DESIGNER MANURES: MANAGING MANURE PRODUCTION AND NUTRIENT QUALITY

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ABSTRACT

Feeding to optimize manure output and to enhance manure nutrient quality for crop production are not current goals for dairy producers. However, there are feeding strategies are available which can be adopted that reduce manure output while maintaining animal performance. Limit feeding programs are promising alternatives in dairy heifer management. Modeling tools such as CNCPS are very useful for evaluating diet alternatives and predicting potential impacts on lactating cow performance and manure excretion. Current research suggests that manure production by the milking herd can be reduced by feeding less alfalfa (reduces urine), feeding more starch (reduces feces), and reducing crude protein intake (reduces urine and feces). Careful prior consideration of any planned feeding change by the herd nutritionist is highly recommended to minimize risk of lowered herd performance.

INTRODUCTION

Manure is an inevitable byproduct of the production of meat and milk for human consumption. It has value as a fertilizer but also adds significant operating, equipment, and facility cost to the dairy operation. Idaho requires all dairy facilities to have a phosphorus driven nutrient management plan. The number of acres required for land application depends on herd size, predicted manure excretion, predicted phosphorus excretion, expected crop yields and crops rotation. Feeding management programs on the dairy are focused on optimizing herd performance and health while accepting manure as the inevitable by-product. In this paper, we take on the challenge of designer manure production. Are there any management strategies for reducing manure excretion while maintaining desirable animal performance and health? If yes, how do we go about it? Finally, we will discuss managing the excretion of nitrogen, phosphorus and potassium content to dairy manure.

ALTERING MANURE EXCRETION

From a designer standpoint, the goal is to reduce total manure production by reducing urine excretion, reducing fecal excretion, or both while maintaining desirable animal performance and profitability. Urine production is largely driven by water intake, mineral intake (sodium plus potassium) and urea nitrogen (Nennich et al., 2006). The single best predictor of feces production and total manure production is dry matter intake (Nennich et al., 2005; Weiss and St-Pierre, 2010). Seven strategies for reducing manure excretion are discussed below.

Limit feeding heifers.

Wisconsin researchers have advocated limit feeding as a method to control growth rates, decrease intakes, and improve feed efficiency (Hoffman, 2009). Since intake is the primary driver of manure production, limiting feeding is expected to reduce manure production. Results of a Wisconsin trial (Hoffman, 2007) are shown in Table 1 where pregnant, 1000 pound heifers were fed at full intake, 90% of full intake (90L), and 80% of full intake (80L). Diets were formulated to provide similar intakes of protein, energy, and minerals which means the limit fed diets contained more corn, protein supplement and minerals than the full fed ration. Daily gains were slightly higher on the limit fed diets and manure was reduced 12% (5.6 pounds) on the 90L diet and 26% (12.5 pounds) on the 80L diet. Intake and excretion of nitrogen and phosphorus did not differ between three diets because the limit fed diets had higher protein and phosphorus content. Using current Idaho feed prices, daily ration costs are 12 to 16 cents higher on the limit fed diets, reflecting our high corn and protein supplement pricing. Limit feeding can be competitive when feeds are closer to historical price ranges. See Hoffman (2009) for a discussion on the management challenges of limit feeding heifers and managing for success.

Precision feeding heifers.

Researchers at Penn State University have developed an approach that uses highly digestible feed sources and restricted intakes to optimize feed efficiency, reduce ration costs, and minimize manure output (Zanton and Heinrichs, 2008). Results from one of the Penn State trials are shown in Table 1. Moody et al. (2007) precision fed one of two diets: high forage diet (77% corn silage: 33% concentrate) or high concentrate diet (33% corn silage: 77% concentrate) to twelve month old heifers. Dry matter intakes and growth were similar between diets. Precision feeding a high concentrate diet decreased wet feces by 10 pounds per day, decreased total manure by 5.9 pounds per day and increased urine production was 4.2 pounds per day. . Intake and excretion of nitrogen and phosphorus did not differ between the two diets because both diets were formulated to similar protein and phosphorus contents. Precision feeding a high concentrate diet delivers in reducing feces and manure output but is not cost effective at current Idaho feed prices. The high concentrate diet is $0.22 more per head due to our high corn and protein prices. Precision feeding heifers can be competitive when feeds are closer to historical prices ranges. See Zanton and Heinrichs (2008) for a thorough discussion on the Penn State precision feeding program.

Limit feeding cows.

There is a potential for limit feeding mid to late lactation cows and far off dry cows on dairies where individual feeding is practiced such as the tie-stall barns in the Midwestern US. Here in Idaho, cows are fed in large groups and production, components, and animal health are enhanced by full feeding the herd. It is common to provide up to 5 to 7% more feed than necessary to ensure full intakes by all cows. Limit feeding specific groups of cows is impractical for our size dairy operations.

Nutritional Models.

The Cornell Net Carbohydrate and Protein System (CNCPS) is a useful tool for the dynamic evaluation of ration changes in lactating cow diets. A partial list of program outputs include predicted milk yield, component yields, rumen ammonia, rumen pH, feces production, urine production, and nitrogen excretion. Consider evaluating ration changes with the model first and if predictions are desirable, then compare actual results to see if goals are attained. A free demo version is available for download at http://cncps.cornell.edu/.

Reducing Alfalfa in the diet.

Alfalfa and corn silage are the two predominant forages in Idaho dairy diets. Alfalfa is a major source of potassium in the diet and directly influences urine excretion. The effect of feeding three different ratios of alfalfa silage to corn silage (75A:25CS, 50A:50CS, and 25A:75CS) to lactating cows are shown in Table 1 (Weiss et al. 2009). All three diets had similar proportions of forage (50% of dry matter) and metabolizable protein (10.4%) but differed in percent starch. Feces production was similar between the three diets but urine excretion increased linearly with each added increment of alfalfa forage. Overall, there was a 22 pound difference in urine between the 75% alfalfa silage diet and 75% corn silage diet. Alfalfa forage is greatly overpriced this year and there would be a significant reduction in ration cost by feeding more corn silage. Other trials have shown a similar positive correlation between percent alfalfa in the diet and urine excretion.

Increasing Starch in the diet.

Cereal grains and high fiber byproduct feeds are common ingredients in dairy rations. The effect of feeding more corn grain (starch source) over more high fiber byproduct feeds (soyhulls and citrus pulp) is shown in Table 1 (Weiss et al. 2009). All three diets had similar proportions of alfalfa forage (50% of dry matter) and metabolizable protein (10.4%) but differed in starch content. Urine production was similar between three diets but fecal excretion increased linearly with each added increment of starch. Overall, there was a 20 pound difference in feces between lowest and highest starch diets. There are practical limits on the amount of starch to include in the ration and these relationships will vary with amount of corn silage and processing of the cereal grains. Changes in dietary starch content need to be made very judiciously to avoid decreasing milk production, altering milk composition or impairing animal health.

Reducing Crude Protein in the diet.

Urine production is positively correlated with overfeeding crude protein and increasing urinary urea (Castillo, 2001). The effect of feeding three crude protein levels (16.5, 17.9, 19.4%) on cow performance and manure production are shown in Table 1 (adapted from Olmos Colmenero, 2006). In this trial, wet feces and urine increased with each additional increment of crude protein. Other studies have shown more dramatic changes in urine production, especially with high rumen degradable protein levels. Dynamic modeling can be particularly helpful for predicting response to change in protein feeding. Changes should only be made after careful consideration since milk income can drop quickly if there is a decrease in milk yield or milk protein yield after the diet change.

ALTERING NITROGEN CONTENT IN MANURE

The nitrogen to phosphorus (N:P) ratio of semi-solid and liquid dairy manures typically range from 5.42 to 6.55 and are somewhat lower than the desired N:P ratio (~8.0) for most grain crops. This implies that manure applications to meet a crop's N requirement would result in manure P applications in excess of crop needs. What can we do about this issue with our designer manures, can we improve the N:P ratio in an economically viable way? Can we produce manures that will have lower nitrogen losses in storage and during land application? Answers to these questions are addressed below.

N:P ratio can be altered by either increasing N, decreasing P, or both. We can easily increase the N content of dairy manure by overfeeding protein and it can be done "economically"

Table 1. Options to decrease manure excretion by growing heifers and lactating cows.

Option A, Limit feed heifers (Hoffman, etal 2007)

Variable	Full-fed	90% of full fed	80% of full fed
Dry matter intake, lbs	22.0	20.0	17.2
Average daily gain, lbs	1.66	1.92	1.84
Feed cost, $/hd/day	$1.64	$1.76	$1.80
Dry feces, lbs	7.7	6.8	5.7
Est. wet feces, lbs @16% DM	48.1	42.5	35.6

Option B, Precision feed high concentrate diets to heifers (Moody etal, 2007)

Variable	High forage	High concentrate
Dry matter intake	14.3	13.6
Average daily gain, lbs	1.80	1.80
Feed cost	$1.20	$1.42
Wet feces	27.3	17.2
Urine	24.0	28.2
Total manure	51.3	45.4

Option C, Feed cows more corn silage, less alfalfa silage (Weiss etal, 2009)

Variable	75% Alf, 25% CS	50% Alf, 50% CS	25%Alf,75%CS
Dry matter intake, lbs	55.4	53.2	51.0
Energy corrected milk yield, lbs	92.4	84.3	84.9
Feed cost, $/cow/day	$6.59	$5.95	$5.34
Wet feces,lbs	109.1	113.0	108.2
Urine, lbs	77.9	62.3	55.9
Total manure, lbs	187.0	175.3	164.1

Option D. Feed cows diet with higher percent starch (Weiss etal, 2009)

Variable	22% starch	26% starch	30% starch
Dry matter intake, lbs	55.0	53.2	53.5
Energy corrected milk yield, lbs	90.6	84.3	90.9
Feed cost, $/cow/day	$6.04	$5.95	$6.09
Wet feces,lbs	124.5	113.0	104.1
Urine, lbs	64.9	62.3	64.5
Total manure, lbs	189.4	175.3	168.5

Option E. Feed less crude protein in diet (Olmos Colmenero, 2006)

Variable	16.5% CP	17.9% CP	19.4% CP
Dry matter intake, lbs	50.6	49.1	48.9
3.5 Fat corrected milk yield, lbs	80.7	78.5	79.4
Feed cost, $/cow/day	$6.21	$6.32	$6.46
Est. wet feces, lbs @ 16% DM	82.9	85.7	86.8
Urine, lbs	39.4	42.7	47.7
Total manure	122.3	128.4	134.5

by utilizing an inexpensive N source such as urea in the diet. However, overfeeding protein is not an environmentally sound practice. It is well established that, as the crude protein (CP) content of the diet increases, the amount of protein degraded in the rumen also increases. If rumen degraded protein (RDP) exceeds microbial needs, then large amounts of ammonia (NH_3) are produced, absorbed into the blood, converted to urea in the liver, and excreted in the urine. Urease in the manure rapidly hydrolyzes urinary urea to NH_3 where it is then volatilized and lost to the environment (Muck, 1982).

The effect of overfeeding protein on N excretion and NH_3 losses can be shown by data from Burgos et al. (2010). They fed diets that varied from 15 to 21 percent crude protein to lactating cows. The source of supplemental protein was urea, a readily digestible source of rumen degradable protein. In the feeding trial, there were significant linear increases in total N intake, total N excretion, urinary urea excretion, and ammonia emissions with increasing dietary CP content. In particular, ammonia emissions averaged 57 grams of N per day on the 15% CP diet and increased to 149 grams of N per day on the 21% CP diet, a 260% increase in ammonia emissions. Clearly overfeeding N with urea is not the method of choice to increase manure N:P ratio.

Current research efforts are focused on optimizing nitrogen utilization and minimizing environmental losses. Significant advances have lead to new diet formulation strategies based on targeting rumen degradable protein and metabolizable protein contents through dynamic rumen and whole system modeling. Dairy nutritionists can reduce ammonia emissions by carefully reducing dietary crude protein while achieving target rumen degradable and metabolizable protein contents in the diet. For a thorough review on ammonia emissions from dairies, see Hristov et al., (2011).

ALTERING PHOSPHORUS CONTENT IN MANURE

Phosphorus (P) excretion by dairy cattle is directly related to P intake. Higher intakes mean more P in the manure, more land base required for manure application, and a greater runoff potential during land application. Decreasing phosphorus content in the manure means more manure can be land applied per acre which also reduces the required amount of commercial nitrogen fertilizer per acre. From a "designer manure" perspective, phosphorus intake should be carefully managed to meet the phosphorus requirements of the cow, thereby minimizing the amount of phosphorus in manure.

The industry has made great strides in managing phosphorus feeding in the last ten years. Inorganic phosphorus supplements have been reduced or replaced in dairy diets. Rations are formulated to meet or slightly exceed the new, lower requirements specified in the 2001 NRC feeding publication. Byproduct feeds are frequently incorporated in dairy diets due to desirable nutrient profiles and competitive pricing. However, several of the byproducts are relatively high in phosphorus and their use tends to cause some overfeeding of phosphorus. It is a tradeoff between economic survival of dairies and a small increase in phosphorus load.

ALTERING POTASSIUM CONTENT OF MANURE

From a designer manure perspective, the goal is to reduce the amount of potassium in manure. However, K is typically high in Idaho soils and manure applications are not likely to increase Idaho soil K concentrations. Dietary supplementation with potassium is generally not necessary for cows fed high alfalfa diets. However, corn silage is lower in K and some K supplementation may be required with corn silage-alfalfa forage blends. Recent research from Washington State University suggests that today's high producing early lactation cows can be deficient in K (Harrison et al., 2011) and are recommending diets with 1.6% potassium during first 75 days of lactation. Milk yield increases were noted with feeding more K during this key time period, particularly when adjusting the dietary cation anion difference (DCAD).

There are two important issues relative to K content of forages, one impacting dry cows and one influencing the milk herd. Magnesium absorption is impaired if the diet is too high in K (Weise, 2004), leading to a mid-lactation milk fever syndrome. The solution is to analyze forages for Mg and K, then supplement with magnesium oxide if K is too high. Close-up dry cows (within three weeks of calving) are frequently fed diets with a negative DCAD to reduce metabolic disease, particularly milk fever. Achieving the desired DCAD is next to impossible with high K forages. There is a clear market and strong demand for low K baled hays for close up dry cows.

CONCLUSIONS

Feeding to optimize manure output and to enhance manure nutrient quality for crop production are not current goals for dairy producers. However, there are feeding strategies which can be adopted that reduce manure output while maintaining animal performance. Limit feeding programs are promising alternatives in dairy heifer management. Modeling tools such as CNCPS are very useful for evaluating diet alternatives and predicting potential impacts on lactating cow performance and manure excretion. Current research suggests that manure production by the milking herd can be reduced by feeding less alfalfa (reduces urine), feeding more starch (reduces feces), and reducing crude protein intake (reduces urine and feces). Careful prior consideration of any planned feeding change by the herd nutritionist is highly recommended to minimize risk of lowered herd performance.

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