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Development and evaluation of empirical equations to predict feed passage rate in cattle

S. Seo [a], L.O. Tedeschi [a,1], C. Lanzas [a], C.G. Schwab [b], D.G. Fox [a,*]

[a] *Department of Animal Science, 130 Morrison Hall, Cornell University, Ithaca, NY 14853, USA*
[b] *Department of Animal and Nutritional Sciences, University of New Hampshire, Durham, NH 03824, USA*

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Abstract

Empirical equations were developed to accurately predict passage rate (K_p) in ration formulation models for all classes of dairy and beef cattle. The database was comprised of studies that used external markers, and 553, 195 and 766 treatment means were used to develop the K_p equations for forages, concentrates and liquid, respectively. A random coefficients model that used each study effect as a random variable was used to select statistically significant input variables to predict rate of passage. The parameters of the variables were estimated using ordinary least square method. The equations developed were: K_p forage = (2.365 + 0.0214FpBW + 0.0734CpBW + 0.069FDMI)/100; K_p concentrate = (1.169 + 0.1375FpBW + 0.1721CpBW)/100 and K_p liquid = (4.524 + 0.0223FpBW + 0.2046CpBW + 0.344FDMI)/100, where K_p is the passage rate, h^{-1}; FpBW the forage DMI as a proportion of BW, g/kg; CpBW the concentrate DMI as a proportion of BW and FDMI is the forage DMI, kg. These K_p equations for forages, concentrates and liquid explained 87%, 95% and 94%, respectively of the variation in passage rates in the database used in equation development after adjustment for random study effect. These and other published equations were evaluated with an independent database. In this evaluation, the R^2 of the new equations were 0.39, 0.40 and 0.25 for prediction of the passage of forages, concentrates and liquid, respectively, which was higher than the R^2 of the previously published equations by 0.03–0.19, 0.01–0.14, and 0.04–0.16 for forages, concentrates and

Abbreviations: CpBW, concentrate dry matter intake as a proportion of BW; FC, fiber carbohydrate; FDMI, forage DMI; FpBW, forage DMI as a proportion of BW; K_p, fractional rate of passage out of the rumen; MP, metabolizable protein; NFC, non-fiber carbohydrate; RDP, rumen degradable protein; RMSPE, root mean square prediction error; RUP, rumen undegradable protein

* Corresponding author. Tel.: +1 607 255 2855; fax: +1 607 255 9829.
E-mail address: dgf4@cornell.edu (D.G. Fox).
[1] Present address: Department of Animal Science, Texas A&M University, College Station, TX 77843, USA.

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liquid, respectively. The root mean square prediction error (RMSPE) was reduced by 3–22%, 2–33%, and 4–31% in the prediction of K_p of forages, concentrates and liquid, respectively, with the new equations. These new empirical equations are suitable for predicting passage rate in cattle, but predictability overall is still low and increases in the accuracy of predicting passage rates requires development of a mechanistic model that accounts for more biologically important variables affecting passage rate (*e.g.* physical property of particles, water intake and flux, and within day variation in intake).

Keywords: Passage rate; Meta-analysis; Empirical model; Model comparison; CNCPS

1. Introduction

Ruminal rate of passage (K_p) is important in ruminant animals since it is related to maximal voluntary feed intake, extent of digestion of the diet, amount of protein which escapes degradation in the rumen, efficiency of microbial growth, extent of methane loss, and susceptibility of animals to bloat (Okine et al., 1998). Accounting for the different components of digesta outflow from the rumen is a pre-requisite for many nutritional models that seek to predict relationships between diet and supply of nutrients to ruminants (Cannas et al., 2004; Fox et al., 2004; NRC, 2001).

The 2001 National Research Council Nutrient Requirements of Dairy Cattle (NRC, 2001) includes three equations to predict rates of passage for dry forages, wet forages and concentrates in dairy cattle using meta-analysis and a random coefficient model. An evaluation of the equations and sensitivity of the NRC model to the equations were documented (Seo et al., 2005). The equations accounted for study variation as a random effect, and thus they were expected to extract correct relationships between input variables and K_p in the data set used in their development. However, the database used to develop the NRC (2001) K_p equations was comprised of studies that only used rare earth markers, which may limit the conditions to which they can be applied. Additionally, a K_p equation for liquid was not developed. The liquid K_p may affect digestion of soluble nutrients (Illius and Gordon, 1991), outflow of end products of fermentation (Lopez et al., 2003), peptide escape (Fox et al., 2004) and microbial growth (Eun et al., 2004; Owens and Goetsch, 1986). Moreover, the equations were not evaluated with an independent dataset.

The objectives of this study were to: (1) develop more robust empirical equations that can be used across all classes of cattle for estimating K_p in ration formulation programs, including the Cornell net carbohydrate and protein system (CNCPS), (2) evaluate predictions of the equations with an independent database, (3) compare the predictions with other published passage equations and (4) analyze the sensitivity of the current version of the CNCPS to implementation of the new equations.

2. Materials and methods

2.1. Database construction

The database described by Seo et al. (2005) was used to develop new K_p equations for forages, concentrates and liquid. This database included 1271 treatment means. The