A Dairy Herd Model for Use in Whole Farm Simulations

C.A. Rotz, D.R. Mertens, D.R. Buckmaster, M.S. Allen and J.H. Harrison

Introduction

The dairy industry faces complex issues related to improving efficiency, reducing negative impact on the environment, and developing a more competitive position in the world economy. To solve economic and environmental issues, a systematic whole farm approach must be taken. All major farm components, the interaction among components, and the interaction with the environment must be considered. This requires an interdisciplinary modeling approach. Farm models require submodels of each of the major farm components. On dairy farms, a major component is the animal herd. Work was undertaken to develop a herd model that predicted feed intake, milk production and manure excretion with rations balanced to meet roughage, energy, and protein requirements, and to verify or validate the important model components by comparing predicted information to that of other widely accepted models and data bases.

Materials and Methods

The model was developed to simulate or predict performance of a dairy herd consisting of growing heifers, lactating cows, and dry cows. The model was developed in five sections. In the first section, the characteristics of the major animal groups making up the herd were established. Next, the allocation of available feeds and the characteristics of those feeds were set. The animal's requirements for roughage, energy, and protein were then determined, and a linear program was used to determine the best mix of feeds to meet the animal's requirements. Finally, based upon the diet fed, the quantity and nutrient content of the manure produced was determined.

Results and Discussion

The herd was described as six animal groups: young stock under one year old, heifers over one year old, three groups of lactating cows, and dry cows. The characteristics of each animal group were a function of the animal type and the period of the lactation cycle covered. The seven available animal types were large Holstein, average Holstein, small Holstein, Brown Swiss, Ayrshire, Guernsey, and Jersey. Feed characteristics used to balance rations and predict feed intake included crude protein, protein fractions, net energy of lactation, and neutral detergent fiber. Protein fractions were the portion of the total protein that was ruminally degradable and the portion of acid detergent insoluble protein. Total digestible nutrient, phosphorous and potassium contents were used to predict manure excretion. A feed allocation scheme was established to match available forage with the animal group that could best use forage of that nutrient content.

Animal diets and performance were modeled using a linear program that simultaneously solved five constraint equations. These constraints included 1) a limit on the rate of fiber passage through the rumen, 2) a minimum roughage requirement, 3) an energy requirement, 4) a minimum requirement of rumen degradable protein, and 5) a minimum requirement of undegradable or bypass protein. Manure production was modeled as feed dry matter consumed minus the digestible DM extracted by the animals plus urine DM and feed DM lost into the manure. Manure nutrients equaled the nutrient intake minus nutrients contained in the milk produced and in the meat produced through animal growth.

Three procedures were used to verify that the dairy herd model worked properly and produced reasonable results. Animal requirements predicted by the model were first compared to those recommended by the National Research Council. Next, diets formulated by the model for each animal group were compared to those formulated by the Spartan Dairy Ration Evaluator/Balancer. Finally, manure excretion predicted by the model was compared to measured data from calorimeter studies performed over a 30-year period at the Energy Metabolism Unit in Beltsville, Maryland.

Dry matter intakes predicted by our model were about 15% less than those from the NRC model for both the late lactation and dry cow groups. This occurred because the forage used in our model included corn silage. With this high-energy forage, requirements for these groups were met with a lower intake. Intakes for all other animal groups were very similar between the two models. Net energy requirements for the early and mid lactation groups were about 5% greater from our model, but they were essentially the same for all other groups. The small difference for the higher producing groups was likely due to a change in the energy constraint of our model that provided an added energy requirement for excreting excess degradable dietary protein. Small differences in undegradable and degradable protein requirements were due to differences in the way acid detergent insoluble and rumen influx proteins were handled in the ration constraints.

Rations were generated for each animal group using alfalfa hay, alfalfa silage, corn silage, high moisture corn grain, soybean meal, and cotton seed. Using the same forage mix and the same feed characteristics, rations were generated by the Spartan Dairy Ration Evaluator/Balancer. Rations formulated by the two models were similar, but some difference occurred. For the early and mid lactation groups, our model used less forage and more concentrate in rations than those from the Spartan program. For all other animal groups, the opposite trend occurred with our model using more forage in rations. This difference was largely due to differences in the logic for use of forage. Our model formulated rations using the maximum amount of forage in the diet while meeting the energy and protein requirements. The assumption in the Spartan program was that feeds were balanced to minimize ration costs using market prices for feeds.

The manure component was validated by comparing predicted and measured dry matter and nitrogen excretions. Our model predicted greater manure excretion than that measured in the calorimeter chambers. Dry matter intakes from our model were also proportionately greater compared to the measured data. Greater intakes, and thus greater manure excretion, might be due to genetic and feeding improvements made over the past 30 years. Values predicted by our model for lactating cows were similar to the average manure production values for dairy cows published in the ASAE Standards. In general, differences in N excretion between predicted and measured values were in proportion to differences in protein or nitrogen intake. Because animal diets could not be formulated to exactly match those fed in the many experiments, differences in N excretion were more a function of the way animals were fed than model or measurement error.

Conclusion

A model was developed that predicts nutrient requirements, feed rations, feed intake, milk production, and manure excretion for a dairy herd. The model was verified to predict feed intakes, nutrient requirements, feed rations, and manure excretion similar to those commonly recommended or expected for the various animal groups making up a dairy herd.