Improving Overall N Efficiency through Better Protein and Amino Acid Formulation

Mike Van Amburgh, Debbie Ross, Marcelo Gutierrez-Botero, Larry Chase, Tom Overton, Andres Ortega, and Andrew LaPierre

Dept. Of Animal Science, Ithaca, NY
mev1@cornell.edu

1

Today's discussion

- What are the opportunities for protein and AA balancing?
  - what are we capable of now?

- Deciding what is first limiting and why?
- Basic biology around amino acids
- Feed chemistry is important
- Feed ingredient options and formulation challenges
- Formulating for metabolizable protein and refining formulations with amino acids
- Summary

2

Improving Efficiency of Use of Intake Nitrogen

- Opportunities exist – need refining
- On farm N efficiencies (milk N:feed N)
  20 to 32%
- Theoretical efficiency limit 40 to 45% in lactating dairy cattle (Van Vuuren and Meijs, 1987; Hvelplund and Madsen, 1995; Dijkstra, 2013)
- Practical limit is ~ 38 to 40% and groups are achieving this
- Requires refinement of current ration formulation models – balancing for rumen N and post-ruminal amino acids
- Requires refinement of feeding management – reduce variation associated with feed, management

There are cows within herds/groups approaching the theoretical limits of protein efficiency

Walnut Ridge Dairy, Lansing NY

High group average production: 120 ± 35 lb/d

Average DMI: 60.1 lb/d, 15.8% CP

Average N efficiency: 38% (productive N:intake N)

Studied group for 4 months and modeled individual cows within the entire group

Cows at high end of production: ~169 lb/d milk

At estimated intake, N efficiency: 41%

Milk Yield and Milk Protein Synthesis

- Are energy driven events
  - Relies on an adequate supply of amino acids
  - Driven by propionate production in the rumen
    - Propionate converted to glucose in the liver – which in turn stimulates insulin and IGF-I secretion
    - Intestinal glucose absorption also supplies energy substrate but there is a discount on energy for lactose synthesis – based on the data of Reynolds et al. and others, about an 18% discount due to tissue use prior to mammary availability

5

Effects of insulin on milk protein

- Hyperinsulinemic-Euglycemic clamps
  - Clamp alone
    - 15% increase in milk protein yield (Mackle et al., 1999)
  - Clamp w/ abomasal infusion of casein
    - 28% increase in milk protein yield (Griinari et al., 1997)
  - Clamp w/ abomasal infusion of BCAA & casein
    - 25% increase in milk protein yield (Mackle et al., 1999)
  - Clamp w/ IV infusion of AA (casein profile)
    - Insulin and insulin plus AA increased milk by 13 to 18% and protein by 10 to 21% in goats
      - (Bequette et al, 2001)

6

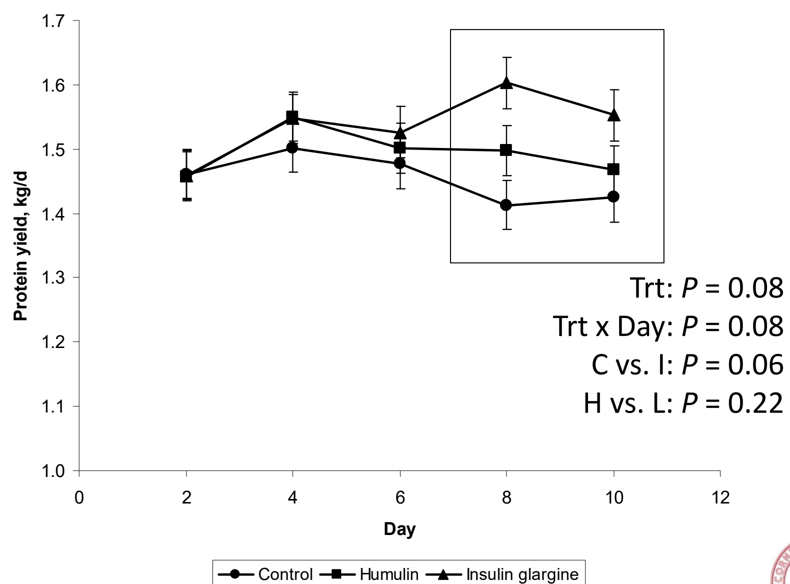
Long-acting insulins and milk protein

- 30 multiparous Holstein cows
  - 52 to 130 DIM, avg. 88 +/- 25
- 3 treatments given at 12-h intervals for 10 d
  - Control
  - 0.2 IU/kg of BW Humulin-N (Eli Lilly and Co.), 2X/d
  - 0.2 IU/kg of BW Insulin glargine (Sanofi-Aventis), 2X/d
- Blood samples
  - Twice daily from coccygeal vein
  - Before morning injections, 6 hours later
- Milk samples every other day, 2x/d

Winkelman and Overton, 2013. J. Dairy Sci. 96:7565-7577.

7

Effect of long-acting insulins on milk protein yield



Winkelman and Overton, 2013. J. Dairy Sci. 96:7565-7577.

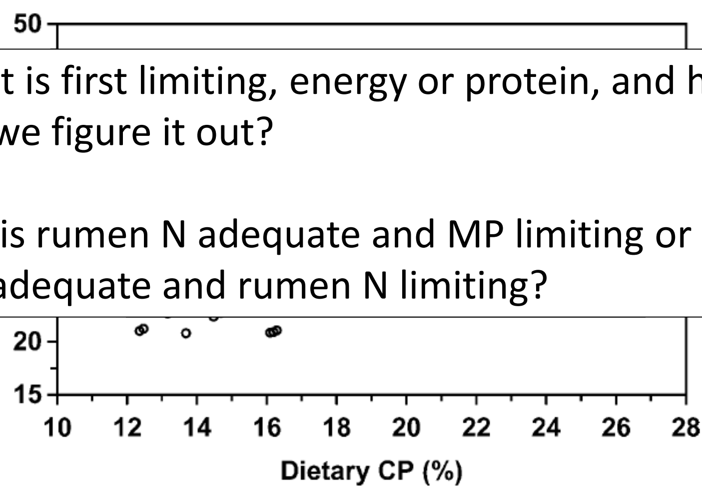
8

Where to Start – Cow has Two Different Requirements

- Need to separate crude protein from true or metabolizable protein and amino acids
- The cow doesn't understand crude protein
  - The rumen has requirements for rumen N, mostly in the form of ammonia and some AA and peptides
  - Post-ruminally the requirements are for digestible amino acids – from undegraded feed and microbes

9

Impacts of source and amounts of CP on intestinal supply of N and performance of cows



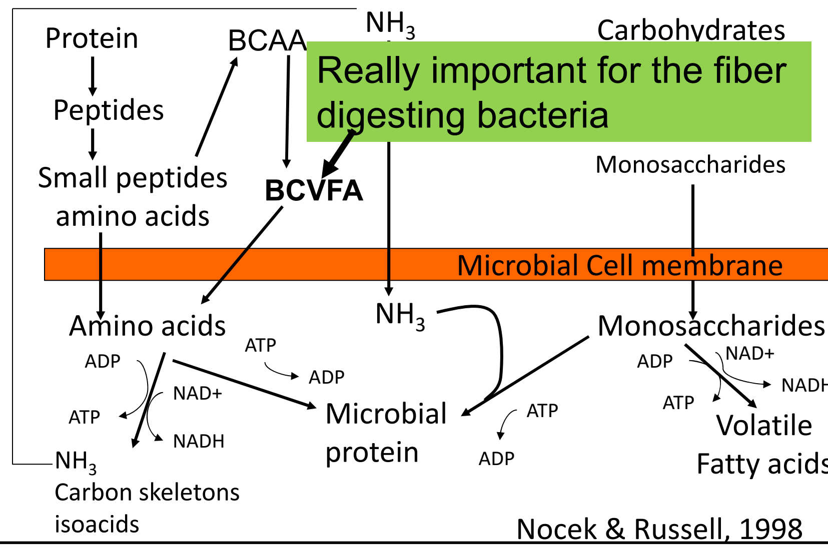
What is first limiting, energy or protein, and how can we figure it out?

And is rumen N adequate and MP limiting or is MP adequate and rumen N limiting?

Ipharraguerre and Clark, 2005

10

Protein/CHO Balance



Nocek & Russell, 1998

Making AA Balancing Work – feed chemistry and digestibility

- From modeling exercises, the most important variable in predicting AA supply is digestible NDF
  - This incorporates three outcomes – better feed intake, good rumen health and more microbial yield due to better digestibility
- The second most important variable is the digestibility of the protein source

Improving Efficiency of Nitrogen Use

- Milk protein output and overall protein efficiency is a function of energy supply
- Amino acid balance enhances efficiency of energy use and sometimes N use – not always direct
- Urine N is variable and is a function of excess nitrogen intake and recycling
- Urine N is most volatile form – so reducing it will reduce the environmental impact and improve efficiency
- Can use monitoring tools like milk urea nitrogen to diagnose independent of production responses or predict it with formulation

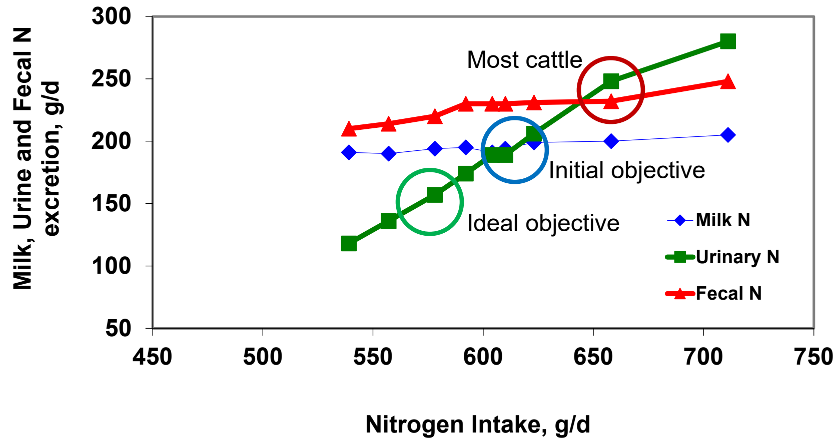
13

Urinary N is main form of excreted N Fecal N is fairly constant

Reference	Intake N (g/d)	Fecal N (g/d)	Urinary N (g/d)
Kauffman and St-Pierre, 2001	429	178	93
	460	184	101
	572	198	190
Hristov and Ropp, 2003	658	208	233
	754	176	279

14

Nitrogen excretion in milk, feces and urine based on N intake in lactating dairy cattle – under controlled conditions of energy as first limiting: 40 kg milk/d @24 kg DMI range in CP intake 14 to 18.7%



Van Amburgh et al. 2015 J. Dairy Sci

15

Productive N to Urinary N ratio

Excretion	
Fecal (kg)	48
Urine (kg)	21
Total Manure (kg)	69
Fecal N (g)	266
Urine N (g)	181
Total Manure N (g)	447
Productive N:Total N	0.38:1
Productive N:Urinary N	1.46:1
Manure N:Total N	0.62:1
Fecal P (g)	71.2
Urine P (g)	1.4
Total Manure P (g)	72.7
Productive P:Total P	0.39:1
Manure P:Total P	0.61:1

Productive N/Total N	34.03 %
Productive N/Urinary N	1.26:1
Manure N/Total N	65.97 %
NH3 Potential	101.23

Productive N: Urine N

Average ratio 0.7:1

Acceptable 1:1

Outstanding 1.25:1

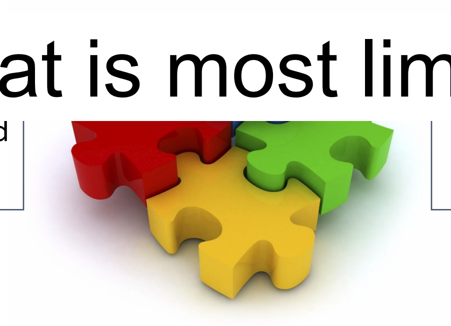
16

Predicting AA Balance – Four Pieces To The Nitrogen/AA Part of the Puzzle

Nitrogen components at the duodenum

What is most limiting?

Total amino acid requirements

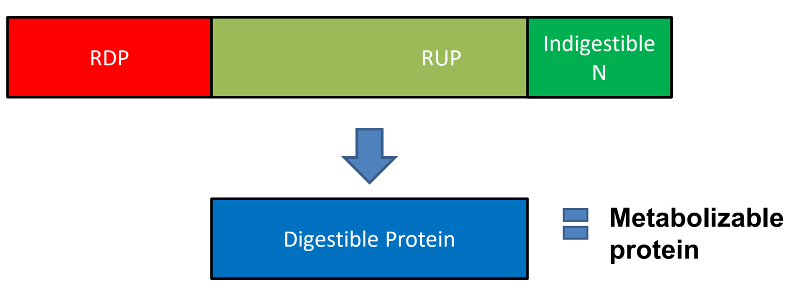


profile of each component

Digestibility in the small intestine

17

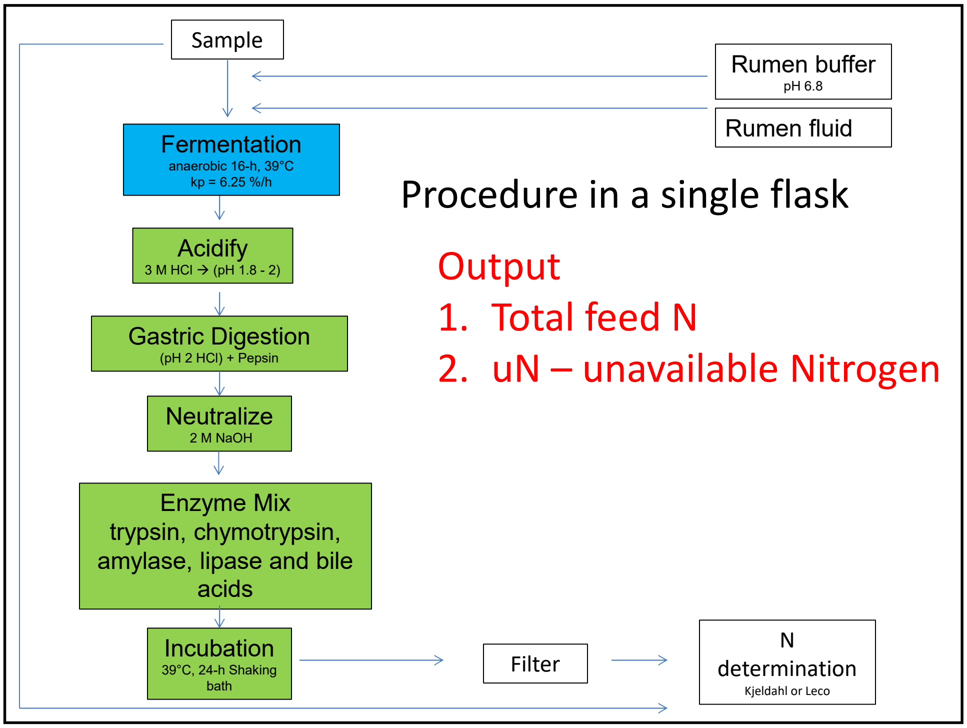
IN RUMINANTS INTESTINAL DIGESTIBILITY IS A CALCULATION



Intestinal digestibility = 1 – [indigestible N/ rumen un-degraded protein]

18

18



Procedure in a single flask

Output

1. Total feed N
2. uN – unavailable Nitrogen

19

Comparison of ADIN and Ross in-vitro indigestible N (uN) assay

	Feed N (% DM)	ADIN (%N)	Ross In-vitro indigestible N (% N)
Regular blood meal	16.2	4.7	16
Heat damaged blood meal	16.1	1.8	93
Soybean meal solvent extracted	7.6	6.7	8
Soybean meal heat treated	7.3	7.9	11

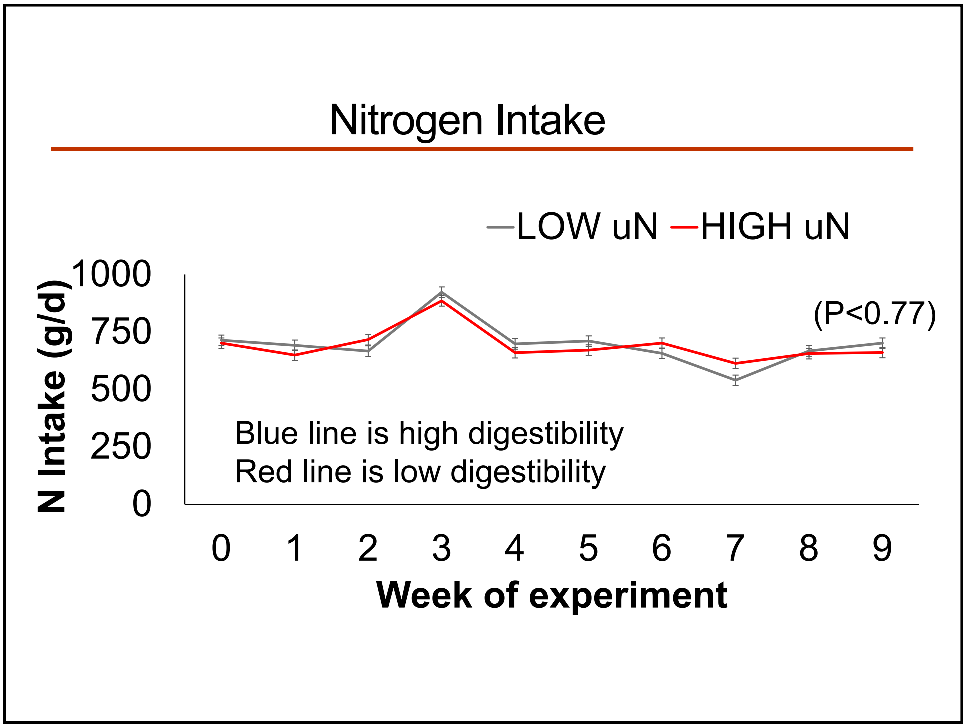
20

Treatment Diets

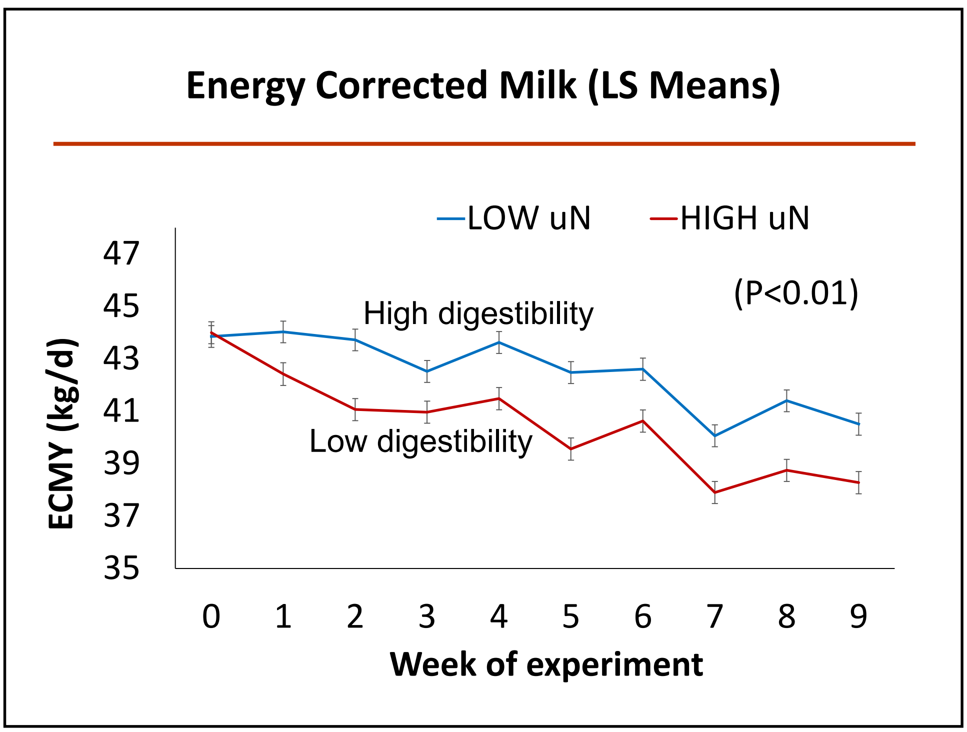
- Diets designed to iso-energetic and iso-nitrogenous
- Treatment difference was created by using two different blood meals
- One blood meal was highly digestible (9% uN), the other had average digestibility (34% uN)
- The calculated difference in N digestibility between the two treatments was 38 g N – cattle were consuming ~667 g N (5.8% of intake)

Chemical Composition of Diets Fed

Item,	Treatment[1] LOW uN	HIGH uN
DM, % as fed	50.0	50.5
CP, % DM	15.2	15.2
NDF, % DM	31.9	32.3
ADF, % DM	21.3	20.5
EE, % DM	4.3	3.9
Starch, % DM	30.4	31.2
Sugar, % DM	3.6	3.3
Ca, % DM	0.65	0.60
P, % DM	0.43	0.43
ME*, Mcal/kg DM	1.8	1.7
Lys:Met*, % MP	3.21	2.89


Nitrogen Intake
LOW uN
HIGH uN
N Intake (g/d)
1000
750
500
250
0
(P<0.77)
Blue line is high digestibility
Red line is low digestibility
0 1 2 3 4 5 6 7 8 9
Week of experiment

23


Energy Corrected Milk (LS Means)
LOW uN
HIGH uN
ECMY (kg/d)
47
45
43
41
39
37
35
(P<0.01)
High digestibility
Low digestibility
0 1 2 3 4 5 6 7 8 9
Week of experiment

24

Results

	LOW uN	HIGH uN	SEM	P-value
n	64	64		
DMI, kg	27.4	27.1	0.61	0.75
N Intake, g/d	671.1	664.4	14.8	0.77
Milk production				
Milk, kg	42.0	40.3	0.31	<0.01
ECM, kg	41.9	40.0	0.32	<0.01
Fat, kg	1.51	1.42	0.02	<0.01
Protein, kg	1.26	1.23	0.01	0.03
Milk composition				
Fat, %	3.6	3.5	0.03	<0.03
Protein, %	3.03	3.06	0.02	0.20
MUN, mg/dl	9.4	8.0	0.18	<0.01

25

CNCPS v6.5 predictions for ME and MP allowable milk

	Treatment	
Item	LOW uN	HIGH uN
Actual milk, kg	42.0	40.4
Predicted ME allowable milk, kg	46.2	46.0
Using ADIN and NDIN		
Predicted MP allowable milk, kg	44.9	45.1
Predicted MP supply, g	3,105	3,144
Using IVNIDA		
Predicted MP allowable milk, kg	42.6	39.3
Predicted MP Supply, g	3,036	2,835

26

Intestinal digestibility study – 96 cows
(HID) diet formulated with 2.7 lb blood meal, low intestinal digestibility
(LID) diet formulated with 2.9 lb blend of 82.8% feather meal and 17.2% of the blood meal.
MP allowable milk of 101 lb/d and 95 lb/d, respectively.

	HID	LID	s.e.	P
N	48	48	-	-
Body weight, lb	1,638	1,641	4	0.4
DMI, lb/d	57.7	56.6	2.6	0.5
Milk, lb/d	101	99	3	0.4
Energy corr. milk, lb/d	**109**	**102**	**3.8**	**0.04**
Fat, %	4.08	3.81	0.1	0.04
Prot, %	3.03	2.93	0.04	0.06
Fat, lb/d	4.14	3.74	0.05	0.01
Protein, lb/d	3.07	2.88	0.01	0.008

C. Hoff, 2018 unpublished

Limiting amino acids in lactating dairy cows

1. Met, Lys, and His identified most often as first limiting

1. Met: when most RUP is provided by oilseed meals, animal-derived proteins, or a combination of the two

2. Lys: when corn or feeds of corn origin provide most or all dietary RUP

3. His: when grass silage, barley and oat diets are fed without supplemental RUP