Feeding Strategies to Decrease Manure Output of Dairy Cows

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Take Home Messages

- The average lactating dairy cow (30 kg milk/day) produces about 70 kg of manure/day but manure output is affected by numerous factors.
- Increasing the concentration of corn silage and reducing the concentration of haycrop forage substantially reduces manure output (this is probably a potassium effect).
- Replacing dietary fiber with starch decreases manure output.
- Feeding more digestible ingredients (high digestible corn silage hybrids, immature hay crop forages) reduces manure output
- On a typical dairy farm, dry cows and replacement animals produce about 25% of the manure. If manure capacity is limiting consider moving these animals off site.

Introduction

Manure is an inevitable byproduct of the production of meat and milk destined for human consumption. Excessive excretion of manure and manure nutrients represents inefficiencies that increase feed costs, increase the environmental impact of dairy farming, and increase costs associated with moving and storing manure. Current environmental regulations are usually based on nitrogen (N) and phosphorus (P) concentrations in the manure and the soil and on crop removal rates of P and N. The primary purpose of this paper is to discuss factors affecting manure output rather than excretion of N and P, but diets that promote high milk production and meet requirements for P and N result in the lowest quantities of N and P excreted per unit of milk produced.

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■ Manure Production by Lactating Cows

Based on research conducted at Ohio State, an average lactating Holstein cow that is producing about 30 kg of milk/day and fed a typical diet produces about 70 kg/day of manure (no bedding is used in our measurements so manure is the sum of feces and urine) with 12.5% dry matter (DM), 0.59% N, and 0.077% P (Table 1). On average about one-third of the manure weight was urine and two-thirds feces but this is highly variable. In 2009, Canada (based on Agriculture Canada Statistics, www.dairyinfo.gc.ca) had approximately 1,000,000 dairy cows and produced approximately 64,000,000 hectoliters of milk. Using equations we developed, last year the Canadian dairy herd (excluding replacements) excreted an estimated 21 million metric tons of manure. But the amount of manure produced by cows varies tremendously because of feed intake, diet composition, and environmental conditions (e.g., hot weather). We can take advantage of this variation and formulate diets that result in less manure production.

Table 1. Statistics describing 15 experiments conducted at Ohio State involving 315 observations and 67 dietary treatments.

Measure	Average	Standard Deviation
Dry matter intake, kg/d	21.9	3.7
Milk yield, kg/day	31.2	7.3
Wet feces, kg/day	44.8	9.9
Urine, kg/day	23.8	9.2
Manure, kg/day	68.6	16.0
Manure dry matter, %	12.5	1.0
Manure nitrogen, %	0.59	0.07
Manure phosphorus, %	0.077	0.017

Relationships between Manure Production and Intake and Milk Production

Manure output and dry matter intake (DMI) are strongly correlated but significant variation still occurs (Figure 1). In our data set, manure output varied by about 35 kg/d within a specific DMI. On average, manure output increased about 3 kg/kg of DMI but this relationship was not constant. Increasing DMI from 16 to 18 kg/day resulted in an increase of 2.7 kg manure/kg of increased DMI, but increasing DMI from 25 to 27 kg/day

resulted in an average increase of 3.5 kg/day of manure/kg of increased DMI. As intake increases, digestive efficiency tends to decrease because feed passes through the digestive system quicker. Because water is needed to move digesta, a small decrease in digestibility results in a much larger increase in excretion of manure. If everything else is equal, we would expect slightly lower digestibility at high intakes resulting in more manure per kilogram of intake at high intakes than at lower intakes. Intake and milk production are correlated and on average high producing cows eat more than low producing cows. You should not restrict intake so that cows produce less manure because it will also likely reduce milk production. Feeding highly digestible diets results in high milk production at reasonable intakes with reasonable rates of manure excretion. Monitoring feed efficiency (kg of fat-corrected milk per kg of DMI) is a means of evaluating diet digestibility. For most situations, herd average feed efficiency should be around 1.5 to 1.6.

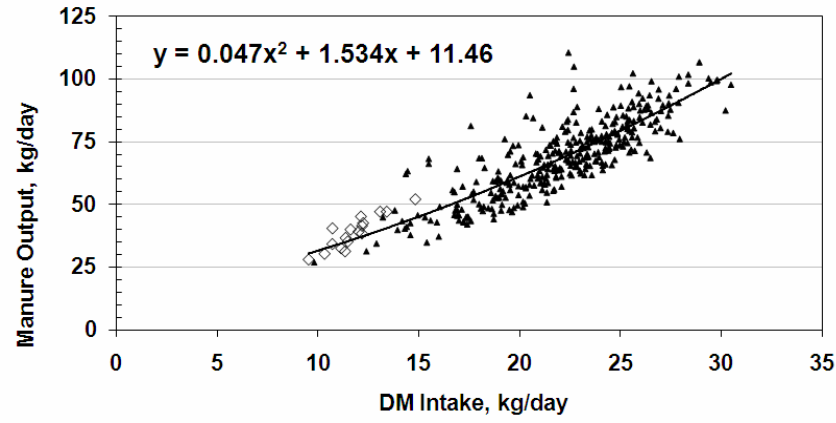

Figure 1. Relationship between dry matter intake and manure excretion in lactating and dry Holstein cows. Open diamonds are data from dry cows, filled triangles represent lactating cows. A linear equation (line not shown) fit almost as well as the quadratic function: Manure output = -9.5 + 3.1*DM intake.

Milk production and manure output are also correlated but the relationship is not strong (Figure 2). This means we can increase milk production without necessarily increasing manure output. Indeed, because cows produce manure even when they are not lactating (30 to 45 kg/day), high producing cows usually produce less manure per pound of milk than do low producing cows. A Holstein cow producing 23 kg of milk averages about 59 kg of manure (2.6 kg of manure/kg of milk) but a Holstein producing 45 kg of milk produces 80 kg of manure or only 1.75 kg of manure/kg of milk. Increasing milk production is usually the most effective means of decreasing manure output per unit of milk produced.

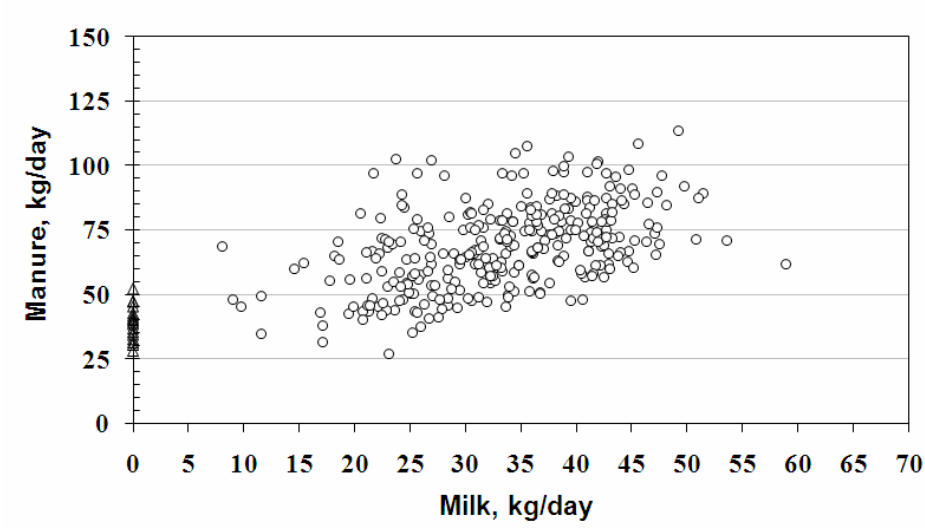

Figure 2. Relationship between milk production and manure output in lactating and dry Holstein cows. Open triangles represent data from dry cows, open circles represent data from lactating cows. Manure output = 38 + 0.9*Milk

Dietary factors

Corn Silage.

The dietary factor that had the greatest effect on manure production in our data set was the ratio of corn silage to haycrop forage (in our experiments, alfalfa silage was the predominant haycrop fed). 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. A 10 percentage unit increase in corn silage (e.g., going from a diet in which the forage dry matter was comprised of 30% corn silage and 70% hay crop to a diet with 40% corn silage and 60% hay crop) would decrease manure output by about 2 kg/day (Weiss et al., 2009). The response in total manure we found was essentially the same as reported in a study from Wisconsin (Wattiaux and Karg, 2004). In our data set, increasing corn silage decreased urine output but had little effect on fecal output but in the Wisconsin study increasing corn silage decreased both urine and fecal output. In our studies, 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 almost always has lower concentrations of potassium than haycrop forages so as corn silage

increases and haycrop decreases, dietary concentrations of potassium usually decrease. Any diet modification that results in lower concentrations of potassium should reduce manure output mainly via a reduction in urine output. Within a reasonable range of corn silage concentrations (between 25 and 75% of the forage dry matter), manure output would change by about 10 kg/d (about 14% of average manure production). Increasing corn silage in the diet should reduce manure output but several studies have shown that the ratio of corn silage to haycrop silage does not affect milk production. Therefore, feeding more corn silage should reduce manure output but have little effect on milk production.

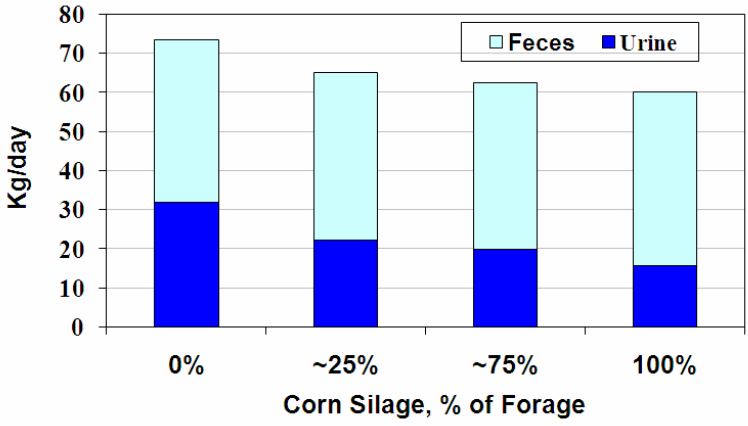

Figure 3. Effect of increasing the amount of corn silage (and reducing the amount of hay crop forage) on manure output by lactating dairy cows. Feeding more corn silage and less hay crop forages usually reduces dietary potassium which greatly reduces urine output.

Protein

Increasing the concentration of protein in the diet usually increases manure output, however in a large experiment we recently completed we found no change in manure output as diets changed from about 14 to 17.7% CP (Weiss et al., 2009). In that study rumen degradable protein was held constant and rumen undegradable protein changed. In other experiments in which rumen degradable and undegradable protein changed, manure output by dairy cows increased by an average of about 0.9 kg/day as dietary crude protein concentration increased by 1 percentage unit (Frank and Swensson, 2002; Wattiaux and Karg, 2004; Weiss and Wyatt, 2006). When diets contain grasses and clover with high concentrations of crude protein (and usually high potassium concentrations), manure output may increase even more as diet protein increases (Van Dorland et al., 2007). On a relative basis, a change in

dietary protein has a very large effect on manure output. However, the concentration of crude protein in the vast majority of diets fed to dairy cows only varies by 3 or 4 percentage units (i.e., most diets contain between 14 and 18% crude protein). That means the overall impact of changing diet crude protein on manure output is quite modest. Increasing protein from 14% to 18% would increase manure output by about 3.5 kg/day (about 5% of average manure production). Usually increasing protein (especially rumen degradable protein) increases urine output with little effect on fecal output, however, sometimes the increase in urine output is countered by a decrease in fecal output resulting in little net change in manure output

Carbohydrates and Digestibility

Manure output usually increases as the concentration of dietary fiber (measured as neutral detergent fiber, NDF) increases. Because NDF concentration is negatively correlated with the concentration of starch in diets, another way to look at this is feeding higher starch diets will reduce manure output. In general, NDF is about 50% as digestible as starch (average starch digestibility = 90% and average NDF digestibility = 50%. On average, a 1 percentage unit increase in starch (approximately equivalent to a 1 percentage unit decrease in NDF) decreases manure output by 0.85 kg/day mostly caused by a decrease in fecal output. Most diets for lactating dairy cows will contain between 20 and 30% starch so the maximal change in manure output caused by changing dietary starch would be about 8 to 9 kg/day (approximately 10% of average manure output).

Other dietary changes that improve digestibility, such as feeding corn silage made from brown midrib hybrids, can also reduce manure output slightly (about 3 kg/day) (Weiss and Wyatt, 2006). Diets with high concentrations of byproducts (e.g., soyhulls, wheat midds, distillers grains) are usually less digestible than typical forage, corn grain, soybean meal diets, but cows often consume more dry matter when fed high byproduct diets which means manure output can be greater. In one study we conducted, cows fed a high byproduct diet produced about 5 kg/day more manure than cows fed a more typical diet.

■ Manure from Non-lactating Animals

Daily manure output by a dry cow or a growing heifer is much less than that by a lactating cow (Table 2), but nonlactating animals still contribute to the manure stream of a dairy farm. Assuming a 2 month dry period, approximately 16% of the adult cows on a typical dairy farm will be in the dry cow group. Based on average calving intervals, age at first calving, and mortality rates, a typical farm will also have 80 to 90 replacements/100 adult

cows. Assuming a typical herd makeup and average manure outputs, nonlactating animals produce about 25% of the total manure produced on a farm (Table 3). Therefore, one method to substantially reduce manure volume on a farm is to move dry cows and heifers to another location. Dietary factors (corn silage, protein, and NDF) probably affect manure output by nonlactating animals in a similar fashion as with lactating cows. However because of the risk of increased metabolic disorders (dry cows), excessive fattening (dry cows and heifers), and feed costs (dry cows and heifers), nutritionists do not have much leeway to change concentrations of corn silage, protein or NDF so it is unlikely we can greatly change manure output by these animals. A new method of raising heifers is being investigated at several universities (especially at University of Wisconsin and Penn State University) that has the potential of substantially reducing manure output. In this system, heifers are fed a high energy diet but intake is severely restricted. Animals are fed only enough energy to meet requirements for the desired rate of gain. Inadequate data are currently available to recommend this method but that may change in the future.

■ Summary

With some simple dietary manipulations, manure output by lactating cows can be reduced substantially. For example switching from a diet that is high in hay crop forage, moderately low in starch (moderately high in NDF) and high in crude protein to a diet that is high in corn silage, contains 75% haycrop (% of diet forage), is moderately high in starch (but not excessive) and moderate in crude protein can reduce manure output by 15 to 20%. This may not result in reduced excretion of nitrogen and phosphorus (i.e., regulated nutrients) but will reduce the storage and handling cost of manure. These dietary changes should not influence milk production if done correctly.

Table 2. Average manure output from various types of Holstein cattle.

Type of cattle	Body weight, kg	Milk, kg/day	DM intake, kg/day	Manure, kg/day
Average lactating cow[1,2]	631	30	21.7	68
High producing cow[2]	590	45	24.5	80
Dry cow[1]	755	0	10.4	39
Heifer, < 1yr old[1]	150	0	3.4	12
Heifer, >1 yr old[1]	440	0	8.3	24

[1] Data from Nennich et al. (2005).

[2] Data from studies conducted at Ohio State.

Table 3. Daily manure production on a typical Holstein dairy farm with 100 lactating cows.

Type of animal	Number of Animals	% of Herd	Manure, kg/day	% of Total Manure
Lactating cows	100	50	6,800	76
Dry cows	16	8	620	7
Heifers, <1 year	44	22	540	6
Heifers, >1 year	40	20	980	11
Total	200	100	8940	100

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