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RESEARCH ARTICLE

Rapid assessment of feed and manure nutrient management on confinement dairy farms

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Abstract A basic function of dairy farming is to transform feed nutrients into milk to generate an economic return. As the price of feed grain escalates, and environmental concerns associated with animal agriculture heighten, many dairy producers seek new ways to track nutrient use on their farms. Relatively little information is available on feed and manure management under producer conditions. The present study provides an overview of an iterative process used to develop and apply techniques for rapid assessment of feed and manure management on confinement-based dairy farms in very different geographic settings. Information was collected on cow diets, milk production and manure management using rapid (2–3 h) survey techniques first on 41 dairy farms in Wisconsin, USA and then on two dairy farms in Shandong Province, China. In both locations, Holstein dairy cows (*Bos taurus*) transformed on average 22–30% of feed nitrogen (N) and phosphorus (P) into milk. These calculated feed N use (FNUE) and feed P use (FPUE) efficiencies corresponded well to published values, but were lower than FNUE and FPUE determined under experimental conditions. Average apparent feed N intake (range of 438–635 g cow^{-1} d^{-1}) were slightly higher than the calculated sum of N outputs in milk (98–145 g cow^{-1} d^{-1}) and manure (328–457 g cow^{-1} d^{-1}). Calculated manure N excretions corresponded well to literature estimates. Average manure collection efficiencies ranged from 56% to 100% in Wisconsin and 55 to 90% in Shandong. Relatively short, face-to-face interviews can provide accurate 'snap-shots' of overall feed and manure management practices on an array of confinement-based dairy farms in diverse geographic locations.

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Introduction

A basic function of dairy farming is to transform nutrients (e.g., feed, fertilizer) into human food (e.g., milk, meat, crops) to generate an economic return. Because they are relatively inexpensive, many producers in industrialized countries use feed and fertilizer nutrients in excess of livestock and plant requirements. Whole-farm nutrient balances (Koelsch 2005), or the difference between nutrients brought onto a farm and nutrients exported in products, provide a general indicator of farms' risks to nutrient buildup, loss, and environmental contamination. Whole-farm nutrient balances generally do not address, however, how nutrient management in one production component (e.g., feed) may affect other components (e.g., meat, milk and manure production, manure nutrient recycling through soils-crops) and the relative impact of each component on profitability and the environment.

Whereas much is known about biological relationships between what is fed to dairy cows, milk and manure production under experimental conditions (c.f., Broderick et al. 2005; Wu et al. 2000; Nennich et al. 2005, 2006), relatively little information is available on feed and manure management under producer conditions. As the price of feed and fertilizers continue to increase dramatically, and livestock producers are increasingly held accountable for the overall environmental performance of their operations, new ways are required to track nutrient management in various components of farming systems.

The present study provides an overview of an iterative process used to develop and apply techniques for rapid assessment of feed and manure management on dairy farms where livestock are fed primarily in confinement in very different geographic settings. The first study in Wisconsin, USA (Powell et al. 2002; Saam et al. 2005) used structured questionnaires, and feed and manure sampling to assess the impact of phosphorus (P) feeding practices on manure P content and recycling through cropland. The second Wisconsin study (Powell et al. 2006, 2007) was expanded to include more detailed information on dietary nitrogen (N) and P feeding strategies, manure spreading practices, and the overall impact of feed, fertilizer and manure management on farmers' abilities to conform to newly developed governmental nutrient management standards. The latter Wisconsin study employed relatively lengthy, structured questionnaires, face-to-face interviews with farmers, detailed record keeping, and feed and manure sampling and analyses.

A previous regional study in China revealed that not much is known about feed and manure management on Chinese dairy farms, although manure can be a valuable commodity, which is often sold and/or bartered for wages (Wattiaux et al. 2002). The objectives of the present study were to modify Wisconsin questionnaires and other survey techniques, and apply them to collect feed and manure management information on two dairy farms in Shandong Province, China; and to compare estimates of feed N and P intake, milk and manure production on Wisconsin and Shandong farms to estimates of these parameters under experimental conditions.

Methods

On-farm surveys

A comprehensive nutrient management survey was conducted on Wisconsin dairy farms during the period 2002–2005 (Powell et al. 2006, 2007). The feed and manure management components of the Wisconsin questionnaire were modified and applied to two dairy farms in Shandong Province, China during June, 2006. Both Shandong farms were located within 3 km of The Yucheng Agricultural Experiment Station (36°57′ N 116°36′ E). Modifications to the Wisconsin questionnaire were made by the study team based on discussion of probable feed and manure practices that would be encountered in Shandong, and by pre-testing the questionnaire with Chinese team members who had dairy industry expertise. Pre-testing provided important insight into how to hone questions, to assess the logical sequence of asking questions, and to predetermine the probable length of the interview, which could be conveyed to producers (along with a clear statement of the survey objectives) at the onset of the interview. Single 2–3 h visits were made to each Shandong farm during which time the questionnaire was used to compile an overall description of the dairy operation, including herd size and composition, livestock facilities, feeding practices, cropping patterns, and fertilizer and manure management practices.

Feed nitrogen and phosphorus intake and use efficiencies

Farmers were asked to define how many groups of lactating cows were being fed the day of the interview, their reasons for grouping cows (e.g., milk production level, days in milk, stage of lactation), the mass (kg cow^{-1} d^{-1}) of individual diet components offered the day of the interview to each feed group, and the mass of milk produced by each group. This information was used to calculate Feed Nitrogen Use Efficiencies (FNUE) and Feed Phosphorus Use Efficiencies (FPUE) using Eqs. 1 and 2.

$$FNUE = 100 * [\text{Milk N production (g cow d}^{-1})/ \text{Apparent feed N intake (g cow d}^{-1})] \quad (1)$$

$$FPUE = 100 * [\text{Milk P production (g cow d}^{-1})/ \text{Apparent feed P intake (g cow d}^{-1})] \quad (2)$$

- Feed N and P intake were derived from farmer-defined amounts of feed offered to lactating cows (wet basis), multiplied by either direct feed analyses (Wisconsin, Powell et al. 2006), literature values of feed DM, N and P concentrations (China, CECAT 1999), or in the case of imported feed concentrates, formulation information provided on feed bags.
- Milk N and P secretions were calculated by multiplying farmer-reported milk production by milk N and P concentrations of, respectively, 4.9 (Nennich et al. 2005) and 0.9 g kg^{-1} (Beede and Davidson 1999).

The relative accuracy of estimates of feed N intake and FNUE were assessed by calculating apparent cow N balance (CNB) using Eq. 3 and equilibrium feed requirement (EFR) using Eq. 5.

$$CNB\ (\text{g N cow}^{-1}\ \text{d}^{-1}) = \text{Daily apparent feed N intake} - \text{Daily milk N} - \text{Daily manure N} \quad (3)$$

- Manure N excretions (ExN) for lactation cows were derived from Eq. 4, developed by Nennich et al. (2005) from an extensive literature review for lactating Holstein dairy cows.

$$ExN\ (\text{g cow}^{-1}\ \text{d}^{-1}) = (DMI \times CP \times 84.1) + (BW \times 0.196) \quad (4)$$

  - DMI = Apparent dry matter intake (kg d^{-1}), CP = CP concentration (g g^{-1}) of DMI, BW = lactating cow bodyweights, an average of 625 kg cow^{-1} was assumed for Wisconsin and 500 kg cow^{-1} for Shandong based on visual observations during farm visits.

Equilibrium feed requirement, the relative amount of additional, or less DMI required to achieve CNB of zero, was calculated using Eq. 5.

$$EFR\ (\%\ \text{of DMI}) = 100 * ((CNB/DMN)/DMI) \quad (5)$$

Manure collection efficiency

On Wisconsin dairy farms, average annual manure collection efficiencies (MCE) were determined to range from 56% to 100%, depending on herd size and livestock housing type (Powell et al. 2005). Procedures similar to those used in Wisconsin were also used in Shandong, and MCEs were calculated according to Eq. 6.

$$MCE\ (\%) = 100 * (\text{Manure N \& P collected}/ \text{Herd manure N \& P excreted}) \quad (6)$$

- Annual manure N & P collected = summation of farmer-estimated fractions of manure mass collected on a seasonal basis.
- Annual herd N & P excretions in manure were derived as follows:
  - For lactating cows: Apparent feed N & P consumed—N & P secreted in milk;
  - For dry cows: Annual manure N & P excretions of 83 and 14.6 kg cow^{-1}, respectively (MWPS 2000); and
  - For heifers: Annual manure N & P excretions of 26 and 3.3 kg $heifer^{-1}$, respectively (MWPS 2000).

In addition to collection of manure mass, estimates were also made of manure N and P losses during storage and land application, based on manure management information (e.g., frequency of manure collection, storage methods) provided by farmers and manure N and P loss values associated with these management practices derived from the literature (Fulhage et al. 2001), and the expertise of the survey team.

Results and discussion

Herd size and cropping characteristics

Herd size and cropping characteristics of Wisconsin dairy farms have been described previously (Powell et al. 2005). In brief, most (60%) dairy farms milk between 50 and 100 Holstein dairy cows, with a median herd size of 60 cows. Wisconsin dairy farmers operate 15–442 ha cropland with a median of 80 ha farm^{-1}. Most (57%) of the cropland area is devoted to forage production. Alfalfa comprises 71% and corn silage 29% of the cropland devoted to forage production.

In Shandong, Farm 1 comprised a collective herd of 250 lactating Holstein dairy cows, 250 dry cows and 600 heifers managed by 72 families. The herd consisted of cross-bred, mostly Holstein dairy cattle. High dry cow numbers reportedly were due to difficulties with insemination. Cows were not fed ad libitum, they were tethered in dirt barnyards with no shade and no obvious water source. Reproductive performance was likely affected adversely by lack of feed and water in the yard, exposure to high temperature, tethering of cows preventing estrous detection, and inaccessibility of bulls to detect estrous. Milk production also likely suffered under these conditions. Farm 1 used a double 12 low line (pit) configuration for milking cows twice daily.

Each family on Farm 1 reportedly cultivated approximately 0.67 ha of wheat and corn grown as relay crops. Land was generally owned, although 10 of the 72 families recently immigrated into the area and rented approximately 0.5 ha cropland per household. Wheat is planted in October, and fertilized with 300 kg ha^{-1} of ammonium phosphate, 225 kg ha^{-1} of calcium phosphate and 45–60 m^3 of manure. Wheat received 150 kg ha^{-1} of urea in March. Farmer-reported average total wheat yields are 14.9, 12.7 and 10.4 Mg ha^{-1} (half grain and half straw) during good, average and poor years, respectively. Corn is planted directly into wheat stubble and 225–300 kg ha^{-1} of urea is applied. Corn ears are removed from stalks at maturity, and all stover is harvested, ensiled, and fed to lactating cows. Average corn grain and stover yields in a typical year are 7.5 and 15 Mg ha^{-1}, respectively. A farm family typically consumes approximately 10% of corn grain, and the remainder is fed to lactating cows.

Farm 2 in Shandong was owned and operated by a single operator. This farm had 80 lactating cows, 220 dry cows and 97 heifers. The high number of dry cows was due to negative impacts on reproductive performance of last year's outbreak of foot-and-mouth disease. Farm 2 used loose housing (roof, open walls and outside brick lots). Cows were milked thrice daily in D-12 parlor. The farm had no cropland and imported all feed.

Feed management

Most cows on Wisconsin dairy farms are fed rations comprised of alfalfa, corn silage, corn grain, protein and mineral supplements (Powell et al. 2006). Approximately one-third of Wisconsin dairy farms feed total mixed rations (TMR) and the remaining two-thirds provide feeds individually. Most Wisconsin dairy cows are fed in confinement; approximately one-half are fed in tie-stall and the other half in free-stall barns.

Both herds in Shandong spend their total time either in barns or in earth or bricked-floored barnyards. During no time of the year are any of the Shandong cattle on pasture.

Besides the small amount (approximately 10 Mg farm^{-1}) of corn stover harvested from 0.67 ha per family on Farm 1, all feed was imported by both Shandong dairy farms. The two study farms differed, however, in the type, amount and how feed ingredients were fed. Although corn stover silage was the principal forage and Tofu by-product was fed on both farms, Farm 1 fed soybean meal and corn grain whereas Farm 2 did not. Farm 2 fed hay and almost three times more concentrate than Farm 1 (Table 1).

Both Shandong farms grouped cows according to milk production and fed concentrate accordingly. On Farm 1, three cow groups produced 30, 20 and 15 kg milk d^{-1} and were given 10, 7.5 and 5 kg concentrate d^{-1}, respectively. On Farm 2, a milk production:concentrate ratio of 3:1 was used. Both farms received assistance in ration formulation: Farm 1 from a university professor and Farm 2 from a

Table 1 Dietary dry matter (DM), crude protein (CP) and phosphorus (P) composition and apparent intake per lactating cow on two dairy farms in Shandong Province, China[a]

Feed component	Offer[b]	Composition[c]			Apparent intake		
		DM	CP	P	DM	N	P
	kg wet	g kg^{-1}			kg	g	g
Farm 1							
Corn stover silage	20.0	450	88	2.7	9.0	127	24.3
Soybean meal	2.0	900	499	7.0	1.8	144	12.6
Corn grain	3.3	860	100	2.9	2.8	45	8.2
Concentrate	3.4	870	150	5.0	3.0	71	14.8
Tofu by-product	8.0	250	161	2.3	2.0	52	4.7
Total diet	36.7		147	3.5	18.6	438	64.6
Farm 2							
Corn stover silage	23.5	450	88	2.7	9.4	132	25.4
Hay	3.0	950	100	2.5	2.9	46	7.1
Concentrate	10.0	870	200	5.0	8.7	278	43.5
Tofu by-product	12.5	250	161	2.3	3.1	81	7.3
Total diet	49.0		139	3.5	24.1	537	83.3

[a] Refer to Powell et al. (2006) for similar information on Wisconsin dairy farms

[b] Farmer-reported feed mass fed per lactating cow

[c] Adapted from CECAT (1999)

consultant. Neither farm has ever had any feed ingredient analyzed for nutrient composition.

On both Shandong dairy farms, feed ingredients were added individually and mixed by hand. On Farm 1, this was done in feed troughs in tie-stall barns. On Farm 2, mixing was done in the feed alley, and then pushed into the mangers. The range of calculated daily feed DM (18.6–24.1 kg cow^{-1}), feed CP (139–147 g kg^{-1} DM) and P (3.5 g kg^{-1} DM, both farms) concentrations offered on these two farms would be within recommended ranges by the US National Research Council (NRC 2001) for lactating dairy cows producing between 20–27.5 kg cow^{-1} d^{-1}.

Feed nitrogen and phosphorus use efficiencies

The relative amount of feed N and P that dairy cows transform into milk and excrete in manure relates to how much feed DM cows consume, and the content and utilization of N and P in feed. The range (22–30%) of calculated FNUE and FPUE on Shandong dairy farms (Table 2) corresponded to the range

Table 2 Apparent feed nitrogen (FNUE) and feed phosphorus (FPUE) use efficiencies on dairy farms in Shandong and Wisconsin

Location	FNUE	FPUE
	% Feed N and P in milk	
Shandong, Farm 1	22	28
Shandong, Farm 2	25	30
Wisconsin, 41 Farms[a]	25 (4.9)[b]	29 (7.4)

[a] Derived from Powell et al. (2006)

[b] Mean, standard deviation in parenthesis

of FNUE and FPUE on Wisconsin dairy farms, and on dairy farms in various parts of eastern U.S.A. (Jonker et al. 2002). As was found in Wisconsin (Powell et al., 2006), higher feed N & P use efficiencies on Farm 2 were likely due to milking thrice, rather than twice daily.

Broderick et al. (2005) determined relationships between feed N intake and FNUE for Holstein dairy cows fed dietary CP levels with the range of 350 and 435 g cow^{-1} d^{-1} (Fig. 1). On average, the highest FNUE (34%) was obtained when feed N intake was approximately 350 g cow^{-1} d^{-1}. FNUE decreased when feed N intakes exceeded this level. Most Wisconsin dairy farmers appeared to feed N at much higher levels, and obtained lower FNUE than determined under experimental conditions (Fig. 1). On one of the Shandong dairy farms, apparent feed N intake and FNUE fell below, and on the other dairy farm apparent feed N intake and FNUE fell above the

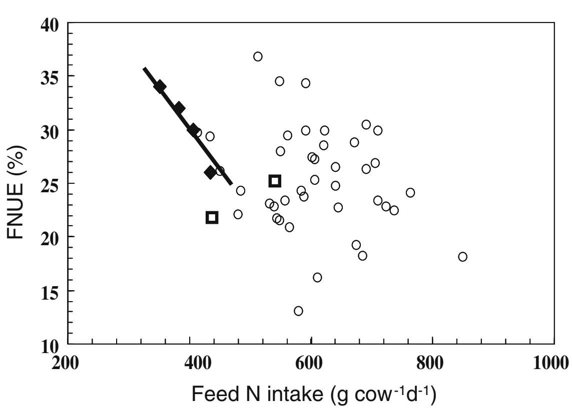

Fig. 1 Comparison of relationship between feed N intake and feed N use efficiency (FNUE) under experimental conditions (♦ = diet means with regression line; Broderick et al. 2005); on 41 Wisconsin dairy farms (○ = individual farms); and on two Shandong dairy farms (□ = individual farms)

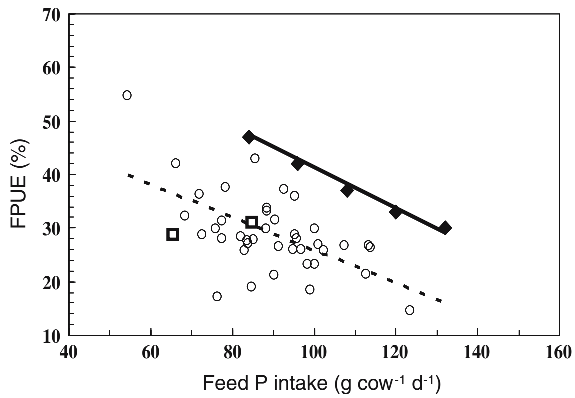

Fig. 2 Comparison of relationship between feed P intake and feed P use efficiency (FPUE) under experimental conditions (♦ = diet means with solid regression line; Wu et al. 2000); on 41 Wisconsin dairy farms (○ = individual farms with dashed regression line); and on two Shandong dairy farms (□ = individual farms)

experimental range. Average feed N and FNUE for the two Shandong dairy farms would fall, however, close to an extended experimental regression line.

Wu et al. (2000) modeled the relationship between feed P intake and FPUE for Holstein dairy cows fed dietary P levels between 60 and 132 g cow^{-1} d^{-1} (Fig. 2). For cows in positive P balance, highest FPUE (47%) were obtained when feed P intake was approximately 84 g cow^{-1} d^{-1}. FPUE decreased when feed P intake exceeded this level.

In a somewhat similar pattern as feed N, apparent P intake on most Wisconsin dairy farms exceeded lactating cow requirements for the level of milk production being attained. There was a significant ($P < 0.05$) negative relationship ($y = -0.31x + 56.5$, $R^2 = .34$) between apparent P intake (x) and FPUE (y) that paralleled the experimental range determined by Wu et al. (2000). Apparent feed P intakes and corresponding FPUE on Shandong dairy farms fell within the range of values determined on Wisconsin dairy farms (Table 2).

Improvements in FNUE and FPUE would enhance dairy farm profits, reduce the amounts of manure N and P that would have to be handled and land-applied and, therefore, reduce the risk of environmental pollution. Possible ways to improve FNUE and FPUE would be to sample and analyze feeds and use this information to frequently balance rations; determine relationship between feed N and milk urea N (MUN) and use this information to feed correct amount of protein (Broderick and Clayton 1997; Jonker et al. 1998; Nousiainen et al. 2004); and determine relationships between dietary P and fecal P (Wu et al. 2000; Powell et al. 2002; Dou et al. 2003, 2007), and use this information to refine diets so P is not fed excessively.

Feed data validation: cow N balances

For dairy farms in both Shandong and Wisconsin, estimates of feed N intake (Table 1) were only slightly more than calculated N outputs in milk and manure, resulting in relatively small positive CNBs (Table 3). Equilibrium feed requirements (Eq. 5) of only 2–4% of estimated DMI would be required to achieve CNB of zero. These relatively low equilibrium feed DM requirements indicate that the rapid feed assessment tool used on dairy farms in Shandong and Wisconsin appeared to provide accurate “snapshots” of feed N and P intake across a fairly wide range of feeding practices on confinement dairy farms located in diverse geographic locations.

Feed data validation: predicted versus estimated manure N excretions

Cow N balances were used to validate calculations of feed N intake and FNUE (Table 3). Calculated FNUE were also compared to FNUE determined under experimental conditions (Fig. 1). An additional method to validate calculations of feed N intake and FNUE is to compare ExN (g cow^{-1} d^{-1}) calculated from the (1) difference in feed N intake and milk N secretions determined from the on-farm surveys, and (2) an algorithm based on an extensive data base of dairy cattle in the U.S. that uses Holstein lactating cow bodyweight and feed N intake (Eq. 4). Comparison of ExN derived from these two methods is presented in Fig. 3. Regression analysis (SAS 1990) determined that ExN based solely on difference between estimated feed intake and milk N (Wisconsin and Shandong dairy farms) were similar to ExN determined from the algorithm derived from the U.S.A.-wide database based on an assumed slope = 1 ($P < 0.05$).

Manure management, Shandong

In Shandong, each family on Farm 1 manages manure deposited in the barn and barnyard assigned

Table 3 Apparent daily feed nitrogen (N) intake, outputs, cow N balance (CNB) and equilibrium feed requirement (EFR) on dairy farms in Shandong and Wisconsin

Location	Feed N	Milk	Manure	CNB	EFR
	g cow^{-1} d^{-1}				(%)
Shandong, Farm 1	438	98	328	+12	−2.7
Shandong, Farm 2	537	135	383	+19	−3.5
Wisconsin, 41 Farms	635 (135)[a]	152 (35)	457 (71)	+27 (59)	−2.5

[a] Mean, standard deviation in parenthesis

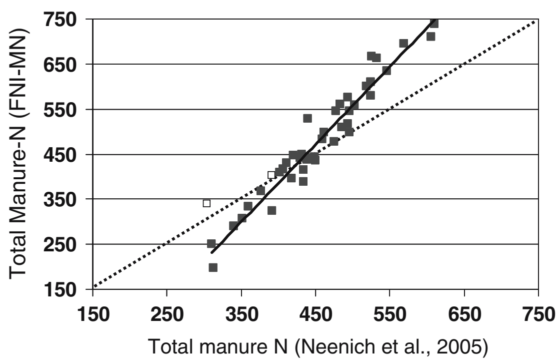

Fig. 3 Comparison of calculated total manure N from Nennich et al. (2005; Eq. 4) and difference between estimated feed N intake (FNI) and milk N (MN) for 41 Wisconsin (■, and solid regression line) and two Shandong (□) dairy farms. Dashed line depicts 1:1 relationship

to them. Manure is scraped by shovel from concrete barn floors and dirt barnyards several times daily, piled in barnyards, and removed from barnyards every-other-day. Between cropping seasons, manure is generally hauled by tractor to family fields and incorporated into soil within a day. Any remaining manure is usually given to vegetable producers, who haul it away without payments. On Farm 1 during the winter, approximately 2 kg of wheat straw per cow is used as bedding. Bedding is changed every 3–4 days. During manure removal from barns and barnyards, feces are separated from bedding. Vegetable growers reportedly do not like bedding (possibly due to adverse effects of bedding on vegetable establishment and growth, difficulty of incorporating straw, etc.). On Farm 2 in Shandong, an external operator manages all manure. The operator scrapes manure from barn and barnyards to piles thrice per day. Manure is hauled off-farm daily. The operator is charged for the amount of manure hauled.

Manure collection efficiency, Shandong

In Shandong, a study objective was to have farmers depict possible seasonal differences in manure management. The first step was to ask farmers to define seasons of the year. In Shandong, there was much discussion about how many months comprised each season. Whereas Farm 1 delineated 3.5, 3.5, 2.5, and 2.5 months for Fall, Winter, Spring and Summer, respectively, Farm 2 delineated only 2 seasons, warm and cool, each lasting approximately 6 months.

Based on seasonal manure collection information provided by the village leader, in-barn manure N recoveries on Farm 1 were estimated to be 60, 65, 70 and 65 during Summer, Fall, Winter, and Spring, respectively; and manure P recoveries were assumed to be similar (95%) across all four seasons. Manure N and P recoveries in barnyards were estimated to be 50% and 85% during Summer, 55% and 90% during Fall, 60% and 90% during Winter, and 55% and 90% during Spring. In-barn and barnyard manure N and P recoveries on Farm 2 were estimated to be 5% greater than Farm 1 across seasons. This increased collection efficiency was due to barn and barnyard cleanings of three times daily on Farm 2, versus twice daily on Farm 1.

Apparent manure N and P collection efficiencies for Farms 1 and 2 in Shandong are depicted in Fig. 4. Approximately 52% of manure N and 90% of manure P excreted by the dairy herd on Farm 1 is apparently collected and available for application to wheat fields and vegetable gardens. Somewhat similar manure N (56%) and manure P (91%) collection efficiencies were calculated for farm 2, where all manure is applied to vegetable gardens.

Both dairy farms in Shandong appeared to be managing manure effectively, given the limitations of the facilities. Eliminating or reducing the size of barnyards can achieve reductions in manure N and P losses. Concentrating cattle would reduce manure surface area exposure to rainfall, runoff, and ammonia volatilization. The installation of roof gutters may also reduce runoff from barnyards. Collected roof water in cisterns could provide drinking water for cattle.

The 72 families of Farm 1 cultivate approximately 47 ha (i.e., 62 families cultivate 0.67 ha each and 10 immigrant families cultivate 0.5 ha each). Whereas

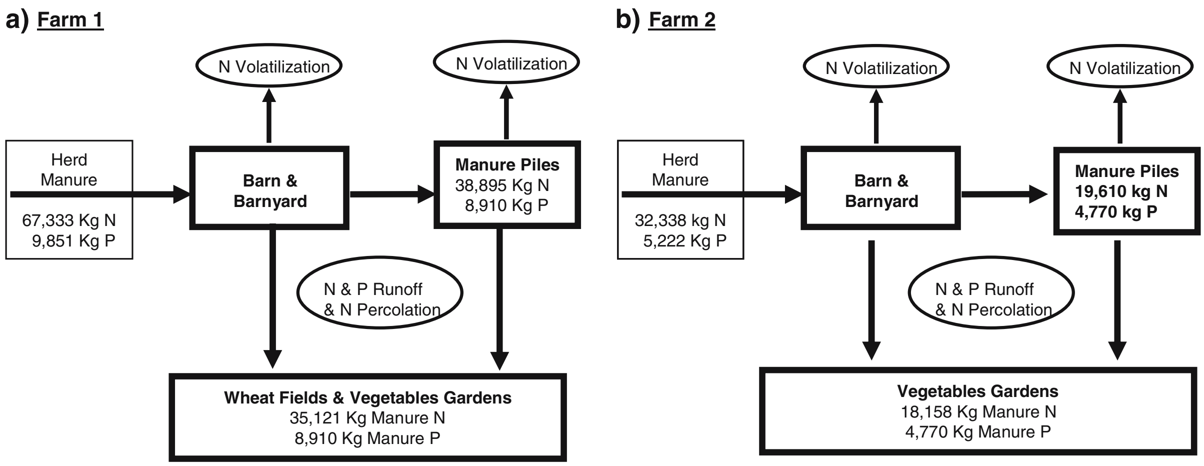

Fig. 4 Apparent manure nitrogen and phosphorus collection efficiencies on two dairy farms in Shandong Province, China

manure N would be lost due to volatilization during transportation from storage through field application, manure P would be relatively stable. The village leader estimated that approximately one-half of manure produced would be spread on cropland and the remainder given *gratis* to neighbor vegetable growers. Spreading approximately one-half of collected manure P (Fig. 4) on 47 ha of cropland would result in a manure P loading rate of approximately 95 kg P ha^{-1}, much higher than annual P requirements of wheat and corn grown on this land. The average annual P removal of corn grain and stover would be approximately 34 kg ha^{-1}, assuming farmer-reported total corn grain and stover DM yields of 6.45 and 6.75 Mg ha^{-1} having P contents of 2.9 and 2.7 g kg^{-1}, respectively (Table 1).

Conclusions

Relatively short, face-to-face interviews with farmers provided accurate, general ‘snap-shots’ of feed and manure management practices, first in Wisconsin then on Shandong confinement dairy farms. Revisions to Wisconsin questionnaire using knowledge of likely dairy farm practices in Shandong, and pre-testing the revised questionnaire provided a survey instrument adaptable to dairy farms having very different nutrient management practices in a very different geographic setting. For both surveys, honing the logical relationships of one question to another (e.g., herd, feed, milk, manure) improved the overall flow of survey questions, provided focus and minimized the time needed to complete the survey. Data reliability can be improved by quickly assessing relationships prior to leaving each farm. For example, having general information on feed DM, N and P composition available during the interview provides quick assessments of data accuracy based on general relationships between feed and milk production. Information derived from rapid assessment can provide general indicators of where gross improvements in N and P use can be made within components of the feed-cow-milk/manure-soil/crop-environmental continuum on confinement dairy farms.

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