Amino Acid Formulation to Achieve Reduced Import of Nitrogen on Farm

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The transition from feeding the dairy cow for her crude protein requirement has clearly progressed today to a more sophisticated approach of formulating for the estimated requirement of amino acids (NRC Recommendation for Dairy Cattle – 2001 - http://bob.nap.edu/books/0309069971/html/). While this transition has been occurring there has been a simultaneous progression of a greater awareness of the interrelationship of diet formulation and feeding management on whole farm nutrient management. Over the past several decades there has been an increase in the cow density (cows/acre) with coincident increases in milk production and imported nutrients to the farm. This has resulted in environmental concerns related to nitrogen (N) and phosphorus (P). The focus of this paper will be to develop the concept of ration balancing for increased profit and reduced environmental impact as it relates to nitrogen. In particular, the merits of formulating for estimated amino acid requirements with the use of ruminally undegraded protein sources (RUP) sources.

Amino acid formulation. Amino acid formulation for dairy cattle has been common practice since the availability of the CNCPS (Fox et al., 1990) model and CPM model. We have used both models successfully to strategically formulate diets to evaluate the merits of sources of RUP, ruminally protected amino acids, and free lysine-HCL (Xu, et al.,1998; Harrison, et al., 2000). Others (VonKeyeserligk et al., 1999; Dinn et al., 1998) have had positive experiences with use of the model to formulate diets to reduce the CP level in the diet while maintaining milk productivity.

Reducing the CP level of the Diet. VonKeyserlingk et al. (1999) formulated two diets to determine the efficacy of the CNCPS system to reduce CP level in the diet and maintain milk yield. The ingredients in the TMR were typical of lower British Columbia and included corn silage (26 % of diet DM), grass silage (15.5 % of diet DM), grass hay (3.5 % of diet DM), and grain mix (55 % of diet DM). The animals were primarily in early lactation. Their approach was to feed a diet formulated according to the 1998 National Research Council nutrient requirement recommendations. A second diet was also formulated with the CNCPS system and included a commercial bypass protein source (Soypass®) and Alimet® (bypass methionine source). This afforded the opportunity to reduce the CP level in the grain mix by 2.9 % units and total diet by 1 % unit (see Table 1).

A summary of the dry matter intake (DM) and yield of milk and milk components is shown in Table 2. No difference was observed in DM intake or milk production between the diets formulated by the two methods. The authors concluded that the CNCPS system afforded the opportunity to reduce the CP level of the diet, maintain milk production, and reduce excess excretion of nitrogen. This was achieved by replacing components in the grain mix with a RUP source of protein in concert with addition of a bypass methionine source (Alimet®).

Table 1. Chemical composition of TMR (VonKeyserlingk et al., 1999).

Item	NRC	CNCPS
CP, % DM	18.7	17.7
ADF, % DM	21.1	21.8
NEL, mcal/kg	1.8	1.9

Table 2. DM intake and yield of milk and milk components (VonKeyserlingk et al., 1999).

Item	NRC	CNCPS
All Cows		
DMI, lb	47.4	46.6
Milk, lb	82.8	81.5
Multiparous Cows		
Milk, lb	96.5	94.3
Milk Fat,lb	2.75	2.93
Milk Fat , %	2.88	3.12
Milk Protein, lb	3.01	2.90
Milk Protein, %	3.12	3.11
Primiparous Cows		
Milk, lb	69.0	68.8
Milk Fat, lb	2.13	2.27
Milk Fat, %	3.17	3.31
Milk Protein, lb	2.18	2.18
Milk Protein, %	3.22	3.2

Comparison of the efficacy of RDP sources and bypass amino acids. Xu et al. (1998) evaluated the efficacy of RDP sources of animal and plant origin on milk productivity. A second objective was to evaluate the role of supplemental sources of bypass methionine and lysine for milk production when added to a diet containing the “poorer quality” plant based RUP source. Two basal diets were formulated with the CNCPS system based on a RDP source of plant origin (corn distillers – called the NEG diet) or of animal origin (blood meal, fish meal, and meat and bone meal – called the POS diet). The sources of bypass methionine and lysine were supplemented to the NEG diet at two levels during the early postpartum period, either 27 g/d of available lysine and 8 g/d of available methionine, or 40 g/d of available lysine and 13 g/d of available methionine. The higher levels of lysine and methionine were evaluated during the early post-partum period as this is a time of low feed intake in the dairy cow. The diets were offered during both the late pre-partum period as well as the first 24 to 43 weeks of lactation. The ingredients in the TMR were typical of lower Western Washington and included grass silage (22 % of diet DM), alfalfa hay (15 % of diet DM), and grain, byproducts and fat (62 % of diet DM).

A summary of the dry matter intake (DM) and yield of milk and milk components is shown in Table 3. An important observation of this experiment was that a diet formulated with a plant source of RUP (corn distillers grains), could sustain equal or greater levels of milk production compared to animal sources of RUP when the corn distillers grains basal diet was supplemented with rumen bypass methionine and lysine. The intake of DM was greatest when cows were fed the diet containing the plant source of RUP and the highest level of supplemental rumen protected methionine and lysine. This stimulatory effect of lysine and methionine on intake had not previously been reported. The increased production of milk which was observed in weeks 1 to 8 with the diets containing the animal source of RUP and effect of bypass methionine and lysine, was also observed in weeks 9 through 16 of lactation, see Table 4.

Table 3. DM intake and yield of milk and milk components in weeks 1 to 8 of lactation. (Xu et al., 1998).

Item	Negative	Positive	Neg + Lys + Met	Neg + High Lys +Meth	P>
DMI, lb	36.5^{b}	37.6^{b}	38.3^{b}	46.2^{a}	.01
Milk, lb	74.4^{c}	86.7^{ab}	82.5^{b}	85.8^{ab}	.08
4% FCM, lb	69.5^{c}	79.2^{b}	80.3^{b}	83.6^{ab}	.05
Milk Fat %	3.66^{bc}	3.56^{c}	3.98^{a}	3.96^{a}	.15
Fat, lb	2.66^{d}	2.97^{c}	3.15^{bc}	3.3^{ab}	.05
Protein, %	3.06^{b}	3.07^{b}	3.06^{b}	3.29^{a}	.01
Milk Protein, lb	2.27^{d}	2.62^{bc}	2.51^{c}	2.79^{ab}	.13

Table 4. DM intake and yield of milk and milk components in weeks 9 to 16 of lactation. (Xu et al., 1998).

Item	Negative	Positive	Neg + Lys + Met	Neg + High Lys +Meth	P>
DMI, lb	47.7	48.6	50.2	48.4	NS
Milk, lb	81.4^{c}	95.3^{ab}	90.4^{b}	89.5^{b}	.06
4% FCM, lb	72.6^{b}	82.5^{a}	80.3^{a}	79.2^{a}	.08
Milk Fat %	3.26	3.12	3.26	3.32	NS
Fat, lb	2.66	2.97	2.95	2.88	NS
Protein, %	3.09^{bc}	3.01^{cd}	2.98^{d}	3.12^{ab}	.06
Milk Protein, lb	2.51^{c}	2.86^{ab}	2.68^{bc}	2.79^{b}	.05

This experiment provided some important insights into the milk response when cows were fed supplemental bypass methionine and lysine to a basal diet formulated with a “poor quality” source of RUP. We also calculated income over feed costs (IOFC) based on data for the first 8 weeks of lactation. The POS diet resulted in ~ $0.66 more IOFC than the NEG diet. While the bypass source of methionine and lysine never made the market place, the product could have been priced (breakeven) for ~ $1.00 for the 27 g/d of intestinally available lysine and 8 g/d of intestinally available methionine.

Comparison of the efficacy of RUP source and supplemental bypass methionine and lysine HCl. Harrison et al. (2000) used the CPM system to formulate two diets containing either a canola based rumen bypass protein source (Amipro™) or an animal-marine blend (Prolak®) bypass protein source. Each of these diets were estimated to be slightly deficient in lysine and methionine. Two additional diets were formulated that were based on either Amipro™ or Prolak® and then supplemented with Alimet® and free lysine HCL to improve the dietary supply of Met and Lys. The postpartum levels of methionine and lysine in the basal diet were targeted to be at ~ 100 % of the requirements (1.9 % Met/MP and 6.4 % Lys/MP) and 116 % of methionine (2.2% Met/MP) and 106 % of lysine (6.6 % Lys/MP) for supplemented diets. When formulating the diets, it was considered that 20 g of Alimet provided 7 g of ruminal escape methionine (Koenig et al., 1998) and 40 g of free lysine-HCl provided 8 g of ruminal escape Lys (Velle et al., 1998). Cows were on experimental diets from ~ 28 days before calving through week 17 postpartum. The diets were typical for the region (Washington) and contained 11.6 % grass silage, 19.2 % corn silage, 11.2 % alfalfa hay, 8.6 % whole cottonseed, and 49.4 % grain mix, on a DM basis. Another important note is that cows received rBSt per label, starting 63 d after calving.

The overall postpartum data is shown in Table 5. When the whole 17 weeks postartum was considered, the important observations were for an increase in milk production and component production when cows were fed the Prolak® based diet. A trend (P<.14) was observed for increased milk fat % when the diets were supplemented with Alimet® and lysine-HCL. Similarly, milk protein % was numerically greater with supplementation as well.

Upon closer evaluation of the milk production curves we noticed that in early lactation, and at ~ 14 to 17 weeks of lactation, there was an improvement in milk that appeared to be related to supplemental Alimet® and lysine HCl – see Table 6. In the early weeks of lactation (weeks 1 to 4) the Alimet® supplemented cows fed the Prolak® diet produced the most milk. The animals on the Ami+ diet had more health issues early postpartum which is reflected in the lower average milk yield in weeks 1 to 4. Approximately 5 weeks after the beginning of rBST use, cows fed both basal diets (Prolak® and Amipro™) produced more milk when supplemented with Alimet® and lysine HCL. These observations support the use of supplemental rumen bypass methionine and lysine particularly during the critical need periods of early lactation and post rBST administration.

Table 5. DM intake and yield of milk and milk components in weeks 1 to 17 of lactation. (Harrison et al., 2000).

						P<	
Item	Ami	Ami+	Pro	Pro+	Protein	**Supplement**	Pro x Supp
DMI, lb	48.2	48.0	48.8	47.7	NS	NS	NS
Milk, lb	85.4	85.6	87.1	87.3	NS	NS	NS
3.5 % FCM, lb	86.9	87.6	89.3	91.1	.08	NS	NS
Milk Fat, lb	3.08	3.12	3.19	3.28	.03	NS	NS
Milk Fat, %	3.65	3.71	3.68	3.80	NS	.14	NS
Milk Protein, %	3.09	3.13	3.12	3.36	NS	NS	NS
Milk Protein, lb	2.62	2.62	2.68	2.86	.22	NS	NS

Table 6. DM intake and yield of milk and milk components in weeks 1 to 4 and weeks 14 to 17 of lactation. (Harrison et al., 2000).

						P<	
Weeks 1 to 4	Ami	Ami+	Pro	Pro+	Protein	**Supplement**	Pro x Supp
Item							
Milk, lb	83.2	73.3	82.5	85.4	.09	NS	.06
Weeks 14 –16							
Item							
FCM, lb	86.9	90.9	88.2	93.9	NS	.05	NS

More recent studies (Harrison et al., 2002, and Harrison et al., 2003) continue to provide evidence that formulating diets for available amino acids can provide the opportunity to reduce CP levels in the diet and reduce on-farm import of nitrogen. A field study (Harrison et al., 2002) was conducted with a high producing herd in WA state to compare their general herd diet formulated at ~ 18 % CP to a diet that was reformulated at ~ 17 % CP (Tables 7 and 8). Results showed that milk production could be maintained while decreasing nitrogen import to the farm (Tables 9 and 10). In addition, the diet reformulation resulted in an increase in IOFC (Table 11).

Table 7. Chemical composition for control and treated diets (Harrison et al., 2002).

Item	Control	Treated
CP, % DM	17.8	16.95
Available CP, % DM	16.4	15.35
Unavailable CP, % DM	1.4	1.55
Neutral Detergent CP, % DM	2.3	2.65
Adjusted CP, % DM	17.8	16.95
Soluble Protein, % DM	6.4	6
Soluble Protein, % CP	35.7	36.95
ADF, % DM	22.55	22.65
NDF, % DM	32.45	32.7
NFC, % DM	39.05	39.8

Table 8. Composition of diets (Harrison et al., 2002).

Item	Control - % DM	Treated - % DM
Alfalfa Hay	29.32	26.23
Corn Silage	19.55	19.99
Corn grain, flaked	16.15	18.01
Whole cottonseed	8.26	8.49
Corn Distiller Grains	4.35	----
Beet pulp pellets	2.10	6.22
Molasses	1.74	1.94
Ener GII	1.48	.63
Soybean Meal	----	3.45
Bakery Mix*	14.28	----
Bakery Waste	----	7.97
Soy Pass	----	3.95
Std Mineral/Vit	2.77	----
Std Minerals + Novus Premix**	----	3.12

*Bakery mix = Canola – 28.8% (as fed), soybean meal – 32.9% (as fed), and bakery waste – 32.8% (as fed).

**contained Alimet and lysine HCL at a5.7% and 24%, respectively.

Table 9. Treatment response to diet reformulation (Harrison et al., 2002).

Item	Control	Treated	SE	P<
DMI,lb	56.7	55.2	-------	--------
CP Intake, lb	10.1	9.35	-------	--------
Milk, lb	99.9	101.9	0.53	.007
3.5% FCM, lb	96.0	96.6	0.46	.32
Fat, %	3.28	3.21	0.014	.001
Milk Fat, lb	3.26	3.23	0.018	.63
Protein, %	2.90	2.93	0.006	.0009
Milk Protein, lb	2.88	2.95	0.015	.0004
MUN, mg/dl	17.5	14.5	-------	-------
Ratio Milk True Protein: Intake Protein Ratio	.285	.316	-------	-------
BW, lb	1396	1395	1.80	.88
Change in BW, lb	34	36	4.3	.70

Table 10. Environmental Characterization (Harrison et al., 2002).

Item	Control	Treated	% Change
Nitrogen Intake, gms/d	734	680	- 7.4
Milk total N, gms/d*	240	246	+ 2.5
Predicted Urinary N, gms/d**	289	239	- 17.3
Calculated Fecal N, gms/d***	205	195	- 5.0

*(Milk True protein - gms/6.38**)** X 1.17

**Estimated per J Dairy Sci.85:227-233. Urinary nitrogen (gm/d) = 0.026 X BW (kg) X MUN (mg/dl)

***Intake N- Milk N- Urine N

Table 11. Economic Evaluation. (Harrison et al., 2002).

Item	Control	Treated
Feed Costs, $/day/cow	4.82	4.88
Milk Income, $/day/cow	11.92	12.10
IOFC*, $/day/cow	7.10	7.22

*IOFC = Income over feed cost.

Another study conducted at the WSU Knott Dairy Center in Pullman, WA (Harrison et al., 2003) showed similar responses to those noted for the field study. In this study we were able to reduce the CP from ~ 18 % to 16 % and also reduce the amount of nitrogen imported to the farm by replacing alfalfa silage with corn silage and bypass protein sources (Tables 13 and 14 - Prolak and ADM–Moormans proprietary source of soybean meal byproduct). Diet evaluation with CPM (Table 15) showed diet three resulted in the best ratio and supply of methionine and lysine. Diet three also provided the best milk production performance, ratio of milk true protein to diet protein, and IOFC. The reduced milk response with diet 2 emphasizes the need to make sure that the ratio of Lys/Met is ~ 3.2:1.

Table 12. Diet composition. (Harrison et al., 2003).

	Diet Number		
	1 Control	2 Met	3 Met + Lys
Feed Ingredients		(DM %)	
Alfalfa Hay	16.6	18.5	18.5
Alfalfa Silage	26.6	0.0	0.0
Corn Silage	0.0	29.1	29.1
Whole Cottonseed	10.2	10.2	10.2
Wheat Mill Run	8.3	5.0	5.0
Grain Mix	38.3	37.2	37.2

Table 13 - Chemical Analyses of TMR – all data expresses as %DM except as noted (Harrison et al., 2003).

Item	Diet 1	Diet 2	Diet 3	S.E.
CP	18.6	16.0	16.0	0.35
ADF	27.4	29.8	32.9	2.19
NDF	38.9	41.2	44.7	1.88
SolCP	7.53	5.1	5.4	0.38
NFC	31.9	34.4	30.7	2.16

Table 14. Diet formulation results from CPM (Harrison et al., 2003).

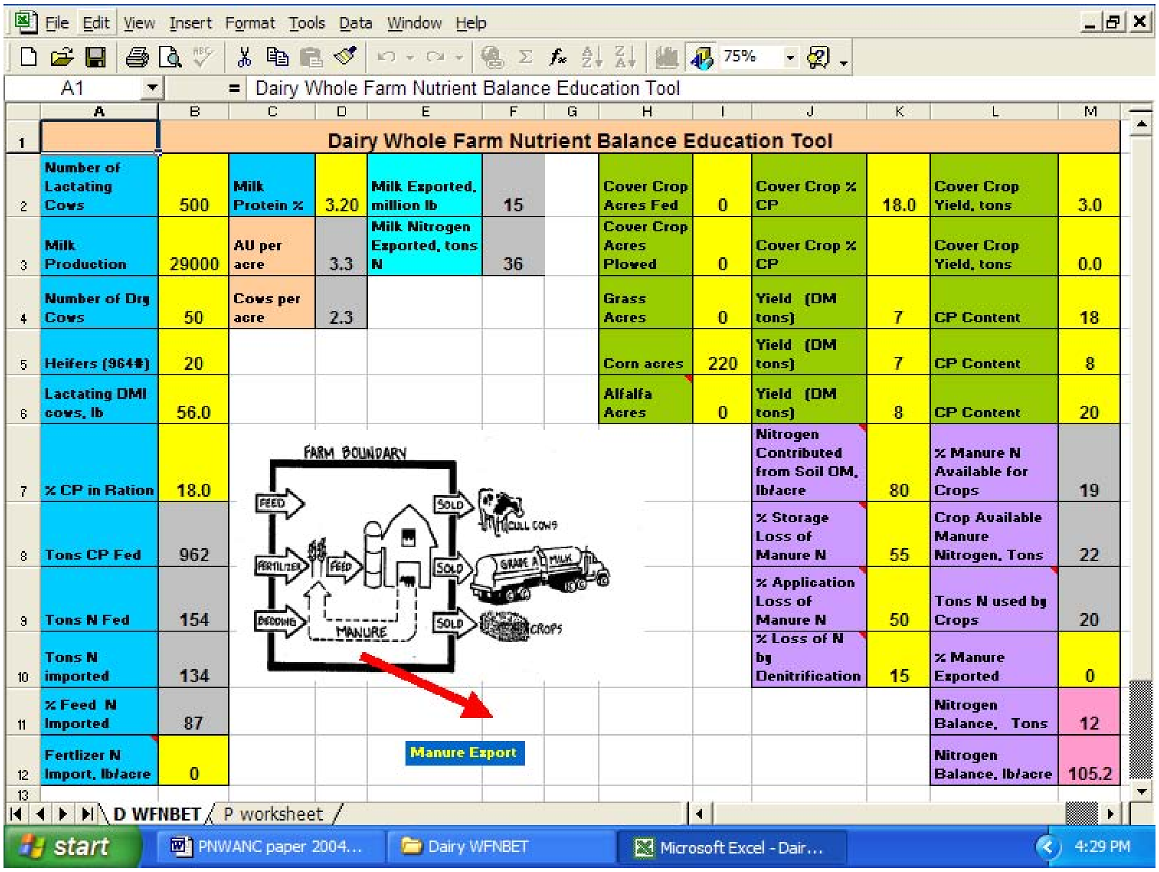
Item	Trt 1	Trt 2	Trt 3
Lys % required	89	99	116
Met % required	91	116	109
Lys/Met	3.32:1	2.89:1	3.16:1
MP balance, gm	-477	-104	-117

Table 15 – Summary of Production Trial (Harrison et al., 2003).

Item	Diet 1	Diet 2	Diet 3	S.E.	TRT p<
DMI, kg	20.4	20.5	20.5	1.35	NS
Milk, kg	35.8	35.4	37.5	2.32	NS
Fat, kg	1.34^a	1.11^b	1.38^a	.083	.02
Protein, kg	1.10	1.08	1.13	.071	NS
Fat %	3.80^a	3.24^b	3.79^a	0.151	.01
Protein %	3.08	3.08	3.07	0.071	NS
MUN, mg/dl	18.8^a	13.0^b	14.4^b	0.92	.01
CP Intake, kg	3.79	3.28	3.28	-----	-----
Milk True Protein /Feed CP	.29	.33	.34	-----	-----
Reduction in protein importation, %	-----	8.6	8.6	-----	-----
Feed Cost/day	\$3.10	\$3.07	\$3.07	-------	-------
Milk Income @ \$10.50/cwt 3.5% FCM	\$8.59	\$7.71	\$8.92	------	-------
IOFC	\$5.49	\$4.64	\$5.85	------	------

It is increasingly evident that reducing the CP content of rations can be achieved by strategic addition of bypass protein sources and amino acids (lysine HCL and Alimet) under a variety of diet conditions and with high producing cows. These successes require the need to use ration balancing software that can estimate the amino acid (met and lys) needs of the lactating dairy cow. In addition, we have found that using bypass protein sources that have dependable supplies of amino acids is critical to achieve consistent production responses.

The next task is to take this effort to the whole farm level and evaluate the impact that reduced CP diets can have on whole farm nitrogen balance. To achieve this type of evaluation we developed a Whole Farm Balance Nutrient Education Tool (WFBNET) (Harrison et al,. 2004) which allows simple what-if scenarios to be considered. The tool is Excel based and consists of two single-page views that consider both nitrogen and phosphorus. The spreadsheet is available at no charge by sending an e-mail to jhharrison@wsu.edu.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Dairy Whole Farm Nutrient Balance Education Tool											
2	Number of Lactating Cows	500	Milk Protein %	3.20	Milk Exported, million lb	15		Cover Crop Acres Fed	0	Cover Crop % CP	18.0	Cover Crop Yield, tons	3.0
3	Milk Production	29000	AU per acre	3.3	Milk Nitrogen Exported, tons N	36		Cover Crop Acres Plowed	0	Cover Crop % CP		Cover Crop Yield, tons	0.0
4	Number of Dry Cows	50	Cows per acre	2.3				Grass Acres	0	Yield (DM tons)	7	CP Content	18
5	Heifers (964#)	20						Corn acres	220	Yield (DM tons)	7	CP Content	8
6	Lactating DMI cows, lb	56.0						Alfalfa Acres	0	Yield (DM tons)	8	CP Content	20
7	% CP in Ration	18.0								Nitrogen Contributed from Soil OM, lb/acre	80	% Manure N Available for Crops	19
8	Tons CP Fed	962								% Storage Loss of Manure N	55	Crop Available Manure Nitrogen, Tons	22
9	Tons N Fed	154								% Application Loss of Manure N	50	Tons N used by Crops	20
10	Tons N imported	134								% Loss of N by Denitrification	15	% Manure Exported	0
11	% Feed N Imported	87										Nitrogen Balance, Tons	12
12	Fertlizer N Import, lb/acre	0			Manure Export							Nitrogen Balance, lb/acre	105.2
13													

References

Dinn, N.E., J. A. Shelford, and L. J. Fisher. 2998. Use of the Cornell Net Carbohydrate and Protein System and rumen-protected lysine and methionine to reduce nitrogen excretion from lactating cows. J Dairy Sci. 81:229-237.

Fox, D. G., C. J. Sniffen, J. D. O'Connor, J. B. Russell, and P. J. Van Soest. 1990. The Cornell Net Carbohydrate and Protein System for evaluating cattle diets. Part 1: A model for predicting cattle requirements and feedstuff utilization. Pages 7-83 in Search: Agriculture No. 34. Cornell Univ. Agric. Exp. Stn., Ithaca, NY.

Harrison, J H, D Davidson, L Johnson, M L swift, M vonKeyserlingk, M Vazquez-Anon, and W Chalupa. 2000. Effect of source of bypass protein and supplemental Alimet and lysine-HCL on lactation performance. J Dairy Sci 83(suppl 1):268.

Harrison, J., L. Johnson, D. Davidson, J. Werkhoven, A. Werkhoven, S. Werkhoven, M. Vazquez-Anon, G. Winter, N. Barney, and W. Chalupa. 2002. Effectiveness of strategic ration balancing on efficiency of milk protein production and environmental impact. J. Dairy Sci. 85:205 (Suppl. 1).

Harrison, J H, R L Kincaid, W Schager, L Johnson, D Davidson, L D Bunting, and W Chalupa. 2003. Strategic ration balancing by supplementing lysine, methionine, and Prolak on efficiency of milk protein production and potential environmental impact. J Dairy Sci. 86:60 (Suppl 1).

Harrison, J.H., T Nennich, and C.A. Rotz. Use of a Dairy Whole Farm Phosphorus Balance Education Tool (Dairy WFPBET) to teach dairy producers and their advisers about nutrient management concepts at the whole-farm level. J Dairy Sci. 87:248 (Suppl 1).

Koenig K.M, L. M. Rode, C. D. Knight, and P. R. McCullough..1999. Ruminal Escape, gastrointestinal absorption, and response of serum methionine to supplementation of liquid methionine hydroxy analog in dairy cows. J. Dairy Sci. 82:355

Vázquez-Añón, M., G. Varga, P. McCullough and T. Cassidy 2001. Effects of Alimet® on nutrient digestibility, bacterial protein synthesis, and ruminal disappearance during continuous culture. J. Dairy Sci. 84:159-166.

Velle W., T.I. Kanui, A. Aulie, and O.C Sjaastad. 1998. Ruminal Escape and Apparent Degradation of Amino Acids Administered Intraruminally in Mixtures to Cows. J. Dairy Sci. 81:3231-3238.

VonKeyserlingk, M. A. G., M. L. Swift, and J. A. Shelford. 1999. Use of the Cornell Net Carbohydrate and Protein System and rumen-protected methionine to maintain milk production in cows receiving reduced protein diets. Can. J. Anim. Sci. 79:397-400.

Xu, S., J.H. Harrison, W. Chalupa, C. Sniffen, W. Julien, H. Sato, T. Fujieda, K. Watanabe, T. Ueda, H. Suzuki. 1998. The Effect of Rumen-Bypass Lysine and Methionine on Milk Yield and Composition in Lactating Cows, J. Dairy Sci. 81:1062.