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The decline in digestive efficiency of US dairy cows from 1970 to 2014

S. B. Potts, M. Shaughness, and R. A. Erdman[1]
Department of Animal and Avian Sciences, University of Maryland, College Park 20742

ABSTRACT

Since the year 1970, US milk production per cow has more than doubled, in part because of large increases in feed intake. It is well established that increasing feed intake reduces diet digestibility in dairy cattle. Our objective was to determine whether the digestive efficiency of US dairy cows had also changed. We assembled a data set consisting of diet digestibility measured either by total collection of feces or by use of indigestible neutral detergent fiber (NDF) in lactating dairy cow studies published in the *Journal of Dairy Science* from July 1970 to July 2014. The data set contained 575 treatment means from 154 individual research trials conducted at 26 US institutions. Based on regression analysis, mean milk yield and dry matter intake (DMI) between 1970 and 2014 increased by 19.7 and 10.3 kg/d, respectively. Temporal effects on digestibility [dry matter (DM), crude protein (CP), and NDF] were determined using the regression model $Y_i = \mathrm{YEAR}_{1970i} + \mathrm{CP}_i + \mathrm{NDF}_i + e_i$, where YEAR_{1970i} is the publication year minus 1970, CP_i and NDF_i are diet constituents (% of diet DM) that were included to account for their known effects on digestibility, and e_i is the residual error. Dry matter digestibility decreased 0.07 percentage units/yr for a total reduction of 3.08 percentage units since 1970. Furthermore, CP and NDF digestibilities decreased 0.04 and 0.17 percentage units/yr, respectively. To account for the potential effect of feed intake on digestibility, DMI as a percentage of body weight was added to the regression model. With DMI as a percentage of body weight in the model, temporal changes in DM, CP, and NDF digestibilities were no longer significant. This suggested that the apparent decline in DM digestibility could be mostly accounted for by simultaneous increases in level of feed intake. Despite lower apparent digestive efficiency, the modern dairy cow has greater production efficiency than the 1970s dairy cow because she produces more milk per unit of feed consumed and digested.

Key words: digestibility, digestive efficiency, dairy cow

INTRODUCTION

Between 1976 and 2016, milk production per cow more than doubled in the United States (NASS, 2016). These tremendous changes in production have been achieved through a combination of genetic selection for milk yield and improvements in nutrition and management that have facilitated the ability of cows to approach their production potential. Because feed intake is largely driven by energy demands (NRC, 2001), feed intake per cow also increased during this time. The development of ration formulation strategies that minimize potential negative effects of gut fill on feed intake have likely also promoted increases in feed intake. It is well established that high levels of feed intake depress diet digestibility (Tyrrell and Moe, 1975). Thus, it seems reasonable that the increase in intake, as a consequence of greater production and more refined ration formulation, might have resulted in a reduction of the efficiency with which gross energy is converted to digested energy, thereby reducing the amount of energy a cow can extract per unit of feed consumed.

Recently, attention has been given to improving feed efficiency in dairy cattle (Connor et al., 2013; Macdonald et al., 2014; VandeHaar et al., 2016). Digestive efficiency, or the efficiency by which gross energy is converted to digested energy, is an important component of biological efficiency and is a function of both an individual animal's ability to digest feed and the relative digestibility of the diet itself. It is important to consider whether intense selection for production over the last 4 decades has resulted in changes in the ability of dairy cows to digest feed, which could have implications for improving the cow's biological efficiency in the future. We hypothesized that digestive efficiency had decreased during the last 4 decades and that most of this reduction could be accounted for by concurrent increases in feed intake. The objective of this study was to determine whether changes in digestive efficiency occurred between 1970 and 2014 and, if changes occurred, whether these changes were associated with increases in feed intake.

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[1]Corresponding author: erdman@umd.edu

MATERIALS AND METHODS

Database Derivation

Literature Search. We constructed a database of peer-reviewed published data to examine temporal effects on the digestibility of DM, CP, and NDF between 1970 and 2014. Journal articles that included "digest" in the title or abstract that were published between July 1970 and July 2014 were included in the initial search. We only used studies published in *Journal of Dairy Science* because we were interested in examining temporal effects on the digestive efficiency of lactating dairy cattle; including other journals would have given results from other species that were not the focus of the analysis.

Data Inclusion and Collection. A total of 1,960 full-length articles resulted from the initial literature search, and only papers that detailed original research were considered for analysis. Publications were retained for analysis if (1) total-tract digestibility was determined in lactating dairy cows; (2) digestibility was measured either by total collection (**TC**) of feces or by use of indigestible NDF (**iNDF**) as an internal marker; (3) treatment DMI was reported; and (4) apparent total-tract digestibility of DM, CP, NDF, or any combination of those 3 was reported. Because we were interested in investigating digestibility changes over time for the US dairy cattle population, only studies conducted at institutions in the United States were included in the final data set.

When available, the following information was obtained from each publication: year of publication; study design; breed of cow studied; number of treatments; number of observations; length of collection period; standard error of the mean for digestibility (DM, CP, or NDF); percentage CP, NDF, starch, NFC, and forage in the diet; milk yield; milk fat concentration; and BW. The number of years between publication year and the year 1970 was calculated as the year of publication minus 1970 ($\mathbf{YEAR_{1970}}$). When both milk yield and fat concentration were reported, 4% FCM was calculated as FCM = 0.4 × milk yield + 15 × (milk fat concentration/100) × milk yield (NRC, 2001). If BW was reported, DMI as a percentage of BW ($\mathbf{DMI_{BW}}$) was also calculated.

Statistical Analysis

Observations for apparent total-tract digestibility of DM, CP, and NDF were weighted as number of observations per standard deviation^2, or the reciprocal of the squared standard error of the mean, according to Firkins et al. (1998) and St-Pierre (2001). If the standard error of the mean or standard deviation were not reported for digestibility (DM, CP, or NDF), observations could not be weighted and therefore were not included in the final analysis. Weights were standardized to a scale of 1 to maintain a weighted mean value that was on a scale similar to that of the response variable by dividing the weight factor for an individual treatment mean by the mean of all weight factors in the data set (St-Pierre, 2001).

To determine temporal effects on digestibility, data were analyzed using the GLM procedure of SAS (version 9.3; SAS Institute, Cary, NC) according to the model

$$Y_i = \mathrm{YEAR}_{1970i} + \mathrm{NDF}_i + \mathrm{CP}_i + e_i, \quad [1]$$

where Y_i is apparent total-tract digestibility (%), YEAR_{1970i} is the year of publication minus 1970, NDF_i and CP_i are the NDF and CP concentrations of the diet (% of DM), and e_i is the residual error. Dietary constituents were included in the model to account for diet composition effects on digestibility. The WEIGHT statement was used to weight individual means as described earlier. To account for possible effects of feed intake on digestibility, $\mathrm{DMI_{BW}}$ was included as a covariate in a second linear model:

$$Y_i = \mathrm{YEAR}_{1970i} + \mathrm{NDF}_i + \mathrm{CP}_i + \mathrm{DMI}_{\mathrm{BW}i} + e_i. \quad [2]$$

Study was not included in either statistical model because study effects would be confounded with time, which was our primary variable of interest. The presence of outliers was determined by visual inspection and Cook's distance obtained for each nutrient digestibility using both Models 1 and 2; single observations with a Cook's distance >0.20 for either model were removed from the analysis of digestibility for the affected nutrient only (DM, CP, or NDF). Collinearity of response and explanatory variables used in Models 1 and 2 for the digestibility of each nutrient was assessed using variance inflation factors and the condition indices generated by the collinearity diagnostics option (COLLINOINT) of the REG procedure of SAS. Condition indices or variance inflation factors >5.0 were considered to be indicative of multicollinearity. Additionally, the relationships among response and explanatory variables included in Models 1 and 2 were investigated using the CORR procedure of SAS. Temporal effects for other response variables (DMI, BW, $\mathrm{DMI_{BW}}$, and diet CP, NDF, NFC, and forage as a percentage of DM) were determined by regressing responses as a function of $\mathrm{YEAR_{1970}}$. Significance was declared at $P < 0.05$, and tendencies were declared at $P < 0.10$.