Forages, Nutrient Loading and Decision Making Solutions

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Take Home Messages:

- It is estimated that 70 to 80% of N brought on today's dairy farm through feed is not exported from the farm in meat or milk.
- As nutritionists, we have a key role in designing diets which are environmentally responsible.
- Tools such as Cornell Pen Minor exist to enable nutritionists to evaluate diets in terms of N excretion.
- Nutritionists should ascertain that the forages they are using in their diets conform to the nutrient analyses in the CPM database.
- B.C. grown corn silage contains less starch and lignin that shown for comparable corn silage in the CPM database. There is a higher proportion of N associated with the ADF and NDF fiber fractions in B.C. grown corn silage.
- B.C. grown grass silage contains less sugar that its counterpart in the CPM database.
- Nutritionists need to take a more active role in recommending and evaluating agronomic practices that have a direct impact on the feeding value of forages.

Agricultural production is recognized as a significant contributor to greenhouse gas (GHG) production (Amon et al., 2006; Monteny et al., 2006). Intensive dairy production, in particular, contributes significant quantities of methane (CH4) and several forms of nitrogen (N) which can contribute to nitrous oxide (N2O) production (Casey et al., 2005; Jarvis et al., 1996) In addition, there is concern regarding N and P pollution originating from livestock production units on surface and ground water quality. Last, but not least, there is the issue of odor. These issues have resulted in various measures ranging from that of increasing producer awareness through articles in the popular press to more direct action such as legislation.

Livestock production is a complex system involving inputs such as feed and fertilizer, animals and the production of manure, storage systems, cropping systems and export of meat and milk as shown below for FarmBC, an actual farm located in the south coastal region of British Columbia (Figure 1). Therefore, it is probable that management changes proposed to reduce emissions of GHG and/or N or P pollution in one area of the production cycle will most certainly have long term effects on other parts of the system. Swift and Bittman (2006) demonstrated this effect using the Integrated Farm System Model, formerly called DAFOSYM (Rotz et al., 1999).

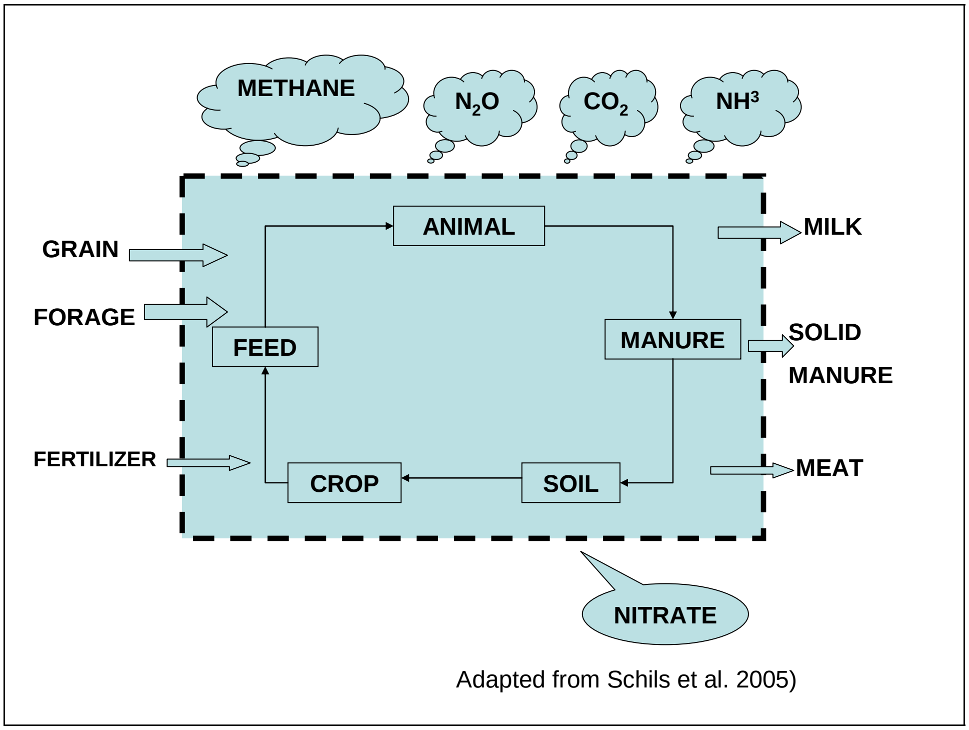

Figure 1. Flow diagram of FarmBC dairy production System.

Using data from FarmBC, Swift and Bittman (2006) evaluated six scenarios including choice of bedding (sawdust versus sand), cover cropping corn land, covered versus non-covered manure storage, manure application by injection versus surface spreading and lastly, annual milk production of 12,200 versus 13,200 liters per cow. Results, expressed as kg N per hectoliter of milk produced clearly showed these strategies served only to "move" N around the farm system. For example, covering manure storage was very effective at reducing losses of N from volatilization but when viewed within the whole farm context, the same best management practice serves to increase leaching and denitrification losses once the manure is applied to crop land. Therefore, the old adage that "an ounce of prevention is worth a pound of cure" certainly applies to managing N and P on farm in that the only effective strategy to reduce N and P pollution is to reduce feed and fertilizer inputs.

One method used to quantify the movement of N and P through dairy and beef production systems is the "farm-gate" balance which simply looks at the difference between inputs and outputs of the nutrient in question. Calculation of a farm-gate balance for FarmBC shows that feed (grain and forage) accounts for 86% of N imported onto the farm annually. Therefore, as nutritionists, we have a large role to play in the design of environmentally responsible diets which support optimum production, animal health, reproductive efficiency and economic return to the producer. No small task!!!!

Depending on type and quality, forage dry matter comprises between 40 and 60% of daily dry matter intake of a high producing dairy cow. In the Pacific Northwest, these forages will be alfalfa hay/silage, grass hay/silage and/or corn silage. Therefore correct characterization of forage nutrient content is important, especially if more complex ration balancing models such as Cornell Pen Minor (CPM) is being used. These models attempt to simulate the digestive and nutrient absorption process in the animal and as such require increasingly sophisticated nutrient input information. The CPM program provides a comprehensive database detailing forage nutrient composition. However, initial comparison of N degradability values for corn and grass forages contained within these databases with that obtained from two projects completed at the University of British Columbia (von Keyserlingk et al., 1996; Swift, 2003) showed significant differences. As a result, Abbotsford Veterinary Clinic (AVC) initiated a project to collect information regarding nutrient content of forages grown in British Columbia to serve as the basis for a geographic specific database. One hundred and sixteen samples of corn silage and 181 samples of grass silage were collected. In addition, information from 32 samples of corn silage collected in 1995, and 69 samples of grass silage collected in 1993 and 1997 was incorporated into the database.

Corn silage nutrient data obtained from the AVC project was grouped according to DM in order to simulate data provided in the CPM forage database (Table 1). Notable differences between the AVC and CPM data include the higher quantity of protein associated with the fiber fractions, decreased digestibility rate of the NDF fraction and lower lignin and starch contents of B.C. grown corn silage.

Similarly, grass silage nutrient data obtained from the AVC project was grouped according to NDF content and compared to data contained within the CPM forage database (Table 2). Of note were the increased content of ash and lower content of sugar in B.C. grown grass forages.

In order to evaluate the significance of these findings, a ration was formulated for a cow producing 40.8 kg (90 lbs) of milk containing 3.7% butterfat and 3.2% total protein using CPM Version 3.08. The dry matter intake of 24.4 kg (53.7 lbs) as required by CPM consisted of 2.2% alfalfa hay (AlfHy25Cp25Ndf15LNdf), 52.1% corn silage, 21.7% grass silage, 16.1% ground barley, 3% each of soybean and canola meals, 0.43% each of corn gluten meal and a commercial bypass fat and 1% limestone, salt, and a vitamin-mineral premix. The nutrient specifications for corn silage was as shown in the CPM data for CrnSilPr30Dm45NdfMed or modified according to the specifications shown in Table 1 for AVC corn silage containing 30% DM. Similarly, the nutrient profile for grass silage was shown in CPM for GrssSil16Cp55Ndf6Lndf or modified according to the specifications in Table 2 for AVC grass silage containing 55% NDF. These rations were formulated to contain 100% and 90% of metabolizable energy and protein requirements, respectively. The rations contained 16.2 and 16.0% crude protein, respectively.

The CPM program provides a farm gate balance for N and P by calculating intake and providing estimates of output through milk, urine and feces. Evaluations of these diets show that N intake is comparable for the CPM and the AVC diets at 629.7 and 624.5 grams per day, respectively. As these diets were formulated for the same milk production, milk N output was the same for the two diets at 207.9 grams per day. However, the urinary output of N differed between the two diets by 10 grams per cow per day (156.5 versus 146.6 grams for the CPM and AVC diets, respectively). Urinary N output is associated with volatilization of N from barns, manure storage and field spreading (Castillo et al., 2000). A difference of 10 grams/cow/day in urinary N output translates into 365 kg of N/100 cows/year or 280 tonne annually for the B.C. dairy industry.

In a recent review, Givens and Rulquin (2004) concluded that the utilization of N fractions in forage, particularly grass and legume forage is poor and called for a "radical rethink" about the way these forages are produced and used. For example, a number of studies have shown that increasing harvest intervals increases content of rumen undegradable protein in grass (as reviewed by Groenenboom, 2005). However, this practice has not been widely adopted due to the increase in NDF content associated with increasing maturity.

In order to evaluate the practice of harvesting grass early to lower NDF content, samples of the first cut grass silage collected in 1993, 1997 and 2002 and used in the Abbotsford Veterinary Clinic project were compared. The average protein content of first cut grass silage in 1993, 1997 and 2002 was 15.6, 13.9 and 17.7%, respectively. The content of soluble protein (% CP) increased some 20% from 1993 to 2002 (45.3 to 63.9%) while the amount of protein associated with the NDF fraction decreased from 31.8 in 1993 to 12.0% in 2002. The content of NDF was 57.8, 57.9 and 50.4% in 1993, 1997 and 2002, respectively. However, the rate of NDF disappearance (% per hour) did not change over the 9 year time period (5.2, 5.3 and 4.9%, respectively).

In summary, today's dairy farm needs to evaluated as a complex system where management changes implemented in one area of the production cycle will most certainly have long term effects on other parts of the system. As nutritionists, we are or will be responsible for providing environmentally responsible rations and as such, will have to utilize tools such as CPM which provide farm gate nutrient balances. Nutritionists need to take a more active role in recommending and evaluating agronomic practices that have a direct impact on the feeding value of forages.

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References

Amon, B., V. Kryvoruchko, T. Amon and S. Zechmeister-Boltenstern. 2006. Methane, nitrous oxide and ammonia emissions during storage and after application of dairy cattle slurry and influence of slurry treatment. Agriculture, Ecosystems and Environment 112: 153-162.

Casey, J. W. and N. M. Holden. 2005. Analysis of greenhouse gas emissions from the average Irish milk production system. Agricultural Systems 86:97-114.

Castillo, A.R., E. Kebreab, D.E. Beever and J. France. 2000. A review of efficiency of nitrogen utilization in lactating dairy cows and its relationship with environmental pollution. J. Animal and Feed Research 9:1-32.

Givens, D.I. and H. Rulquin. 2004. Utilisation by ruminants of nitrogen compounds in silage-based diets. Anim. Feed Sci. Technol. 114:1-18.

Groenenboom, P. 2004. Investigating reduced nitrogen fertilization and delayed harvest of orchardgrass as a means of reducing the amount and altering the form of nitrogen excreted by lactating dairy cattle. M.Sc. Thesis. University of British Columbia, Vancouver, B.C.

Jarvis, S. C. and B. F. Pain. 1994. Greenhouse gas emissions from intensive livestock systems: Their estimation and technologies for reduction. Climatic Change 27: 27-38.

Monteny, G.J., A Bannink and D. Chadwick. 2006. Greenhouse gas abatement strategies for animal husbandry. Agriculture, Ecosystems and Environment 112: 163-170.

Rotz, C.A., D. R. Mertens, D. R. Buckmaster, M.S. Allen and J. H. Harrison. 1999. A dairy herd model for use in whole farm simulations. J. Dairy Science 82:2826-2840.

Swift, M. L. 2003. Prediction of protein fractions and amino acid content of corn and grass forages using near infrared spectroscopy (NIRS). PhD Thesis, University of British Columbia, Vancouver, B.C.

Swift, M.L. and S. Bittman. 2006. "Whole Farm Modelling to Evaluate Economic and Production Implications of BMP's Designed to Reduce Greenhouse Gas Emissions: Case study of dairy production in coastal British Columbia. Biocap Canada Research Integration Program. www.biocap.ca

von Keyserlingk, M. A. G., M. L. Swift, R. Puchala, and J. A. Shelford. 1996. Degradability characteristics of dry matter and crude protein of forages in ruminants. Anim. Feed Sci. Technol. 57:291–311.

Table 1. Comparisons between mean nutrient values contained with CPM database (CPM) and actual values (AVC DATA) from corn silage samples collected from the lower Fraser Valley/Vancouver Island in 1995, 2002 and 2003. Comparisons grouped in regards to CPM model partition by dry matter content.

	CPM DM = 25%		CPM DM = 30%		CPM DM = 35%	
	CPM	AVC DATA	CPM	AVC DATA	CPM	AVC DATA
Dry Matter %	25.0	23.5	30.0	30	35	34
Crude Protein %DM	9.5	9.2	9.2	8.8	9.2	8.5
Soluble Protein %CP	58.0	55.3	53.0	52.8	53.0	46.5
ADF Protein %CP	7.0	10.9	7.0	10.6	7.0	11.0
NDF Protein %CP	16.0	19.2	16.0	19.6	16	22.8
ADF	30.0	30.7	28.0	27.1	28	25.2
NDF	49.0	49.2	45.0	45.0	45.0	44.5
NDF Digest %/h 1	6.80	3.84	5.95	3.81	5.10	3.65
Lignin % NDF DM	10.0	6.6	9.0	6.7	9.0	6.2
Fat % DM	3.2	3.3	3.2	3.2	3.2	3.1
Ash % DM	4.0	5.4	4.0	4.7	4.0	4.3
Starch % NSC	77.0	54.8	77.0	63.0	77.0	64.5
NSC % DM	35.8	34.7	40.1	39.9	40.0	41.7
Calcium %DM	0.23	0.22	0.31	0.19	0.310	0.19
Phosphorus %DM	0.24	0.19	0.27	0.19	0.19	0.20
Magnesium %DM	0.13	0.16	0.22	0.16	0.22	0.15
Potassium %DM	0.95	1.07	1.22	0.95	1.22	0.82
Sodium %DM	0.01	0.02	0.01	0.02	0.01	0.02
Sulphur %DM	0.12	0.13	0.12	0.13	0.12	0.13
Chloride %DM	0.32	0.41	0.32	0.38	0.32	0.33

CP = crude protein; ADF = acid detergent fiber; NDF= neutral detergent fiber; NSC = non-structural carbohydrate. 1Equation to calculate NDF Digestibility Rate %/h provided by M. VanAmburgh, Cornell University.

Table 2. Comparisons between mean nutrient values contained with CPM database (CPM) and actual values (AVC DATA) from grass silage samples collected from the lower Fraser alley/Vancouver Island in 1993, 1995, 2002 and 2003. Comparisons grouped in regards to CPM model partition by NDF content.

	CPM NDF = 48%		CPM NDF = 55%		CPM DM = 67%	
	CPM	AVC DATA	CPM	AVC DATA	CPM	AVC DATA
Dry Matter %	35	38	35	36	40	35
Crude Protein %DM	20	21	16	16	10	14
Soluble Protein %CP	60	59	50	48	40	44
ADF Protein %CP	6	6	8	9	12	14
NDF Protein %CP	20	19	25	31	40	33
ADF %DM	30	29	40	35	45	39
NDF %DM	48	44	55	55	67	61
NDF Digest %/h 1	6.5	5.9	5.5	5	4.0	4.5
Lignin % NDF DM	7	8	8	8	9	9
Fat % DM	4	5	4	4	4	4
Ash % DM	6	11	6.3	11	7.2	10
Sugar % NSC	21	16	21	8	18	8
NSC % DM	26	24	22.7	19	15.8	19
Calcium %DM	0.57	0.54	0.57	0.50	0.57	0.41
Phosphorus %DM	0.36	0.39	0.36	0.36	0.36	0.31
Magnesium %DM	0.22	0.25	0.22	0.24	0.22	0.20
Potassium %DM	3.11	3.0	2.78	2.7	2.58	2.10
Sodium %DM	0.05	0.13	0.05	0.12	0.05	0.11
Sulphur %DM	0.2	0.31	0.2	0.28	0.2	0.24
Chloride %DM	0.67	0.90	0.76	0.92	0.810	0.63

CP = crude protein; ADF = acid detergent fiber; NDF= neutral detergent fiber; NSC = non-structural carbohydrate.

1Equation to calculate NDF Digestibility Rate %/h provided by M. VanAmburgh, Cornell University.