Improving the Efficiency of Use of Nitrogen in Lactating Dairy Cattle: Revisiting the CNCPS Approach

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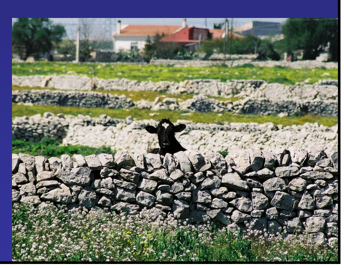


CNCPS V6.1

- Several updates to the biology and "fixes"
  - New carbohydrate fractions – the CHO A pool has been fractionated into the constituents: volatile fatty acids, lactic acid, organic acids, and sugars (Lanzas et al., 2007)
  - New solid and liquid passage rate equations (Seo et al., 2006)
  - Bacterial ash accounting (Tylutki et al. in press)

Forthcoming Carbohydrate & Fiber Fractionation – CNCPS v 6.1

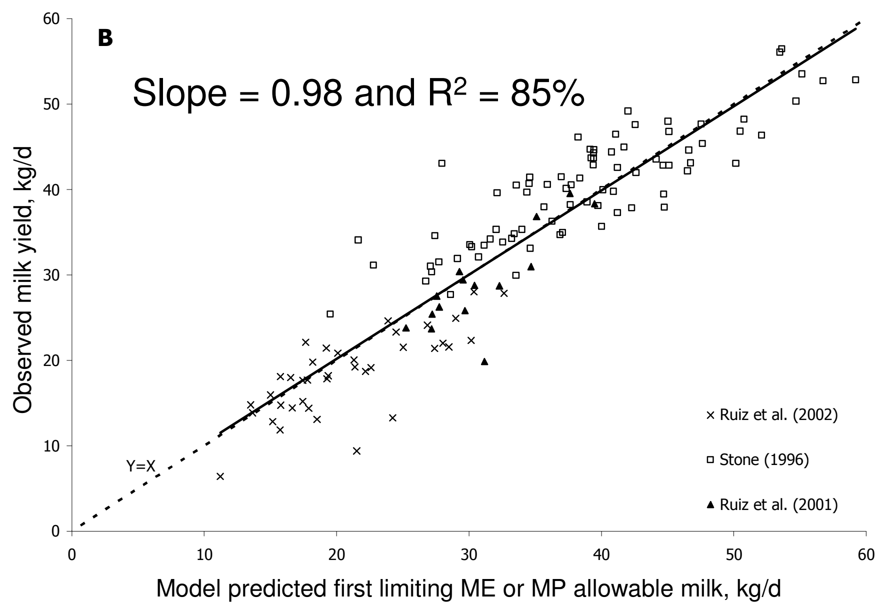
- Volatile Fatty Acids (A1)
- Lactic acid (A2)
- Organic acids as a separate pool (A3)
- Sugar as separate pool (A4)
- Starch as a separate pool (B1)
- Soluble Fiber as a separate pool (B2)
- Neutral Detergent Fiber (B3)
- Lignin as % NDF (C)

Protein Fractionation – CNCPS v 6.1

- Pro A - Non-protein Nitrogen
- Pro B1 - Rapidly Degradable Protein
- Pro B2 - Medium Degradable Protein
- Pro B3 - Slowly Degradable Protein
- Pro C - Unavailable Protein (bound)

Amino acids on the insoluble pools B2, B3 and C

CNCPS Observed versus Predicted – Three Data Sets



Email Question from Dr. Robert Fry

- “Why does the model not attribute significant MP from alfalfa haylage in this session? You will see that the CP of this diet is ~ 26% with lots of peptides and NH3. Why does the model want so much SBM coupled with the alfalfa?”

  “Any idea what I am missing?”

Implication – all of the soluble protein from the alfalfa is all NPN and has no MP value (not true), or it never leaves the rumen (most likely not true either)

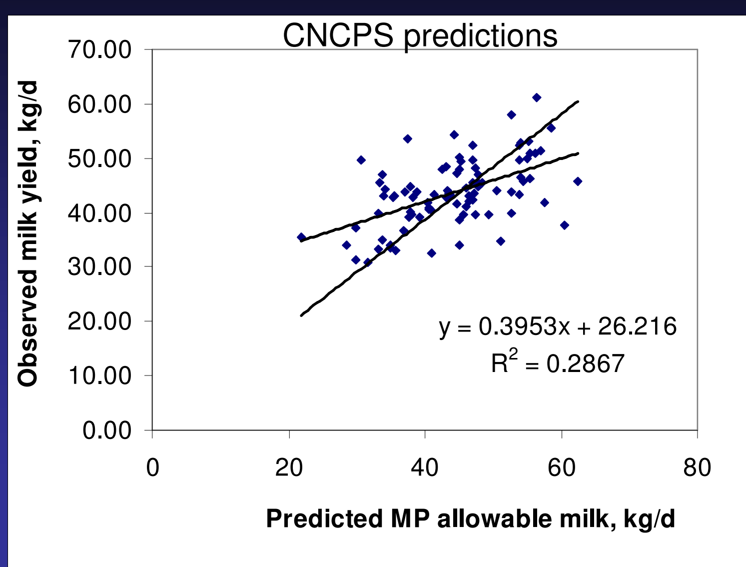
Nitrogen Utilization and Efficiency Study – Recktenwald et al., 2007

	Diet P	Diet N	Diet T
CP, % DM	16.2	14.1	14.0
Soluble protein, % CP	29.9	35.6	30.4
PUN, mg/dl	11.31[a]	8.40[b]	7.13[c]
Ruminal NH_3, mg/dl	6.58[a]	8.32[a]	5.84[a]
Milk yield, lb/d	99.2	94.0	95.4

Nitrogen Utilization and Efficiency Study – Recktenwald et al.

Actual Milk Yields and Predictions	Diet P	Diet N	Diet T
Actual milk yield, kg/d	45.00	42.62	43.29
CPM Model Prediction			
Actual BW changes included			
ME allowable milk, kg/d	48.9	49.2	47
ME balance, Mcal/d	3.7	6.2	3.4
MP allowable milk, kg/d	43.3	34.6	40.0
MP balance, g/d	-71	-362	-146
Peptide and NH_3 balance, g/d	56	48	-22
Peptide and NH_3 balance, % requirement	113	111	95
Peptide balance, g/d	17	-3	-51
Peptide balance, % requirement	107	99	77

Nitrogen Utilization and Efficiency Study – Recktenwald et al.



MP Predictions and Sensitivity to Variation in Nitrogen Fractionation

- We evaluated several other data sets and found similar responses – especially when Intake N was limiting (Broderick, 2003; Wattiux and Karg, 2004; Kalscheur et al., 2006; Olmos Colmenero and Broderick, 2006; and Huhtanen)
- Part of the response was due to separating the CHO pools – once the A fraction was properly characterized - increased sensitivity
- Predicted Rumen NH3 Balance was high, despite the low N intakes – suggested too much N being degraded in the rumen and lower MP supply from the soluble protein

Evaluation Data from Huhtanen et al.

- Observed Milk versus ME Allowable R^2 = 0.99
- However, Observed Milk versus MP Allowable – approximately 9 kg bias on diets ranging from 12.7 to 17% CP

Factors to Evaluate

- Are the Protein pool characteristics consistent with the current literature?
- Are the rates assigned to the protein pools consistent with current experimental data – especially in light of the CHO pools?
- Are the passage rate equations appropriately assigned to reflect flow out of the rumen?

Assumptions about Protein Pools

- We have assumed that the rate of degradation of the Protein A pool has been infinite (10,000%/h)
- Also assumed that most of the feed protein associated with the B pools, especially B1 and B2, that solublizes disappears into bacteria or is converted to ammonia
- Also assumed that the NDF digestion rates and the associated Protein rates (B3- NDIP) are independent

Protein A and B1

- Data demonstrate that from 5 and 15% of the total AA flow is from soluble peptides and proteins (Hristov et al. 2001; Volden et al. 2002, Choi et al. 2002; Reynal et al., 2007)

- Thus, properly accounting for the pool size and rates are important to predict AA flow

Protein A and B1

- Separated to characterize the peptide pool relative to NSC bacteria utilization

- Reynal et al. 2007 describes the use of ultrafiltration to define the peptides by molecular weight – more precise

- Data from Choi et al. 2002 and Volden et al. 2003 demonstrate that the rate limiting step is the conversion of soluble peptides into amino acids

Pool Size – Primarily Protein A & B1

Two concerns:

1. The current NPN pool contains ammonia, nitrates, amino acids and small peptides

   - might need to separate those if we maintain the peptide stimulation component

2. The current procedure by Licitra et al. 1996 does not appropriately determine the B1 pool as described.

Protein A and B1 Rates of Degradation

Data from omasal flow studies:
Rate of degradation of the A and B1 pools is not as high as previously characterized can contribute to the AA flow to the cow (Choi et al., 2002, Volden et al., 2003, and Reynal et al. 2007)

Review of the literature suggests that Protein B1 rates range from 20 to 50%/h (Lanzas et al., 2007)

Omasal Flow of Soluble Amino Acids (SAA) -Reynal et al., 2007

Soluble AA flow	Urea	SBM	Xylose SBM	Corn Gluten Meal
Total g/d	254	308	266	377
% TAA flow	15.5	11.6	9.2	15.9
Microbial, g/d	90.3	70.7	62.4	109.5
% of TSAA flow	33.2	20.6	21.7	28.8
% of TAA flow	5.4	1.8	2.1	5.3
Dietary, g/d	168	242	206	271
% of TSAA flow	66.8	79.4	78.3	71.2
% of TAA flow	10.7	8.0	8.2	13.1

Rates of degradation (kd) of protein A and B1 pools in CNCPS v5.0 and v6.1.

Feed	**ProtA kd v.5.0**	**ProtA kd v.6.1**	**ProtB1 kd v.5.0**	**ProtB1 kd v.6.1**
Corn Grain Ground	10000	200	135	50
Corn High Moisture 22%	10000	200	135	50
Soybean Meal 44	10000	200	230	46
Soybean Meal 48	10000	200	230	46
Corn Silage	10000	200	300	28
Grass Silage	10000	200	200	49
Alfalfa Silage	10000	200	150	28

From: Broderick, 1989; Volden et al. 2002, Choi et al., 2003; Hequist and Uden, 2006; Lanzas et al., 2007

Protein B3 – NDIP Rate

- Rates of protein degradation were assumed to be independent of the carbohydrate and a function of the type of protein (Sniffen et al., 1992)
- For example, NDF kd – 4%/d and NDIP kd of 0.35%/h – implies that as the ND fraction digests, protein accumulates in the residue or in the rumen
- Data from several labs suggest this is incorrect
- Also we have the “Sulfite or no sulfite” in the NDF analyses – The AOAC method uses sulfite
- If the rate of degradation of the B3 pool is similar to the NDF, then the sulfite question is made less relevant

Protein B3 – NDIP Rate

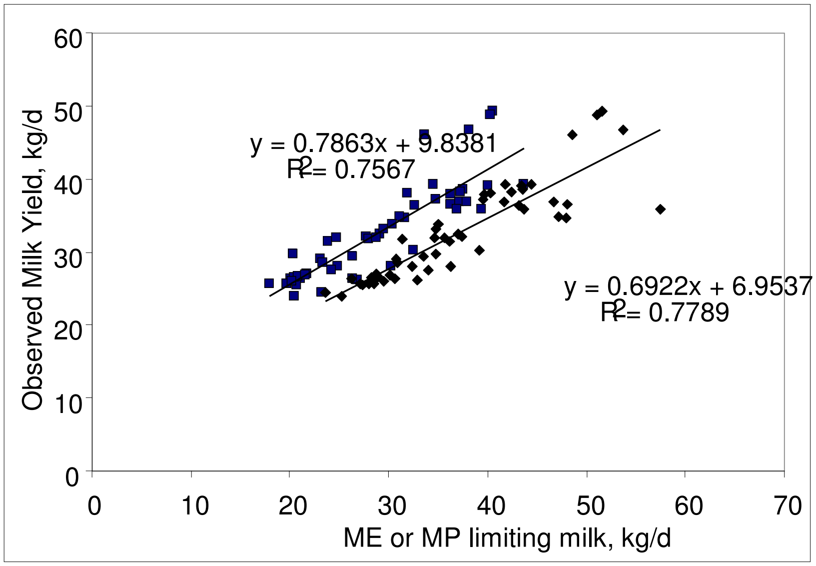
- Data from our lab, Alice Pell, Pekka Huhtanen and Cristina Lanzas evaluations all demonstrate that the Protein B3 pool digests at the same rate as the NDF – at least for forages
  - Thus, in the latest release of the CNCPS, when you adjust the NDF kd, the Protein B3 pool assumes the same rate
  - This needs to be evaluated for all of the concentrates and byproducts

One More Update

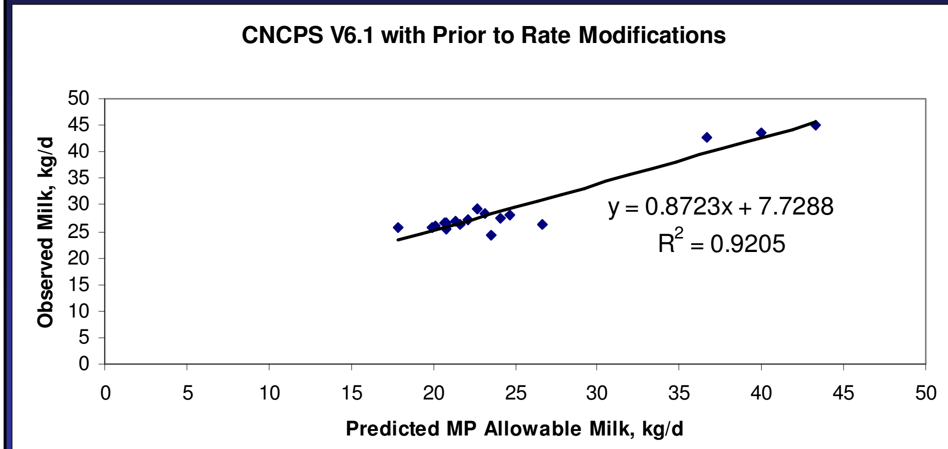
- After making adjustments to the feed library to reflect the rate changes, predictions were still biased
- Resulted in working through the code one more time
- Realized that the soluble CHO and Protein Fractions (CHO A and Protein A+B1) were linked to the solids passage rate – thus the model was very insensitive to rates of these pools and over predicted the Rumen NH3 balance (this was discussed in Lanzas et al., 2007)
- In the release version, the passage rate assignments have been updated

So What Happens To Model Predictions After All This?

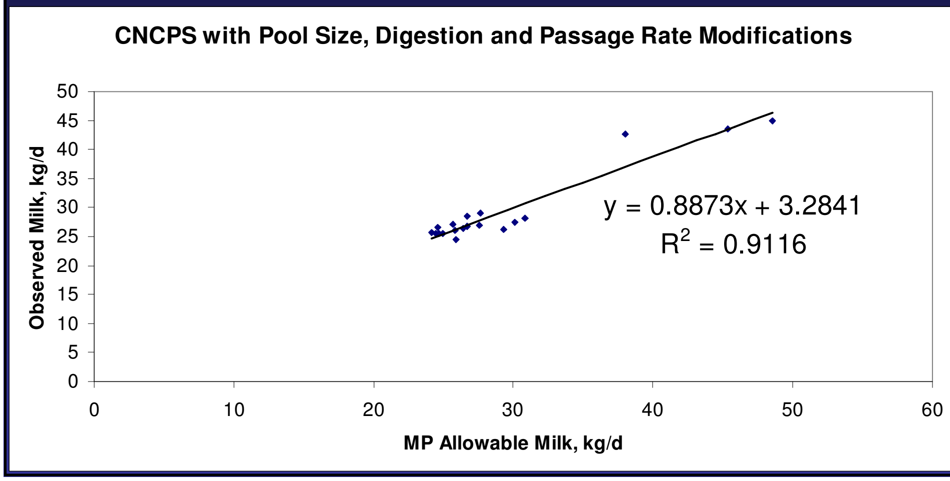
CNCPS V6.1 Observed versus ME or MP Limiting After Modifications To Digestion and Passage Rates for Protein Limited Diets



Observed vs MP Allowable Milk, Partial Data of Huhtanen and Recktenwald – No Rate Updates to CNCPS



Observed vs MP Allowable Milk, Partial Data of Huhtanen and Recktenwald – with Rate Updates to CNCPS



Observed versus Predicted ME and MP Allowable Milk, And Statistics (Six studies, 22 treatments)

prediction	CNCPS status	Obs. mean, kg	Predicted mean, kg	slope	y intercept	r^2
MP	Initial	39.62	37.04	0.73	12.63	0.75
MP	Post	39.62	43.75	0.71	8.55	0.64
ME	Initial	39.62	44.97	0.66	9.91	0.70
ME	Post	39.62	44.69	0.67	9.63	0.69

Observed versus Predicted ME and MP Allowable Milk and Statistics

prediction	CNCPS status	Obs., kg	Predicted mean, kg	slope	y intercept	r^2
Most limiting	Initial	39.62	36.91	0.74	12.48	0.76
Most limiting	Post	39.62	42.09	0.76	7.63	0.70
Most limiting, no negative rumen N balance	Initial	38.65	35.37	0.76	11.79	0.76
Most limiting, no negative rumen N balance	Post	38.65	41.58	0.77	6.80	0.71

Data of Recktenwald, 2007

Diet	P		N		T	
	Prior	After	Prior	After	Prior	After
Actual milk, kg	45.0		42.6		43.1	
MP allowable, kg	43.3	46.7	34.6	40.0	40.0	42.2
Rumen NH3 balance, % reqd	145	110	137	119	114	82

Field Application of the CNCPS V6.1 Updates

- Currently being applied in two herds
- Each herd balanced for ME and MP allowable milk and producing at approximately 41 kg/d
- Diets are 14.4 and 15.5% CP and positive for Rumen NH3 balance respectively.

"Nitrogen To Do List"

- Revisit feed N fractionation scheme – looks like we can simplify
- Instead of Soluble and True Protein – use Ammonia and Soluble protein – assume most of the difference is peptide N of some form
- Update the predicted urea N recycling and add endogenous uptake equations
- Improve the prediction of Intestinal Digestibility of the escape fractions

Precipitable true protein of trypticase with varying PPT agents and pore size

PPT Agent	Filter pore, µm	True protein	Filtrate peptide chain length
Tungstic acid	1	34.4	3.0
	6	23.1	4.3
	20	1.8	4.2
Stabilized TA	1	31.0	3.3
	6	28.5	3.4
	20	4.4	3.6
TCA	1	2.57	3.4
	6	0.78	4.3
	20	0.42	5.0
Perchloric Acid	1	1.36	3.2
	6	1.56	4.1

Conclusions:
With changes to passage rate assignments – model is much more sensitive to soluble protein pool characteristics

We will revisit the protein fractionation approach to improve efficiency of N utilization (Possibly collapse B2 and B3 protein pools, move to ammonia and soluble protein for "A and B1" pools)

Changes should be consistent with current laboratory methods.