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Prediction of Manure and Nutrient Excretion from Dairy Cattle

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ABSTRACT

Accurate estimates of manure excretion are needed for planning manure storage facilities and for nutrient management. Data sets from metabolism studies conducted at several universities were compiled and evaluated for excretion of total manure, N, P, and K. Animal groups included calves weighing up to 204 kg, heifers weighing between 274 and 613 kg, nonlactating cows, and lactating cows. Regression equations were developed to predict excretion of total manure, total dry matter, N, P, and K. Predictors used in the regression equations for lactating cows included milk yield, percentages of protein and fat in milk, dietary concentrations of crude protein and neutral detergent fiber, and intakes of nutrients. The regression equations provide improved predictions of excretion and enable more accurate planning of manure storage and nutrients to be managed at the farm level.
(**Key words:** manure, nitrogen, phosphorus, potassium)

Abbreviation key: ASAE = American Society of Agricultural Engineers, **DMD** = DM digestibility, $\mathbf{DM_E}$ = manure DM excretion, $\mathbf{K_E}$ = K excretion, $\mathbf{M_E}$ = manure excretion, **MF** = milk fat percentage, **MILK** = milk yield, **MilkP** = P in milk, **MTP** = milk true protein, $\mathbf{N_E}$ = N excretion, $\mathbf{P_E}$ = P excretion.

INTRODUCTION

Accurate estimates of manure and nutrient excretion are important for designing adequate manure storage facilities and developing effective nutrient management plans. Recent modifications to the Clean Water Act have resulted in new regulations related to nutrient management on concentrated animal feeding operations (Environmental Protection Agency, 2003). It is expected that concentrated animal feeding operations will develop nutrient management plans that include designs for collection and storage of manure, as well as strategies for land application of manure at agronomic rates. According to the Natural Resources Conservation Service standard for nutrient management planning (NRCS, 2001), nutrient budgets should be established for N, P, and K. In addition, estimates of manure DM excretion are useful for designing manure treatment and handling technologies such as anaerobic digesters, or for the development of future manure treatment technologies.

Estimates for manure and nutrient excretion by dairy cattle are found in the American Society of Agricultural Engineers (**ASAE**) Standard D384.1 (ASAE, 2001). These estimates are limited in their utility and accuracy as they are based on data from the late 1960s and early 1970s, and were taken from a data set that was of limited known origin. In addition, the ASAE standard was revised in 1988 to merge a dairy heifer column with a dairy cow column for one single column for all dairy cattle categories.

Recent reports of excretion data from dairy cows were compiled from lactating Holstein dairy cows producing an average of 20.3 and 29 kg of milk/d (Tomlinson et al., 1996; Wilkerson et al., 1997). Today, many dairy cattle are producing milk at twice those levels. Contemporary manure and nutrient excretion estimates are needed to more precisely predict excretion from higher producing cows. Most important, equations need to be developed to reflect the relationship between milk production and manure or nutrient excretion.

Previous evaluations of manure excretion from dairy cattle indicated that the ASAE (2001) manure excretion estimates underestimated excretion from high-producing cows (Tomlinson et al., 1996) and that using only

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BW is not an accurate method of predicting manure or nutrient excretion (James et al., 1999). As production and management of dairy cattle have changed in recent decades, changes may also have occurred in manure and nutrient excretion. In addition, excretion estimates for calves and heifers have not been published in recent years. Feed consumption (quality and quantity) differs from young calves to springing heifers. It is reasonable to assume that BW alone is not a good predictor of manure and nutrient excretion for all heifer categories. As an example, dairies with high culling rates and approximately equal number of replacement heifers as lactating cows need to have precise estimates for manure and nutrient excretion to adequately establish a nutrient plan. Furthermore, heifer data are essential for replacement heifer operations. Technical assistance providers, dairy operators, and staff from regulatory agencies are seeking site-specific information on manure volume and nutrient content to more precisely develop nutrient management plans and design adequate manure storage systems. Updated information is critical to owners of animals residing in environmentally sensitive areas.

In 2001, a committee was developed by the ASAE Structures and Environment Committee 412 and members from the Federation of Animal Science Societies to revise the ASAE manure excretion values using data from contemporary diets and levels of productivity (ASAE Standard Tables D384.1). The committee structure consisted of animal species subgroups, which included dairy cattle. The outcomes of the dairy subgroup's efforts are reported in this paper. The overall goal of the dairy subgroup's effort was to evaluate data collected from studies with contemporary diets that represented a broad geographical context and included data from cows milking >40 kg of milk per day. The primary objectives of the dairy subgroup were to develop regression equations to predict manure, DM, and nutrient excretion of calves, heifers, and nonlactating and lactating Holstein dairy cows, and to document nutritional parameters associated with manure and nutrient excretion.

MATERIALS AND METHODS

Data sets from Washington State University, The Ohio State University, The Pennsylvania State University, and the University of California, Davis were combined and used for estimations of excretion from dairy cattle (Table 1). The overall data set included records from a wide variety of animal ages, ranging from calves to multiparous lactating cows. Data were categorized into 4 groups: lactating cows (LACT), dry cows (DRY), heifers (HEIFER), and calves (CALF). The LACT data set (554 cows or cow-periods from Latin square experiments) included multiparous lactating Holstein cows. The DRY data set (18 cow-periods) animals were defined as multiparous, nonlactating cows that were pregnant. The HEIFER data set (60 animal-periods) included female, nonlactating animals that had not calved and included animals of various ages weighing >250 kg. The CALF data set (46 animal-periods) included animals weighing <250 kg (Table 2).

The LACT data set included observations from 26 individual feeding studies. Most feeding studies were originally intended to evaluate nutritional hypotheses. The California studies were designed specifically to evaluate the applicability of ASAE Standards under California conditions. Variation in animal location and dietary ingredients increased the errors associated with development of regression equations, but provided a broader base to account for differences in the commercial industry. An effort was made to include several equations for each dependent variable during the development of prediction equations to provide users flexibility depending on the accuracy and availability of input variables for a given dairy operation.

The independent variables included in the LACT data set were BW, DIM, DMI, DM digestibility (**DMD**), milk yield (**MILK**), percentage milk fat (**MF**), and percentage milk protein (Table 3). Milk CP values in the data set were converted to milk true protein (**MTP**) values using a conversion factor of 0.9345 (Mackle et al., 1999). Dietary ingredients and characteristics were used as additional prediction factors for equations, including dietary concentrations of CP, NDF, P, and K. Dependent variables included in the LACT data set were (Table 3) manure excretion ($\mathbf{M_E}$), DM excretion ($\mathbf{DM_E}$), N excretion ($\mathbf{N_E}$), P excretion ($\mathbf{P_E}$), and K excretion ($\mathbf{K_E}$). Dry matter excretion included both fecal and urinary DM and was determined by adding actual fecal DM and 4.5% of urinary excretion.

Quadratic models were evaluated for excretion variables using the LACT data set. Variables evaluated in equations included squared and 2-way interactions of DMI, MILK, DIM, BW, and dietary NDF and CP concentrations.

Data on P and K intake and excretion for lactating animals were only available for a subset of animals in the LACT data set. The MINERAL data set (85 cow-periods) included cows for which excretion of feces and urine were known. Intakes of minerals were determined through analyses of both feed and orts. One study of early lactation cows (Johnson et al., 1998, experiment 2; 15 cow-periods ranging from 16 to 61 DIM) was not included in the MINERAL data set due to negative P and K balances for the early lactation animals.