Factors Affecting Manure Output on Dairy Farms

William P. Weiss[1], Normand R. St-Pierre, and Lynn B. Willett
Department of Animal Sciences
The Ohio State University

Summary

The amount of manure produced on dairy farms can affect the financial bottom line. Labor, equipment, and facilities are needed to move and store manure, all of which have a cost. Increased output of manure can represent losses in potentially digestible nutrients (increased feed costs). Lastly, the environmental impact of dairy farming is strongly related with the quantity and composition of manure produced. Based on our research, the average lactating cow fed a typical Midwestern diet produces about 150 lb/day of manure (in our measurements, no bedding is used so manure is only the sum of feces and urine). Dry matter intake and manure output have a strong positive relationship. On average, manure output increases approximately 3 lb of manure per additional pound of intake. Although, on average, manure output increases as milk production increases, the relationship is not very strong, which means we can have high milk production without necessarily increasing manure output. Indeed, because cows produce manure even when they are not lactating (approximately 84 lb/day), high producing cows usually produce less manure per pound of milk than low producing cows. The dietary factor that had the greatest effect on manure production in our data set was the ratio of corn silage to haycrop forage. As the percentage of forage that was corn silage increased (resulting in a decrease in the percentage of haycrop forage) urine output decreased substantially, resulting in a significant decrease in manure output. As the percentage of forage as corn silage increased 10 units (and haycrop decreased 10 units), manure output decreased by about 4 lb/day.

Introduction

Manure is an inevitable byproduct of the production of milk. Although manure can be a valuable resource for crop production, it also has associated costs and excessive production of manure can adversely affect profitability of a dairy farm. Manure must be moved from the pens, stored, and then moved to fields; all these operations require equipment, energy, and labor (i.e., money). Excessive production of manure also can mean that some dietary nutrients are not being digested efficiently, which can elevate feed costs. Lastly, society, and therefore, the government, is becoming increasingly concerned about the environmental impact of animal agriculture, and several states and the federal government have enacted regulations regarding manure nutrients.

Current regulations are mainly concerned with excretion of specific nutrients (i.e., nitrogen and phosphorus). The influence of diet on excretion of those nutrients has been discussed at previous Tri-State Dairy Nutrition Conferences (Beede and Davidson, 1999; Broderick, 2005) and will not be covered in this paper.

Profitability of a dairy farm often can be enhanced when feeding and management practices

[1]Contact at: 1680 Madison Ave., OARDC, Wooster, OH 44691, (330) 263-3622, FAX: (330) 263-3949, Email: weiss.6@osu.edu

are used that reduce manure production per unit of milk produced. Fortunately, diet has a substantial influence on the amount of manure excreted, and therefore, we can formulate diets that result in reduced production of manure.

Variability in Manure Output

Over the last decade, our laboratory has conducted numerous experiments that involved measuring fecal and urinary output by dairy cows. The current data base contains data from 15 experiments with lactating cows (339 observations) fed 67 different diets. We also have data from one experiment with dry cows (17 cows). Measuring manure output is time-consuming and expensive. In our experiments, cows are fed the diet of interest for at least 2 weeks and then they are moved to stalls designed for total collection of feces and urine. Cows spend 4 to 6 days in those stalls and feed intake, milk production, fecal output, and urine output were measured and sampled each day. No bedding is used during these measurements; therefore, manure is comprised only of feces and urine. Descriptive statistics concerning the lactating cows (all cows used in these experiments were Holstein cows in their second or greater lactation) used in these experiments are in Table 1. The 'average cow' in our database is very similar to the 'average cow' in the Tri-state area. The diets fed were extremely diverse, but almost all diets included corn silage and/or alfalfa silage (a few diets had alfalfa hay and a few diets had orchardgrass silage). Ground, dry corn was the main source of supplemental starch and soybean meal was the main source of supplemental protein. In some experiments, diets contained soyhulls, wheat midds, distillers grains, and/or animal protein meals. Overall, this data set contained diets that are typical of those fed in the Midwest.

Our data base for dry cows is extremely limited and will not be discussed in detail. The dry cows produced an average of 23 lb of urine and 63 lb of feces for a total of 86 lb/day of manure (data not shown). Dry cow data are shown in some figures, but the data were not included in the statistical analyses.

On average, lactating cows produced about 150 lb/day of manure of which approximately 50 lb was urine and 100 lb was feces (Table 2). Output of feces, manure, and especially urine was extremely variable (Table 2). The coefficients of variation (standard deviation divided by the mean times 100) were 22, 39, and 23% for output of feces, urine, and manure. A major goal of our research program is to determine what factors account for substantial proportions of that variation.

Factors Affecting Excretion of Manure

Cow factors

Dry matter intake **(DMI)** and milk production were positively correlated with manure output (Figures 1 and 2). Although the relationship between milk yield and manure output was statistically significant ($P < 0.05$), Figure 1 clearly illustrates that high milk production does not necessarily mean high manure output. For cows producing approximately 100 lb/day of milk, manure output ranged from about 125 lb/day to about 250 lb/day. Conversely, cows that produced 150 lb/day of manure had milk yields ranging from 50 to 100 lb/day. When manure output was regressed on milk yield (experiment was included in the model as a random effect), the equation was (manure and milk are in lb/day):

[1] Manure output = 84 + (0.9 x milk yield)

The dry cows were not included in this analysis but their data (open circles, Figure 1) appeared to fit the equation quite well. This equation means that, on average, a cow will produce about 84 lb of manure when she is not lactating (this has a similar connotation as a maintenance requirement),

and then, on average, manure output increases about 0.9 lb for every pound of milk produced. The poor fit of this equation (Figure 1) means that Equation [1] will not produce very precise estimates of manure output. Although the equation relating manure output to milk is not very precise, it illustrates an important concept. Since cows produce a substantial amount of manure even when they produce no milk, cows that have high milk yields will, on average, produce less manure per pound of milk than low producing cows. For example, a cow producing 50 lb/day of milk will produce 2.6 lb of manure per pound of milk, but a cow producing 100 lb/day of milk will produce only 1.7 lb of manure per pound of milk.

The relationship between manure output and DMI was much stronger than the relationship between milk yield and manure output. Within a certain DMI, manure output varied by about 75 lb/day. Again, the data from the dry cows (open circles, Figure 2) were not included in the statistical analysis but appeared to fit the lactating cow equation reasonably well. The linear relationship between DMI and manure production (experiment was included as a random effect; manure and DMI are in lb/day) was:

[2] Manure output = -1.8 + (3.1 x DMI)

The intercept was not statistically different from 0, but animals continue to produce manure even during starvation. Therefore, the intercept from the linear relationship is not biologically accurate. A quadratic model was evaluated and also was statistically signficant:

[3] Manure output = 47.6 + (1.0 x DMI) + (0.022 x DMI^2)

Data are not available for manure output by cows that are not fed; therefore, the accuracy of the intercept in equation [3] cannot be evaluated. The other terms in the equation show that manure output increases at an increasing rate as DMI increases. Based on Equation [2], increasing DMI from 35 to 40 lb/day results in an increase of 2.7 lb of manure per pound of increased DMI, but increasing DMI from 55 to 60 lb/day results in an average increase of 3.5 lb/day of manure per pound of increased DMI.

Dietary factors

The data set we are using is a composite of several experiments that were conducted to answer a variety of questions. Therefore, diets often differ in several aspects. For example, diets with high concentrations of alfalfa silage usually have higher concentrations of potassium, soluble nitrogen, and rumen degradable protein and lower concentrations of water than diets with high concentrations of corn silage. Because of multiple differences among diets, we decided not to evaluate relationships between specific nutrients and manure output in this data set (we are finishing a large experiment that was designed to examine specific nutrients, but at this time, the experiment is not complete). Instead, we examined the effect of dietary ingredients on manure output. Using this approach, we cannot definitely state which specific nutrient (if any) causes differences in manure output, but we can determine if specific feeds are related to manure output. In our original data set (232 observations), the most important dietary variable that was related to manure output was the concentration of corn silage (expressed as a percentage of total forage). As the concentration of corn silage increased (resulting in a subsequent decrease in the percentage of haycrop forage), manure output decreased substantially (Figure 3). On average, cows fed diets in which all the forage was corn silage produced about 16% less manure (equal to about 25 lb/day) than cows fed diets with haycrop (mostly alfalfa silage) as the sole forage. Milk production was not affected by changes in forages. The preliminary analysis of the experiment we are now completing supports this relationship. In that study, cows fed a diet with 75% of the forage as corn silage (25% was alfalfa

silage) produced 14% less manure (165 versus 191 lb/day) than cows fed a diet with 25% of the forage as corn silage (75% as alfalfa).

The effect of the ratio of corn silage to haycrop forage on manure output was caused almost entirely by its effect on urine output. Cows fed diets with 100% of the forage as haycrop forage produced about twice as much urine per day as cows fed diets with 100% corn silage (Figure 3). The most likely reason for this effect is differences in potassium concentrations in diets. Corn silage produced at our research farm averages about 1% K and alfalfa averages about 3% K. We made no attempt to balance diets for K. Supplemental K was only added when normal ingredients did not meet NRC requirements (occurred very rarely). Therefore, diets with all the forage as alfalfa had about 1 percentage unit more K than diets with corn silage as the sole forage (because forage K concentrations are highly dependent on soil K; differences between forages will vary among farms depending on soil K). Bannink et al. (1999) showed that increasing the intake of K substantially increases urine output in dairy cows. Increasing the dietary concentrations of protein and sodium can also increase urine output (Bannink et al., 1999; Weiss and Wyatt, 2006), but compared to the effects we observed by changing the amount of corn silage in the diets, effects of sodium and protein are small.

Conclusions

The output of manure is influenced by diet, and we can formulate diets that result in good milk production with reduced manure output. The ratio of corn silage to haycrop forage has a major impact on manure production but does not have an effect on milk production when diets are balanced correctly. Feeding more corn silage and less haycrop forage should reduce manure output, but it generally does not greatly affect excretion of nitrogen and phosphorus (these are more related to concentration of protein and phosphorus in the diet).

References

Bannink, A., H. Valk, and A.M. VanVuuren. 1999. Intake and excretion of sodium, potassium, and nitrogen and the effects on urine production by lactating dairy cows. J. Dairy Sci. 82(5):1008-1018.

Beede, D.K., and J.A. Davidson. 1999. Phosphorus: Nutritional management for Y2K and beyond. Tri-State Dairy Nutr. Conf., Ft. Wayne, IN. pages 51-97.

Broderick, G.A. 2005. Feeding dairy cows to minimize nitrogen excretion. Tri-State Dairy Nutr. Conf., Ft. Wayne, IN. pages 137-152.

Weiss, W.P., and D.J. Wyatt. 2006. Effect of corn silage hybrid and metabolizable protein supply on nitrogen metabolism of lactating dairy cows. J. Dairy Sci. 89:1644-1653.

Table 1. Simple statistics describing the Holstein cows and diets used in the total collection digestion trials. Data are from 15 experiments with 67 dietary treatments (n = 315).

	Mean	SD[1]	Minimum	Maximum
Cow characteristics				
Days in milk	163	57	67	272
Body weight, lb	1331	141	906	1780
Dry matter intake, lb/day	48.2	8.1	21.6	67.1
Milk yield, lb/day	68.6	16.0	17.6	129.8
Diet characteristics				
Forage, % of DM	54	9	40	80
Corn silage, % of forage DM	59	35	0	100
NDF, % of DM	33.4	5.1	24.7	45.8
Crude protein, % of DM	16.8	1.6	10.5	20.9

[1]SD = Standard deviation.

Table 2. Production and characteristics of manure from lactating Holstein cows. Data are from 15 experiments with 67 dietary treatments (n = 315 except as noted).

	Mean	SD[1]	Minimum	Maximum
Wet feces, lb/day	98.5	21.8	38.9	169.8
Urine, lb/day	52.4	20.2	18.5	137.7
Manure, lb/day	150.9	35.1	59.6	249.7
Manure composition				
DM[2], %	12.5	1	8.2	15.1
Urine, % of wet weight	34.1	7.8	16.5	62.4
N[3], % of wet weight	0.59	0.07	0.38	0.80
P[3], % of wet weight	0.077	0.017	0.028	0.12

[1]SD = Standard deviation.
[2]Dry matter calculated using measured DM concentration of feces and assuming urine contained 4% DM.
[3]Number of observations for N was 202 and 161 for P.

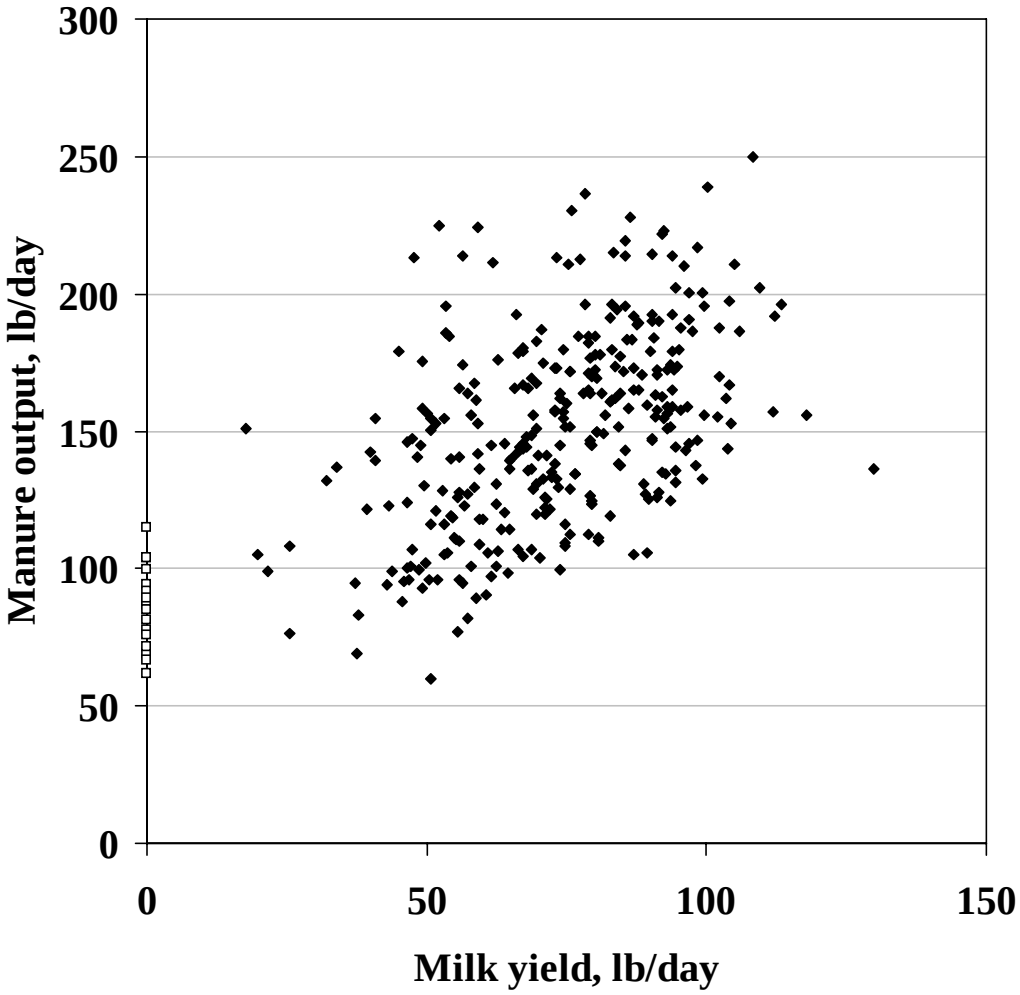

Figure 1. Relationship between milk production and manure (feces plus urine) output. The open symbols at 0 milk yield are data from dry cows. Dry cow data were not included in the regression analysis. Overall, manure output increased as milk yield increased, but the relationship was not very strong.

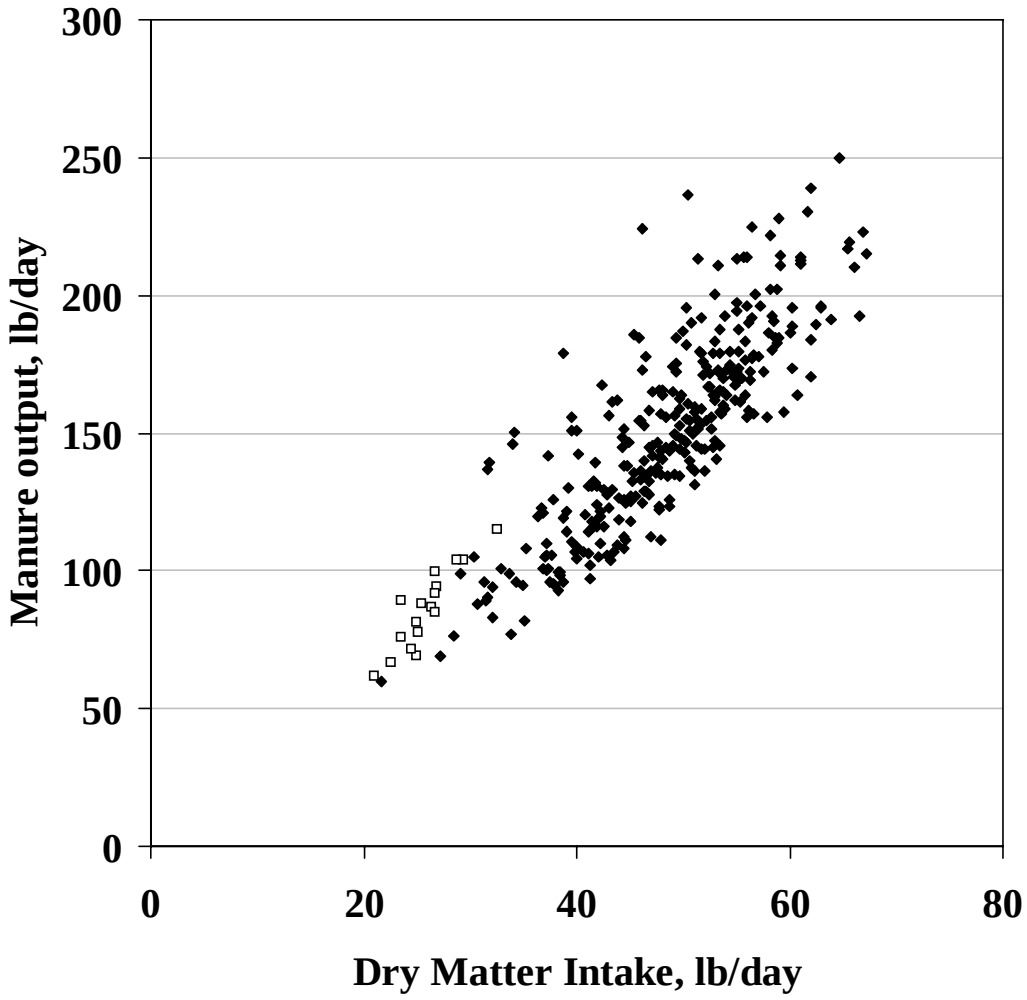

Figure 2. Relationship between dry matter intake and manure production. Open symbols represent data from dry cows and were not included in the regression analysis.

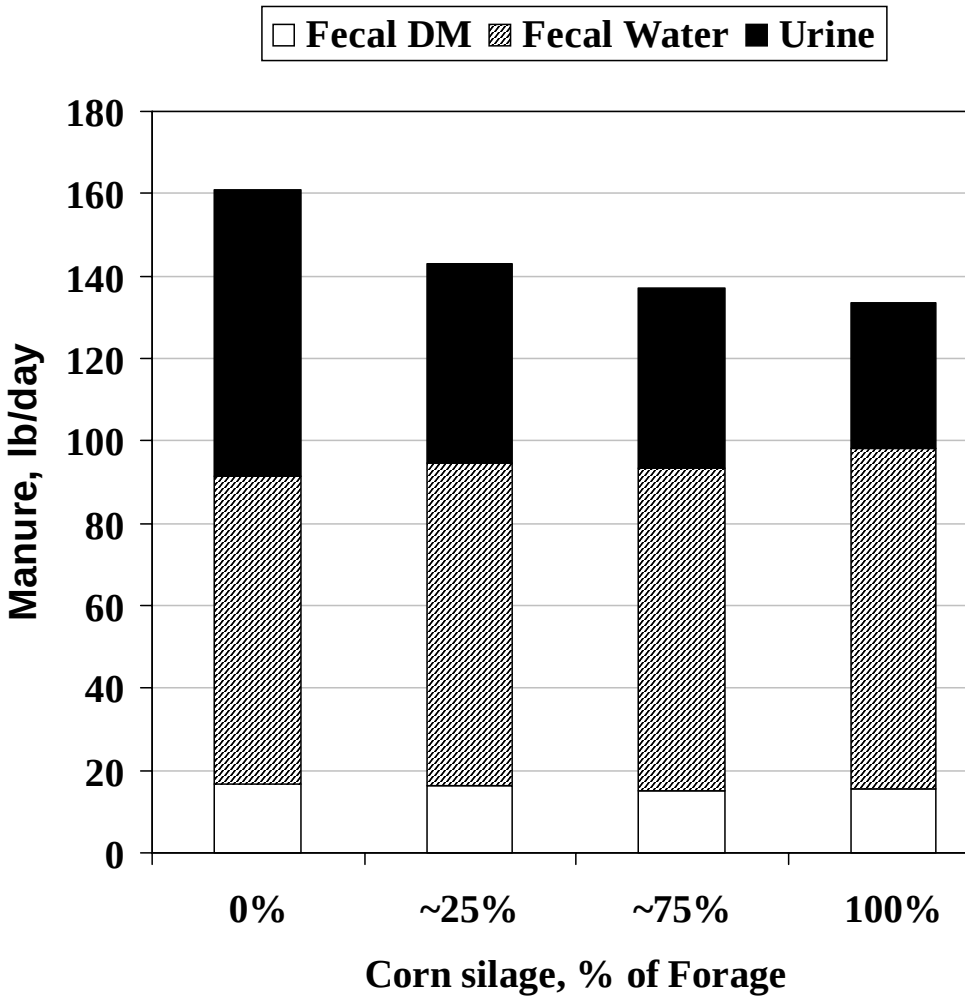

Figure 3. Effect of corn silage (the remaining forage was provided by haycrop forages) on manure production. As the concentration of corn silage increased (and haycrop decreased), urine and total manure outputs decreased substantially.