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DEVELOPMENT OF STANDARD METHODS TO ESTIMATE MANURE PRODUCTION AND NUTRIENT CHARACTERISTICS FROM DAIRY CATTLE

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ABSTRACT

Total collection data from many universities were pooled for statistical analyses to evaluate existing data from dairy animals and determine if one or more modifications were needed for Standard Table D384.1. Many of these studies were carried out to evaluate nutritional characteristics associated with different diets. The data collected were sufficient to evaluate total manure, total and volatile solids, and N excretion values. Some experiments had sufficient number of samples analyzed to evaluate P, K, Ca, Mg, Na, Cl, S, and micro-elements. Statistical analyses were conducted to determine if a single column value was appropriate and define the regression equations necessary to estimate excretions if the assumptions of the column inputs were not met.

The results indicate that separate classifications are needed for replacement heifers and mature animals. Final classifications for replacement heifers included: milk fed calves, weaned calves weighing less than 274 kg, heifers weighing between 273 and 613 kg, and veal calves. Additionally, classifications for lactating and dry animals are needed. Previously, the estimates for manure production and nutrient excretion were based on body weight. These findings indicate that a better predictor for lactating cattle is daily milk production instead of body weight. Milk production drives feed intake in the lactating animal. It is most appropriate that estimated manure and nutrient excretion values reflect the relationship between feed intake, milk production (nutrient utilization) and nutrient excretion.

KEYWORDS. Dairy manure production, nutrient excretion characteristics.

INTRODUCTION

Standard Table D384.1 published by the American Society of Agricultural Engineers (ASAE, 2000) identifies manure production and nutrient characteristics from livestock and poultry. The columns used to represent dairy animals were modified once since 1969. The modification resulted in merging two columns: heifers and mature animals. This combined dairy column is being used beyond its original intent with the onset of new Federal and State regulations and the potential need for a permit nutrient plan or a comprehensive nutrient management plan for some dairy producers. Emphasis of current regulatory trends makes it imperative to have a more precise method to estimate nutrient excretion on a site-specific basis as well as having reasonable table values to utilize when planning.

Production practices on dairy facilities continue to change. Over the last few decades, dairies have increased herd size and production through development and implementation of new technologies. Technologies to improve milking and reduce labor, mix and deliver feed, and manage information have improved both the efficiency of milk production and production per cow. Greater knowledge of the feed value of non-traditional feedstuffs and mechanization of feed delivery systems have aided in the ability to increase herd size without the need to grow more feedstuffs locally. These improvements in milk production may lead to facility or area imbalances of nutrients imported, compared to the sum of nutrients utilized by local crop production systems and nutrients exported off-farm.

It is essential to review and revise manure production characteristics at this time. Average milk production per cow has increased 70% from 4,500 kg/cow/year (1971) to nearly 7,300 kg/cow/year (2000), resulting in changes in manure production. There is increased need to improve precision of estimates for manure production (to assist in design and storage criteria) and manure nutrient excretions (to assist in development of whole farm nutrient balance calculations). An average dairy herd in the United States increased from 25 milking and dry cows in 1975 to 82 milking and dry cows in 1999. The average herd size in the year 2000 for California, Wisconsin, and New York was 533, 61, and 85 cows, respectively. As herd sizes and productivity have increased there has been greater focus from legislators, environmental regulators, and environmentalists on the potential adverse impacts of animal production.

There were many reports and proposed regulations during the 1990s related to the effect of animal feeding operations on the environment. Most importantly, the United States Environmental Protection Agency (US EPA) entered into a consent decree to review and revise the definition of Concentrated Animal Feeding Operations (CAFO) and the associated Effluent Limitations Guidelines (ELG). The final law was promulgated on December 15, 2002 (US EPA, 2003). Additionally, The United States Department of Agriculture Natural Resources Conservation Service finalized its Guidance for Comprehensive Nutrient Management Plans two years prior (USDA NRCS, 2000).

Van Horn et al. (1994) estimated nutrient excretion for N and P through the relationship of feed intake minus milk output. The data for P were based on experiments by Morse et al. (1994) and N estimates were later compared to results from Tomlinson et al. (1996). This relatively simple approach requires that producers know nutrient content of diets and amount of dry matter fed as well as nutrient outputs in milk. The precision of data at each dairy may vary significantly. The precision of estimating nutrients excreted would rely on the precision of the assumption that nutrient intake was based on formulated diet values. Errors associated with estimating nutrient outputs by this method can occur, as nutrients consumed by the animals may vary significantly from what was formulated, due to deviations in the feed mixing process and animal selectivity of feeds. Consequently, the estimates of nutrients excreted may not represent the facility. Alternatively, one may chose to track whole farm nutrient inputs and outputs over a six or 12 month period. Errors associated with estimating nutrient outputs by this method include errors in measuring starting and ending inventories and the database used to estimate nutrient content of individual feedstuffs.

Wilkerson et al. (1997) evaluated 1801 individual calorimetric studies from the Energy Metabolism Unit at Beltsville, MD. The lactating cattle were categorized by milk production as high producing (> 20 kg/d) with an average of 29 kg/d, or low producing (≤ 20 kg/d) with an average of 14 kg/d. Data from growing heifers and steers were used from animals 0.8 to 1.6 yr of age. Mean amount of manure excreted by cows in the high producing group was similar to ASAE while N excretion was greater than ASAE by 0.092 kg/d. The authors indicated that the large standard deviations for manure and N excretion and the variation in diets and animal variation within group suggested that regression equations may predict excretion more accurately than means. They ran detailed regression equations with stepwise regression procedure (SAS, 1990). Their descriptive models used the maximum amount of data available. Their detailed models included body weight, day of pregnancy, days in milk, milk production, dry matter crude protein content, dry matter neutral detergent fiber content, and quadratic and interaction terms as appropriate. Many of the regression coefficients were very small. The authors indicated that the model equations which provided the best description of variation possible, might not be the best prediction equation because they require inputs which are unknown or are unavailable to the user. The reduced models they reported still had quadratic (percent neutral detergent fiber squared, milk production squared) and significant interaction terms. Their final estimates for manure production for 20, 30, and 40 kg of fat corrected milk were 46.0, 55.5, and 65.2 kg/d, respectively. (ASAE value for a 600 kg animal would be 51.6 kg/d).

Objectives of this study were to take results from total collection studies from various universities and establish simple regression equations to estimate manure production and mass of N, P, and K excretion. Standard Table values would be determined for reasonable levels of milk production. Standard Table values and simple regression equations provide reasonable data for planning purposes and calculations of site specific nutrient balance.

MATERIALS AND METHODS

Multiple data sets from Washington State University, University of California - Davis, The Ohio State University, and Pennsylvania State University were used. The data sets include records from different classifications of animals, ranging from calves to multiparous lactating cows. Animals were housed and fed according to specific protocols approved for animal handling and care at each institution. Animals were fed specific diets for an initial adjustment period. Following the adjustment period the collection period began. The data set for lactating cows was evaluated to compare the amount of metabolizable protein (MP) required to the MP supplied to the cow using the 2001 Dairy NRC Model (National Research Council, 2001). Only data from cows fed less than 112% of MP requirements were used. The data set was used to develop regression equations based on milk production. The average values reported for lactating cows were determined using the regression equation for a cow producing 40 kg of milk. Total collection of feces and urine occurred in separate containers through methods approved in each protocol. Fecal and urine samples were analyzed separately and total daily manure production (feces + urine) was calculated. Analyses were made to calculate total solids (TS), volatile solids (VS), N, P, and K excretion. Associated production data were also available (parity, days in milk, milk production, milk composition, and days pregnant).

The data for the calves and heifers were separated according to animal body weight: weaned calves weighing less than 274 kg; and heifers weighing between 273 to 613 kg. Excretion estimates for veal calves were adapted from Sutton et al. (1989). The other classifications of animals included non-lactating cows and lactating cows.

Lactating cow excretion estimates were derived from regression equations developed through the SAS Mixed Model analysis (SAS, 1996) where location, experiment, and cow were assumed to be random. Models with multiple parameters were used and results were compared to those of reduced models. The final model used acknowledged the loss of precision (increase in BIC fit summary statistic) to estimate the independent variables.

RESULTS AND DISCUSSION

Results of manure excretion are compared to previous Standard values from 2000 and shown in Figures 1, and 2. The values were derived from developed regression equations. For animals fed above 112% of NRC recommended levels more detailed calculations would need to be made on farm to estimate nutrient consumption and nutrients exported off in animal product (milk and meat).

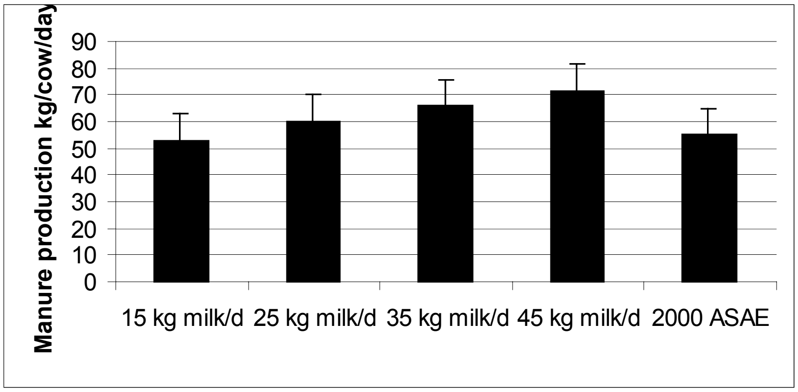

Figure 1. Manure excretion by milk production (manure excretion (kg/cow/d)= milk production (kg) 0.647 + 43.212) and previously published ASAE table values.

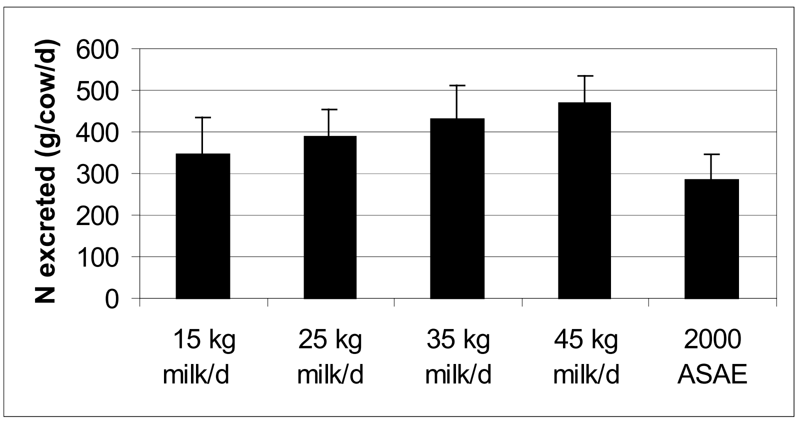

Figure 2. Nitrogen excretion by milk production (N excretion g/cow/d=milk*0.4204+283.3) compared to previously published ASAE table values.

Manure excretion estimates for various levels of milk production, along with the estimate from the 2000 ASAE Standard Table are shown in Figure 1. The 2000 ASAE value for manure production is between the estimated value associated with milk production of 15 kg (34) and 25 kg (57 lbs) per day. Therefore, cows producing over 25 kg of milk per day are predicted to excrete more manure than outlined by the current ASAE Standard Table. When milk production is over 45 kg (99 lbs) per day, manure excretion is underestimated by the 2000 ASAE Standard by approximately 40%. Our results for 15, 25, 35, and 45 kg of milk/d estimated manure production to be 53, 60, 66, and 72 kg/d, respectively. These are the estimates and standard errors (±4.5 to 5.5 kg/d) should be considered when planning or designing a dairy facility. Wilkerson et al. (1997) evaluated manure production and N excretion from a compilation of 1801 total collection data points. They concluded that mean manure excretion from dairy animals with 29 kg/d milk production was 3 kg/d per 1000 kg of body weight more than the value in the 2000 ASAE Standard. However, their manure production estimates were 65.2 kg/d for cows producing 40 kg of fat corrected milk. Clearly, both sets of data support the need to revise existing values in Standard Table D 384.1 to more precisely estimate manure generation for lactating cattle based on milk production.

The underestimation of manure excretion could lead to storage facilities that are inadequate to hold the quantity of manure produced by a dairy operation. As herd sizes increase it is essential to have more precise methods to estimate manure volume and nutrients available for land application. For example, if the average milk production for a dairy operation is 45 kg/cow/d, manure excretion would be underestimated by as much as 17 kg/cow/d. Over the period of a year, approximately 527,000 kg or 520 m^3 of additional manure would be excreted for a 100-cow dairy (assuming 85% milking per day). This number would increase to 5.27 million kg of additional manure produced each year for a 1000 cow dairy.

Body weight and dry matter intake were used to estimate manure excretion from dry cows and replacement heifers. Manure excretion was estimated at 37.8 kg/cow/d for a 727 kg animal. This was considerably less manure production when compared to the Standard Table (62.5 kg/cow/d). A replacement heifer weighing 318 kg (274 to 613 kg data set range) was estimated to excrete 23.5 kg/animal/d compared to a Standard Table value of 27.4 kg/animal/d. For the young replacements the difference between the 2000 Standard Table and new estimate was minimal. Estimates for young calves (fed milk replacer) differed from those on commercial calf diets or on replacement heifer diets where forage was the primary nutrient source.

CONCLUSIONS

Separate categories should be used to estimate excretion and nutrient content for calves, replacement heifers, and lactating cows. Our findings indicate that a better predictor for lactating cattle is to consider daily milk production. Milk production drives feed intake in the lactating animal and it is most appropriate that values reflect this relationship. Our results for 15, 25, 35, and 45 kg of milk/d estimated manure production to be 53, 60, 66, and 72 kg/d. Estimates of manure production and nutrient content for dry cows and replacement heifers (calves fed milk replacer, weaned calves under 274 kg, calves between 274 and 613 kg) should not rely on existing Standard Table values to estimate manure production or nutrient excretion.

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