, %MP) to optimize milk protein yield is 2.6% which is approximately 11% greater than the v6.0 and is difficult to achieve without adding rumen protected AA. Given the breakpoint analysis assuming energy is not first limiting, the grams of Met per Mcal ME was found to be between 1.12-1.15 g for lactating dairy cattle. For dairy cattle consuming 60 Mcals ME, that would equate to (60 Mcals * 1.12 g Met/Mcal) 67.2 g of metabolizable methionine to meet the requirements for milk protein yield. The requirements for milk protein concentration are greater by several grams, so the suggestion is to start with this approach and evaluate cattle responses before increasing the supply.

The breakpoint for lysine for milk protein yield is 7.0% digestible lysine %MP in v6.5, therefore, the updated ratio is (7/2.6 = 2.69). Thus, the lysine supply to optimize milk protein yield would be 2.69 * 67.2 g Met = 181 g and would increase with increasing methionine and ME supply. Given the evaluations that have been conducted, we recommend that the user start with methionine calculations and then follow with the related lysine supply.

One additional modification to the amino acid supply is the inclusion of the tissue amino acid profile to the metabolizable protein that is generated when a cow is in negative energy balance. The CNCPS has inputs for body condition score change and when the change is a loss, the energy from mobilized tissue contributes to the ME allowable milk and the protein associated with the mobilization of that tissue contributes to the MP supply. The approach assumes that the profile of tissue mobilized is of similar composition to the tissue that was last deposited, so a cow mobilizing energy will mobilize tissue that is approximately 60-70% adipose tissue, 9-11% protein, some minerals and water. For example, a BCS loss of 0.5 over 30 days at 40 days in milk would result in approximately 8 Mcals of ME which is equal to about 21 lb of ME allowable milk, and about 320 g of MP which would provide for about 29 lb of MP allowable milk. The associated AA supply would be about 7 g of Met and 21 g of Lys based on the tissue composition of AA (Van Amburgh et al., 2015).

Rumen ammonia

With updates to the model, it is possible to formulate diets for high producing lactating cattle at or below 15% CP and when doing so, both MP supply and rumen ammonia balance are important to ensure adequate N for the rumen and protein and AA for the animal. Rumen ammonia is estimated from dietary soluble protein and rumen degradable protein that is converted to ammonia via degradation, and some urea recycling from the plasma urea pool. With the updates to the feed library and model, the rumen ammonia prediction is more accurate and sensitive to changes in carbohydrate fermentation and protein supply. The increase in sensitivity is partly due to the re-assignment of the soluble components of feeds to the liquid passage rates which increases the rumen escape of soluble proteins. This change is coupled with decreased rates of degradation of the soluble proteins, which when calculated together reduces rumen ammonia production, thus relying more on recycled nitrogen.

Generally, maintaining a rumen ammonia balance of 110 to 120% is adequate to ensure good ruminal NDF digestion. The robustness of rumen ammonia prediction assumes the user has described the cattle, feeds and DMI of the diets accurately and that feeding behavior follows normal time budgets and is not negatively influenced by overcrowding or excessive time spent away from the feed bunk (Gomez and Cook, 2010). Monitoring of MUN as a proxy for N status is acceptable if done on groups and not the bulk tank and the user is confident the laboratory conducting the MUN measurements have calibrated the system to changes in MUN below the standard ranges and basically close to zero to ensure linearity of the prediction. With the ability to formulate diets at lower crude protein levels, management factors around the cows can influence the meal pattern in such a way that the true dynamics of recycling is not completely captured since the model still integrates on a 24 hour basis. Most recommendations are for MUN to be between 8 and 12 mg/dl, however if the MUN values are less than 7 mg/dl, there is a good possibility that the rumen N balance is negative during periods of the day and this could be exacerbated by time budgets of the cows and impacting microbial yields and forage digestibility. If diets are 15% -15.5% CP or less, monitor groups or individual cows within groups and if the feed intake and manure are not consistent, measure plasma urea nitrogen (PUN) to verify the MUN data.

aNDFom and uNDF

To account for ash contamination in NDF, aNDFom should be measured if at all possible to provide more accurate fiber levels for diet formulation. Depending on the forage type, and irrigation and harvest methods, laboratory data are demonstrating that in certain forages and in regions of the country there can be significant contamination of forages with soil. In regions where there are sandy soils and flood irrigation, the aNDFom content of total mixed rations has decreased up to 5 units compared to measurements of aNDF. The cows will be at greater risk of sub-acute ruminal acidosis and the solution is to increase the amount of forage fed to achieve the target intakes. The formulation objectives for aNDFom are the same as those for NDF and aNDF for total aNDFom, NDF as a percent of BW and all other goals related to fiber (Mertens, 2009).

With the implementation of uNDFom240 in place of lignin x 2.4 as the NDF unavailable to rumen digestion, the estimation of integrated of rates of aNDFom digestion are improved. The approach provides a more dynamic calculation of the rates of digestion and allows the user to account for the agronomic conditions the forages were grown in. Further, based on the data being generated from Miner Institute and University of Bologna, the ratio of rumen content to intake of uNDF is about 1.60 regardless of forage and intake. The range in uNDFom240 intake among studies has been observed between 0.30-0.48% if BW and the range in rumen contents is 0.48% to 0.62% of BW (Cotanch et al. 2014).

Feeding to a percentage is difficult, and the data further describe the amount of uNDF that is consumed by cattle among studies. The value has some variability, but is relatively consistent among the range in forage inclusion levels and digestibility of the studies from Miner Institute (Cotanch et al., 2014). Among all the treatments analyzed, the cattle consumed approximately 2.2 ± 0.24 kg of uNDF per day. This would represent total uNDF intake and the value can be used as benchmark to evaluate intake limitations due to the size of the pool. This value includes the uNDF from all feeds, so if the user is relying only on forages, the value will be lower and usually between 70% and 80% of the total diet. This is still an active area of research and the data are intriguing and provide the user with new values on which to estimate DMI potential of forages and diets.

Rate of passage for forages and NDF

The evaluations conducted and published on large lactating dairy cattle data sets indicated the model is doing a reasonable job of predicting ME and MP allowable milk, most limiting ME or MP and provides a good prediction of total MP supply (Van Amburgh et al., 2015). One of the problems with the evaluation was the dearth of information on dry cows, heifers and pasture fed cattle. Feedback from users of the model over the last year has indicated that ME and MP supplies are being under-predicted in cattle fed high forage diets at more moderate intakes than a high producing lactating dairy cow. This is especially true for dry cows, heifers and pasture fed cattle. Consequently, another evaluation of the model is being conducted.

The forage passage rate in CNCPSv6.5 is predicted by an equation from Seo et al. (2006) and was built from the same database used to develop the 2001 Dairy NRC (NRC, 2001) equations. The predicted passage rate of forage from the evaluation was 0.04 h^{-1} with a range of 0.013 to 0.074 h^{-1} (Seo et al., 2006). Comparisons to omasal flow and rumen evacuation data in a large meta-analysis demonstrated that the predicted passage rate of forage from that equation is too fast and would underestimate the digestibility of fiber in the rumen (Krizsan et al., 2010). This discrepancy between measured flow using the omasal flow technique versus the prediction of Seo et al. (2006) was also identified during the development of CNCPS v7.0 and alternative equations were adopted (Higgs, 2014).

Several equations were evaluated during the development of v7.0 and the equation for forage and fiber passage rates was adopted from the NorFor modeling effort (NorFor, 2011). The equation is:

NDF(For) = 0.48+1.5106/(1+((ΣDMIi*NDFi)/(BW*7.484))^-3.198), where ΣDMI is the total dry matter intake, NDFi is the NDF content of each feedstuff, and BW is the body weight of the cow.

As expected there was a significant difference in the predicted passage rate of forages between the two equations. Within one of the databases, the Seo equation mean kp prediction was 4.8% h^{-1} whereas the NorFor equation prediction was 1.7% h^{-1}. The predicted decrease in passage from the rumen with the NorFor equation allows for greater rumen residency time and greater ruminal NDF digestibility and subsequently increased ME and MP supplies. The increase in ME supply among lactating cattle diets evaluated was between 2 and 3 Mcal. A re-evaluation of the lactating cattle data set was conducted, but the data were incomplete due to a database issue, so no formal statistics are presented here, however, the evaluation suggested that ME was more positively influenced than MP and the change in MP was generally less than 100 g for the average diet.

As with all modifications to the model, there is an offset either downstream or upstream from these calculations that requires modification to allow for proper balance. In this case, the offset is in the intestinal digestibility of NDF. Since the inception of the model, the intestinal digestibility of NDF was set at 20% and this was done to account for potential hindgut fermentation. However, a review of the literature and remodeling the digestion of NDF through the entire gastrointestinal tract suggests that on average, post-ruminal NDF digestibility is approximately 5% (Higgs, 2014). Therefore, to allow for greater ruminal digestibility due to the adoption of the NorFor equation and offset such a high post-ruminal digestibility in v6.5, the post-ruminal digestibility was set to 5%.

The impact of the change in passage rate prediction was evaluated on dry cows with data from work being conducted in the Overton group. The impact on predictions of ME and MP supply for the dry cow diets demonstrated that with the NorFor equation, the increase in ME supply was more consistent with the observed energy balance of the cattle. Unpublished data from Sweeney and Overton were used to conduct the evaluation. In this evaluation, the data are from cattle on control diets from -21 days to calving. The diet characteristics are found in Table 2 and the body weight and body condition score change are in Table 3. Cattle were fed the diet starting between day -38 to day -31 of calving and measurements were taken between -21 and calving.

Table 2. Diet characteristics of dry cows -21 days prior to calving until parturition. (Sweeney and Overton, unpublished data).

Ingredient	pounds
BMR corn silage	14.4
Wheat straw	9.0
Amino Plus	2.6
Citrus pulp	1.1
Soybean hulls	0.7
Canola meal	0.7
Molasses	0.2
Calcium phosphate	0.1
Ground corn grain	0.1
Salt	0.1
Wheat midds	1.0
Calcium carbonate	0.9
Corn distillers (ethanol)	0.7
Magnesium oxide	0.2
Urea	0.1
Total DMI, lb/d	32.1

Over the period analyzed, the total body weight change was less than 2 lb, demonstrating that on average, energy balance was near zero. In this evaluation, the model predictions were improved with the implementation of the NorFor kp equations and there was a 1.5 Mcal increase in ME supply and a modest reduction in maintenance requirements which changed the ME balance from -3.1 to -1.1 Mcals (Table 4). These predictions were more consistent with the behavior of the cattle, especially the observed body weight and body condition score change, therefore we believe the adoption of the NorFor equation will reduce the amount of ME supplied to dry cows and minimize weight gain, adiposity and possible post-partum issues. We are continuing to build the database of dry cow data and will provide additional evaluations as data become available.

Some evaluations of growing heifers have been conducted and the updated passage rate equations appear to provide ME allowable gain predictions that are more consistent with the observed growth rates for heavier heifers, but not prior to puberty.

Before updating the equations for growing heifers, a more robust data set is required to fully evaluate the range in body weight and growth rates the model would be expected to predict for. At the time of this writing, there was a paucity of data, so a complete and satisfactory evaluation could not be accomplished.

Table 3. Body weight and body condition score and change over the 21 day treatment period. (Sweeney and Overton, unpublished data).

	Control
Body weight, lb	1,777
Body weight change, lb	-1.37
Body condition score (1-5)	3.37
Body condition score change	0.01

Table 4. CNCPS predictions with 6.5 (CNCPSv6.5) or 6.5 with 5% NDF intestinal digestibility and the NorFor equation for passage rate of forage NDF (CNCPSv6.5-_NorFor) (Sweeney and Overton, unpublished data).

	CNCPS6.5		CNCPS6.5_NorFor	
	ME (Mcals)	MP (g)	ME (Mcals)	MP (g)
Supply				
Diet	29.5	1305	31.0	1386
Body condition score	0.0	0.0	0.0	0.0
Total	29.5	1305	31.0	1386
Requirements				
Maintenance	21.0	707	20.6	671
Pregnancy	5.2	299	5.2	299
Growth	3.6	94	3.6	94
Desired reserves flux	2.7	5	2.7	5
Total	32.5	1105	32.1	1070
Balance	-3.1	199	-1.1	316

SUMMARY

The CNCPS is an evolving model and that is the primary reason it is useful. Like all models, there are offsetting errors and eventually, as components of the model are refined and improved, some of the offsets have to be fixed or replaced. The amino acid predictions and efficiencies of use are good examples of where a replacement was necessary. As long as the model predictions are improved and the predictions are consistent with the observed data, the process of model development works and creates a more useful and robust tool for evaluation and prediction.

We thank Brittany Sweeney and Tom Overton for dry cow data for evaluation.

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