Targeted Feeding to Save Nutrients

Charles J. Sniffen, Ph.D.
Fencrest, LLC
fencrest@msn.com

William Chalupa, Ph.D.
University of Pennsylvania
wmchalupa@aol.com

Introduction

There is increasing pressure at federal, state and local levels about nutrient waste and pollution relative to N, P, CH_4 and CO_2 discharges from the animal industry. Large animal operations have come under more intense scrutiny than small animal operations, with CAFO regulations being put in place.

This has put increasing pressure on producers and us as nutritionists to provide some of the solutions to the problem. There has been considerable research conducted in the last decade in this area; the focus of this paper will be to examine what can be done in the formulation of rations to save nutrients and as a result to increase efficiency, profitability and sustainability for the producer.

Farm Nutrition Management

As nutritionists, we assess farms as to animal grouping, degree of over stocking, management of the groups and the environment surrounding each group. We then look at the quality of the forages being offered and most importantly the variability of the quality of the forages and other on farm feeds. We then make decisions as to how much safety we need to build into the rations being developed; basically the more variability in the management and the feeds the higher are the safety factors that are built into a ration resulting in a lower efficiency and a greater loss of nutrients. There are several approaches that can be taken to increase efficiency; the first is to have more groups; when we have few replacement groups and few lactating groups, by definition we will need to overfeed some of the animals within that group as well as underfeeding other animals within that group. We will, in developing rations, not feed for the average cow in the group but for the top 20 to 30% of the animals in the group, which will result in inefficiencies. Having multiple groups for many dairies is not possible and so we will need to develop strategies to improve efficiencies within these constraints as well.

There is also an opportunity to increase the efficiency of nutrient use with the use of robotic systems which will allow the ability to target the requirements of the cow more closely; this might mean the development of more than one parlor mix to more properly target each cow's requirements.

Nutrition Advancements

Saving nutrients has been the focus of many studies in recent years; admittedly not always from an environmental viewpoint but to increase efficiency and to reduce costs in feeding the cows. We have fed cows based on the Weende feed analyses system since the late 1800's; this was a significant advance at the time that was so powerful that it has continued to this day!! We still use CP, EE, ash, and calculated NFC routinely in our evaluations of rations. Crude fiber is still being used in parts of the industry. A significant change was made with the change from crude fiber to initially ADF and then NDF and with the latest models aNDFom. We then incorporated the measurement of lignin. With the use of NDF, this resulted in a reduction in the calculated NFC. As we know, N has been a big issue in the environment resulting in many regulations. The fact is we, in the dairy industry, have been overfeeding N for a long time; our standard for many years has been to have a ration for high producing cows with 17 to 18 % CP. We used to be concerned when the MUN went below 14 to 15 or when it went above 18 mg/dl. We now know that we can feed rations for high groups in the 14 to 15 %CP range; This started with the work of Broderick (Colmenero & Broderick, 2006) who did some classic work many years ago showing that milk production could be maintained with a lower CP and further that MUN's and more importantly that there was significantly less wasted N being excreted as urinary N.

Nitrogen intake and excretion from rations varying in CP levels

Ration CP,%	13.5	15	16.5	17.9	19.4
N intake, g/day	483	531	605	641	711
Milk N, g/day	173	180	185	177	180
Total manure N, g/day	309	316	376	410	467
Fecal N, g/day	196	176	186	197	210
Urinary N, g/day	113	140	180	213	257
Urinary N, % of manure N	36.5	44.3	47.8	52	55
Milk N, % of N intake	36.5	34	30.8	27.5	25.4

Source: Olmos Colmenero and Broderick, J. Dairy Sci. 89:1704, 2006

There have been many other studies since then that corroborated this work. The models used at the time were the early NRC models to formulate these rations. With the initial release of the CNCPS system and NRC 2001, there was a significant step forward in our understanding of N utilization by the cow.

With the release of the latest versions of CNCPS there have been the developments of several platforms incorporating this model. Additionally there are available other platforms based on either CNCPS or NRC. We will use only a two platforms to demonstrate the opportunities to formulate rations to increase efficiency.

Below is an example from NDS of the different things we need to think about monitoring going forward.

Fecal excretion and wet manure				Fecal composition					
	Total lbs	N g	P g		%		%		%
Dry Feces	20.50			Total CHO	57.72	NDF/NDF diet	54.64	Protein	17.42
Wet Feces	121.61	259.20	50.13	Starch	2.67	pdNDF/pdNDF diet	43.79	Lipid	8.67
Urine	48.48	185.62	1.26	Soluble fiber	0.42	Starch/Starch diet	3.68	Ash	16.19
Wet manure	170.09	444.82	51.39	NDF	54.21				
Intake		679.25	90.15	uNDF (240)	19.15				
Productive		234.43	38.76	Lignin	7.98				

Productive N/Total N	34.51 %	Productive P/Total P	43.00 %	CH4 (Mcal)	6.50
Productive N/Urinary N	1.26:1	Manure P/Total P	57.00 %	CH4 (liters/day)	711.09
Manure N/Total N	65.49 %			CH4 (g/day)	509.72
NH3 Potential (g)	120.65			CH4 (g/lbs milk)	5.10
				CO2 (lbs/day)	34.41
				CO2 (lbs/lbs milk)	0.34

The focus is on N and P excretion and CH_4 & CO_2 emissions. We need to become comfortable with monitoring N not only the excretion of N but also the NH_3 potential.

Our challenge is to formulate rations to reduce excess N & P excretion as well as to control CH_4, CO_2 & NH_3 and nitrous oxide (N_2O). The use of the new technologies in the NRC & CNCPS models allows us to make a step forward in achieving a reduction in excess nutrients and emissions. The above figure does not address N_2O but does the others. For N the correlation between excess N intake, N in urine and the MUN are highly correlated. We do not measure the N excreted in the urine or the manure routinely but we all monitor MUN's now. We use to accept MUN's in the 14 to 16 mg/dl area but now we routinely expect to achieve MUN's below 10 mg/dl. Below is an example from AMTS for predicted MUN.

Diet CP	15.33 %DM
RDP	56.58 %CP
RDP	8.67 %DM
Soluble Protein	37.97 %CP
Predicted MUN	10.8 mg/dl

Reports now provide information like above; if using CPM (recently the UPENN Model), Dalex, NDS or AMTS, they all have predictions; with the predictions in Dalex, NDS & AMTS being a little more accurate when using the 6.1 or 6.5 models.

Ration Formulation

Ration formulation starts with a critical evaluation of the groups that are to be fed a ration. This starts with an evaluation of first the mature frame size weight and then the weighted average weight of the cows in the group that are being fed; this is very important in the CNCPS based models, because it impacts not only animal requirements but the prediction of the rate of passage and CHO & protein digestibility. Next we want to define things like the days in milk, the amount of milk and the milk components; milk and milk components is a two-step process; first we need to be in the evaluation mode to determine if the model predicts the current milk and components accurately and if the model is predicting within a few lbs. we can then formulate for the milk and components desired. Additional information is important as well; we need to know about the environment that surrounds the group we are feeding – temperature, humidity, air flow, degree of overcrowding, bunk space and water space, to name a few. With this information we can more accurately assess the performance and to formulate a ration more accurately. We will be using the CNCPS model using AMTS 6.1(AMTS 6.5 will be released in the first quarter 2015) and NDS 6.5 for the demonstration of the concepts in targeted ration formulation.

In order to achieve a high efficiency of N utilization there needs to first be a balance of not exceeding the rumen NH3 and peptide requirements. This is many times difficult to achieve when one is locked into an on farm inventory of feeds that need to be fed out at certain rates. In the long term, working with the nutritionist and agronomist the forages in the rations can be planned to reduce N & P excesses.

Feed	lbs/day (DM)	lbs/day (AF)	%DM
Alfalfa Hay 20 CP 37 NDF 17 LNDF	11.4	12.7	18.848
Corn Silage Processed 35 DM 45 NDF Coarse	18.0	51.4	29.758
Wheat Silage 12 CP 58 NDF 10 LNDF	2.4	7.3	3.968
Corn Grain Ground Fine-fencrest	5.775	6.563	9.547
Corn Grain Flaked 28 lb	7.864	9.145	13.000
Soybean Hulls Ground	2.257	2.480	3.731
Citrus Pulp Dry-fencrest	4.192	4.732	6.930
Almond Hulls 33 NDF	2.240	2.575	3.703
Megalac-fencrest	0.380	0.392	0.628
Urea 281 CP-fencrest	0.225	0.227	0.372
Soybean Meal 475 Solvent	2.100	2.333	3.471
Soy Plus-AMTS	2.700	3.030	4.463
Blood Meal Average	0.000	0.000	0.000
AJIPRO_L-AMTS	0.210	0.219	0.347
Smartamine M-AMTS	0.050	0.051	0.083
Min Vit Premix	0.6954	0.6999	1.150
Total	60.4931	103.8217	100.000

Above is a ration in AMTS 6.1 with a mixture of ingredients that might be used in the Western part of the US. It will be noted that urea and a fat source are put into the ration for consideration when the ration is optimized; again the forages are on farm forages and there may be minimum and/or maximum constraints placed on these forages due to inventory considerations. Note also that blood meal was a consideration but when the ration was optimized it was not used; this of course can change depending on prices.

Below are the results of the optimized ration in AMTS 6.1. For those used to using CPM this is the familiar default screen.

DMI (lbs/day)	60.49	Model	55.74	% Model	108.54
ME Bal (Mcal)	1.6	CP (%)	15.4	NDF (%)	31.2
MP Bal (g)	13.9	RUP (%CP)	43.4	Forage NDF (%NDF)	72.6
NP/MP (%)	67.0	LCFA (%)	3.1	Forage NDF (%DM)	22.7
Bact. MP (%MP)	51.76	EE (%)	4.0	peNDF (%)	23.1
				Lignin (%DM)	3.4
				Lignin (%NDF)	11.3
Rumen N Balance				NFC (%)	44.1
Pept (g)	101	Pept & NH3 (g)	44	Silage Acids (%)	0.7
% Rqd	144	% Rqd	122	Sugar (%)	6.6
				Starch (%)	26.6
Amino Acid Balance				Sol. Fiber (%)	8.8
MET (g)	23.0	LYS (g)	51.6		
MET (%Rqd)	146	LYS (%Rqd)	131	LYS:MET	2.98
MET (%MP)	2.4	LYS (%MP)	7.0		
ME & MP Production					
	Milk (lbs)	Fat (%)	TP (%)		
Trg:	100.0	3.70	3.13		
ME:	103.2	N/A	N/A		
MP:	100.7	N/A	N/A		
Ration DM (%)	58.27	Forage DM (%)	52.57		

The ration CP is at 15.4% which is up a little bit from the original formulation of 14.8% but there was an indication of a potential NH_3 deficit so urea came into the solution. Note that the approach used was to use an optimization procedure rather than by substitution. With this approach one can first establish the prices of the feeds to be considered, next the minimum and maximum amounts to be considered in the ration and then the nutritional constraints such as the minimum MP and ME in the ration. With the advancement of the models we now have the capability to refine rations so that we are not overfeeding N or P as we have in the past. Understand though, nutritionists will overfeed nutrients when they observe day to day variability in the on farm feeds offered to the different animal groups so as to maintain productivity.

One of the challenges is the number of groups we should have. It is advantageous from a nutrient management stand point to have homogenous groups based on a physiological requirements basis as well as being able to fine tune the rations; we can further fine tune this with robotic systems. However, having many groups adds challenges relative to increased labor costs in feeding as well as increased challenges in animals adapting to pen & ration changes. With a one group system we will be overfeeding many of the cows which will potentially decrease efficiencies.

Refinement with the advanced models starts on the carbohydrate side with improved prediction of the ruminal digestibility of the NDF in the ration. We first need a better prediction of the potentially available NDF which we now have with the use of what we now call $uNDF_{240}$. This is an estimate of the indigestible NDF which replaces lignin*2.4. With this and the NDF digestibility at 30 and 120 hours we can improve our estimates of fiber digestion in the rumen. We now have a much improved understanding of the ruminal starch digestibility with the use of the 7hr Invitro measurement, which at this point is a good ranking tool and has allowed us to refine our estimates of

the rate of digestion of the starch being fed. These two sources of fermentable CHO make up the biggest percentage of rumen degradable CHO. With the improved estimates we have an improved prediction of microbial protein yield and also the ability to better predict the ruminal N needs so that we can minimize excess NH_3 being absorbed into the blood and being excreted in the urine. The model continues to use the NRC 2001 mineral submodel with the estimates of the bioavailability's; very important as we consider over formulating minerals and the impact to the environment.
It is suggested that we need to now consider formulating for fermentable CHO fractions rather than total fractions. Below is the fermentable CHO profile from NDS of the above ration. We try to achieve a total CHO fermentability of over 40% DM and a fermentable NDF of over 10% DM. Due to the cost of corn grain in the not too distant past, we started to reduce the amount of purchased fermentable starch which has moved us to higher amounts of fermentable soluble fiber and sugar. Additionally it should be pointed out that when we have less than optimum management situations and/or excessive heat and humidity we can put a maximum on the fermentable starch and increase the fermentable soluble fiber; our goal in this case is to drop the fermentable starch as a % of the total fermentable CHO down closer to 42 to 43% DM.

	Fermentability			Escape	
	% DM	%	% Ferm.CHO	% DM	%
Proteins	8.57	55.7		6.82	44.3
Totals CHO	42.62	56.5		32.73	43.4
NDF	10.72	34.3	25.16	20.56	65.7
Starch	19.51	73.4	45.76	7.07	26.6
Soluble fiber	7.15	80.8	16.77	1.70	19.2
Sugars	4.81	72.8	11.28	1.80	27.2
Other NFC	0.44	21.4	1.03	1.60	78.6

With the optimization of the CHO fermentation, balancing for meeting the ME & MP the CP in the ration will be in the 14 to 15+ %DM; this will increase the risk of certain amino acids being deficit. With high amounts of the proteins coming from corn and soybean meal the first limiting AA are Lys & Met. However, with rations which have significant amounts of barley and canola then His can also be limiting. Further it is also possible for the branch chain AA's to become limiting. A review by Robinson (2010) suggests that considering only Met & Lys may not lead to increases in the efficiencies desired; this thinking is corroborated by Arriola Apelo, et al (2014) suggesting a need to refine the models even though they showed positive results from lowering the CP down to 15%. Below are the AA supplies and balances shown from NDS. It needs to be pointed out that in CNCPS 6.5 as shown in NDS the AA supplies are different than in 6.1 because of the updated CNCPS database. This points out that even though the 6.5 database is improved; assuming that the AA profile of each feedstuff is constant is not true; we will hopefully move to receiving AA analyses as a routine assay sometime in the future. The key points from the table below (NDS) is that when you look at duodenal flow you will see that a significant % of the total AA flow comes from bacterial AA; this points out the importance of good estimates of ruminal CHO fermentation and rumen available N to match the potential CHO fermentation.

		Duodenal AA Flow			MP AA Supply				Metabolizable Amino Acids			Ratios
		Bact.	RUP	Total	Tissue *	Bact.	RUP	Total	Req.	Balance	% Req.	% MP
		g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day	g/day		
Met	2,30 - 2,65	59.1	41.5	100.6	0.0	43.0	37.3	80.3	70.9	9.4	113.2%	2.55
Lys	6,40 - 7,20	169.2	115.7	284.9	0.0	131.7	92.1	223.8	200.4	23.4	111.7%	7.10
Arg	> 5,00	137.3	93.4	230.8	0.0	111.8	81.3	193.0	129.3	63.7	149.3%	6.13
Thr	> 4,60	111.8	69.1	180.9	0.0	89.8	58.3	148.1	106.6	41.5	139.0%	4.70
Leu	< 8,70	160.1	148.5	308.6	0.0	120.6	125.7	246.3	261.9	-15.6	94.0%	7.82
Ile	4,75 - 5,00	121.2	73.0	194.2	0.0	94.4	62.1	156.6	143.1	13.5	109.4%	4.97
Val	> 5,85	130.4	87.9	218.2	0.0	98.9	74.1	173.0	156.4	16.6	110.6%	5.49
His	> 2,75	54.8	43.1	97.9	0.0	43.2	36.8	80.0	68.2	11.8	117.4%	2.54
Phe	4,90 - 5,10	111.0	85.4	196.4	0.0	82.9	72.6	155.5	143.6	11.9	108.3%	4.93
Trp	< 1,40	37.1	20.3	57.4	0.0	26.2	17.2	43.3	41.2	2.2	105.3%	1.38
Lys:Met		2.79:1		Optimum ratio 2.70:1 (2.68÷2.72)								

The next area is minerals. Our labs give us routinely NIR predictions and they are not quantitative estimates but qualitative; NIR prediction reliability is low. Given that P is a concern it is probably wise to develop good regional mineral analyses for the feeds fed that are regional for the area being served that reflects the soils and the soil management of the regions.

Nutrient	Diet Concentration	Diet Intake	Added	Water Intake	Absorbed			%Rqd
					Supplied	Rqd	Balance	
Ca	0.81 %DM	222.34	49.25	0	112.09	74.36	37.73 g/day	151 %
P	0.36 %DM	98.36	15.1	-	68.48	68.25	0.23 g/day	100 %
Mg	0.22 %DM	60.36	5.02	-	14.32	8.49	5.82 g/day	169 %
K	1.42 %DM	391.38	0.08	0	352.24	258.01	94.22 g/day	137 %
S	0.20 %DM	55.14	6.86	0	55.14	55.1	0.04 g/day	100 %
Na	0.21 %DM	58.15	49.99	0	52.33	52.27	0.06 g/day	100 %
Cl	0.60 %DM	164.36	77.08	0	147.92	64.61	83.31 g/day	229 %
Fe	204.07 ppm	5621.94	734.7	0	562.19	45.71	516.49 mg/day	1230 %
Zn	37.06 ppm	1020.92	359.18	0	204.18	204.4	-0.22 mg/day	100 %
Cu	9.32 ppm	256.68	25.96	0	11.78	11.73	0.05 mg/day	100 %
Mn	24.82 ppm	683.73	24.5	0	6.84	2.66	4.18 mg/day	257 %
Se	0.30 ppm	8.26	6.16	-	8.26	8.26	-0.01 mg/day	100 %
Co	0.19 ppm	5.23	0.82	-	5.23	3.03	2.20 mg/day	173 %
I	0.45 ppm	12.47	10.82	-	11.22	9.82	1.40 mg/day	114 %

In the ration above (AMTS) the minerals were balanced with a little di-calcium phosphate and salt as well as inorganic trace minerals and vitamins. The P was just met as well as the Na & S, but according to the book value analyses other macro minerals were exceeded relative to requirements. This points out the importance of developing a robust mineral analyses in the regions that are served and then going forward having good chemistry for the on the farm supply of forages plus the off farm ingredient suppliers. Note that the ration was balanced to meet the P requirement (Wu et al, 2000, Cerosaletti et al 2004). It has been a concern for several years that we do not over feed the other minerals. Too often the trace minerals are fed to requirement without taking into account the trace mineral contributions from the forages and grains which are organic sources of the trace minerals. We have, for example, seen excess amounts of Cu leading to reduced yields of corn silage. It will also be noticed that there is a column for water analyses. We recommend that it is important to have water analyses done for each source of water on every farm; too often we have excess of minerals that we need to take into account, especially for dry cows where DCAD balances can become crucial.

Nutrient Balances

The goal is to achieve good balances to achieve nutrient savings. The optimized ration shown above resulted in the N & P losses for this group is shown below (NDS).

Fecal excretion and wet manure			
	Total lbs	N g	P g
Dry Feces	20.08		
Wet Feces	119.10	261.73	57.96
Urine	48.30	177.32	1.26
Wet manure	167.40	439.04	59.21
Intake		676.79	98.95
Productive		237.75	39.73

Productive N/Total N	35.13 %	Productive P/Total P	40.15 %
Productive N/Urinary N	1.34:1	Manure P/Total P	59.85 %
Manure N/Total N	64.87 %		
NH3 Potential (g)	115.26		

The key numbers that we are trying to influence are the ratios of Productive N/Total N and then the manure and urine ratios. The P is primarily excreted in the feces and the two ratios we need to monitor. We need to increase the productive P for the total P intake and decrease the manure P per the total P intake.

Below (NDS) are the two major areas that are very much on the global warming radar screen now, methane and carbon dioxide which ironically, we have made great strides in improving over the last 50 years.

CH4 (Mcal)	6.49
CH4 (liters/day)	709.91
CH4 (g/day)	508.88
CH4 (g/lbs milk)	5.09
CO2 (lbs/day)	34.55
CO2 (lbs/lbs milk)	0.35

There has been considerable research in the last few years looking at both CH_4 and CO_2 emissions not only from individual cows but also from farms.

We focused on the high group in this presentation but the more pertinent numbers are the whole farm balances. This means that we need to carefully balance the rations for replacements and dry cows as well. Too often we might do a good job with the lactating herd and then over-feed the replacements, contributing significantly to upsetting the nutrient balances on the farm. As we move forward there will be improvements in the models that predict the outcomes of feeding management and the rations that are being fed. Chase (2010, 2011, 2014), as well as Chase et al (2009) discussed at length the relationships, from controlled and field research as well as field experiences and the use of the CNCPS model and the predictions of excretions of N & P as well as gaseous emissions. Higgs et al (2012) in two papers discussed both controlled studies as well as a case study in with the use of the CNCPS system relative to N excretion. Below is an Excretion Report from AMTS which depicts the annual whole farm N & P excretions.

Example of an annual whole farm excretion of N & P.

Location	# Animals	# Days	Feces (Total lbs)	Urine (Total lbs)	Manure (Total lbs)	Fecal N (Total lbs)	Urine N (Total lbs)	Manure N (Total lbs)	Fecal P (Total lbs)	Urine P (Total lbs)	Manure P (Total lbs)
Dry Cow barn	40	365	748,383	581,754	1,330,137	3,485	4,392	7,876	725	39	764
Heifer Barn	300	365	2,379,714	2,589,452	4,969,166	14,400	20,286	34,686	2,726	171	2,897
Lactating Barn	430	365	14,338,040	7,554,685	21,892,720	77,896	74,004	151,899	14,583	453	15,036
Total			17,466,130	10,725,890	28,192,020	95,780	98,682	194,462	18,035	663	18,698

Cela et al (2014) did an in depth analysis of whole farm N, P and K balances using detailed data from many NY farms, concluding when 70% of the feeds fed the cows are produced on the farm and the rations are balanced to meet requirements then the farms will be in nutrient balance. Given the concerns about NH_3, N_20, CH_4 & CO_2 emissions we need to include these in the reports in the future as well.

Summary

With rapid and affordable access to forage and feed analyses, improved nutrition models and the platforms that they are in, we have the opportunity to improve our capabilities in targeting feeding in a manner to increase the amount of nutrients fed into productive nutrients with a reduction in nutrient losses.

It is important for a farm to not only just look at the potential losses from inefficiencies but also when looking at N & P consider what % of these losses are recycled back through the soil and retained by forages grown either on the farm or through neighbors' farms who are using the nutrients to grow crops; in this scenario where less than 70% of the feeds are grown on the farm, a regional balance. Also it is important for a farm to consider how to reduce the variability of the on farm feeds as well as the purchased feeds; this will allow the nutritionist to formulate closer to the needs of each group of animals on the farm. Additionally there can be opportunities to regroup animals and to improve the environment surrounding the cows as well as the management that will reduce nutrient losses.

We have made significant progress over the last several decades in reducing nutrient wastage and our carbon footprint but we still have some challenges ahead.

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