J. Dairy Sci. 97:7185–7196
http://dx.doi.org/10.3168/jds.2014-8632

Using the Small Ruminant Nutrition System to develop and evaluate an alternative approach to estimating the dry matter intake of goats when accounting for ruminal fiber stratification

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ABSTRACT

The first objective of this research was to assess the ability of the Small Ruminant Nutrition System (SRNS) mechanistic model to predict metabolizable energy intake (MEI) and milk yield (MY) when using a heterogeneous fiber pool scenario (GnG1), compared with a traditional, homogeneous scenario (G1). The second objective was to evaluate an alternative approach to estimating the dry matter intake (DMI) of goats to be used in the SRNS model. The GnG1 scenario considers an age-dependent fractional transference rate for fiber particles from the first ruminal fiber pool (raft) to an escapable pool (λ_r), and that this second ruminal fiber pool (i.e., escapable pool) follows an age-independent fractional escape rate for fiber particles (k_e). Scenario G1 adopted only a single fractional passage rate (k_p). All parameters were estimated individually by using equations published in the literature, except for 2 passage rate equations in the G1 scenario: 1 developed with sheep data (G1-S) and another developed with goat data (G1-G). The alternative approach to estimating DMI was based on an optimization process using a series of dietary constraints. The DMI, MEI, and MY estimated for the GnG1 and G1 scenarios were compared with the results of an independent dataset (n = 327) that contained information regarding DMI, MEI, MY, and milk and dietary compositions. The evaluation of the scenarios was performed using the coefficient of determination (R^2) between the observed and predicted values, mean bias (MB), bias correction factor (C_b), and concordance correlation coefficient. The MEI estimated by the GnG1 scenario yielded precise and accurate values (R^2 = 0·82; MB = 0.21 Mcal/d; C_b = 0.98) similar to those of the G1-S (R^2 = 0.85; MB = 0.10 Mcal/d; C_b = 0.99) and G1-G (R^2 = 0.84; MB = 0.18 Mcal/d; C_b = 0.98) scenarios. The results were also similar for the MY, but a substantial MB was found as follows: GnG1 (R^2 = 0.74; MB = 0.70 kg/d; C_b = 0.79), G1-S (R^2 = 0.71; MB = 0.58 kg/d[1]; C_b = 0.85) and G1-G (R^2 = 0.71; MB = 0.65 kg/d; C_b = 0.82). The alternative approach for DMI prediction provided better results with the G1-G scenario (R^2 = 0.88; MB = −71.67 g/d; C_b = 0.98). We concluded that the GnG1 scenario is valid within mechanistic models such as the SRNS and that the alternative approach for estimating DMI is reasonable and can be used in diet formulations for goats.
Key words: heterogeneous fiber pool, nonlinear optimization, rumen capacity

INTRODUCTION

The nutritional value of ruminant feedstuffs depends on the retention time in the gastrointestinal tract, animal species, BW, DMI, and many other factors that can affect feedstuffs' availability and digestibility (Van Soest, 1994). The only way to evaluate the interactions between these variables is to use nonspecific and comprehensive methods. In response to this limitation, mechanistic nutrition models have been developed to predict different aspects of ruminant nutrition. The Small Ruminant Nutrition System (**SRNS**) (Cannas et al., 2007a; Tedeschi et al., 2010) is the most recent nutrition model for sheep and goats. The SRNS bases its logical calculation to predict the dietary supply of energy and nutrients on the Cornell Net Carbohydrate and Protein System (**CNCPS**) for cattle (Fox et al.,

Received July 17, 2014.
Accepted August 8, 2014.
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2004) and sheep (Cannas et al., 2004). However, because the SNRS model is still under development, its modeling of goats under diverse production scenarios is not complete. Only one paper has evaluated lactating does with the SRNS (Cannas et al., 2007b), so additional evaluations with larger databases are needed to study the predictive power of the SRNS for goats.

Furthermore, most mathematical nutrition models currently in use include a submodel to predict DMI, but a range of factors that interact among each other determines changes in DMI. Theoretical and practical models that predict DMI based on the physical intake control theory have been proposed and tested (Illius and Gordon, 1991; Poppi et al., 1994; Forbes, 2007), but none of them have been evaluated in mechanistic models with the same ruminal modeling approach of the SRNS.

Vieira et al. (2008) proposed that DMI can be predicted by using an optimization process that includes typical constraints of ruminant diet formulation. If valid, this hypothesis may be an interesting tool for diet formulations and ruminant DMI predictions. This model would predict DMI with an approach more biologically sound than using DMI as a model input. Usually, the constraints that software adopts to formulate ruminant diets encompass nutritional requirements and nutritional constraints for avoiding dietary unbalances (e.g., an excess of NFC and fats). Extra constraints can be added to the optimization process to achieve physical fiber restrictions.

Another factor that can influence the physical aspects of intake control by ruminants is ruminal fiber stratification, which may occur when ruminants are fed considerable amounts of fiber (Sutherland, 1988). Equations used to estimate the fractional passage rate and fiber digestion in the SRNS model do not properly account for ruminal fiber stratification, so an evaluation of how to embed this approach into the SRNS model is necessary.

Thus, the objectives of this research were to evaluate the inclusion of a heterogeneous fiber pool approach in the SRNS model and to assess an alternative approach to predicting DMI for dairy goats.

MATERIALS AND METHODS

Model Descriptions and General Assumptions

A modified SRNS model (available in its original form at http://nutritionmodels.tamu.edu/srns.html, verified on June 26, 2014) was used to evaluate a heterogeneous rumen fiber approach and mass fiber restrictions for goats. The SRNS uses the equations described by Tedeschi et al. (2010) to predict goat nutritional requirements, the CNCPS equations described by Fox et al. (2004), with modifications, in the calculation of fecal CP, and the rate of passage equations of Cannas et al. (2004) to predict the dietary supply of energy and nutrients.

However, because of updates to the CNCPS model, we inserted the following modifications and assumptions in our assay.

(1) We included the modified predictions for ruminal pH and microbial growth (Tylutki et al., 2008), but we did not consider the submodel of FA absorption (Tylutki et al., 2008).
(2) Instead of using the new carbohydrate fractionation described by Lanzas et al. (2007), we assumed the original (Sniffen et al., 1992) 4 carbohydrate fractions: organic acids and sugars (**CA**), soluble fiber and starch (**CB1**), available insoluble fiber (**CB2**), and unavailable fiber fraction (**CC**).
(3) We considered the heterogeneous pool scenario only for the fiber fraction (CB2 + CC); we considered the ruminal pool of all other feed fractions (carbohydrate and protein) to be homogeneous, and we calculated the ruminal digestibility (**RD**) using the linear, one-pool, age-independent steady-state approach: $RD = k_d/(k_d + k_p)$, in which $\boldsymbol{k_d}$ and $\boldsymbol{k_p}$ are fractional rates of degradation and passage, respectively, but we calculated the k_p used to estimate RD as the reciprocal of the total mean rumen retention time (**TMRT**).
(4) We adopted the Ca and P requirements as described by the AFRC (1993).

Submodel for Estimating Passage Rate and Ruminal Fiber Digestibility

The submodel described below is based on a heterogeneous ruminal fiber pool in goats receiving high-fiber diets and it considers general assumptions regarding particle flow as described by Matis (1972) and more recently by Vieira et al. (2008). These general assumptions include that the first ruminal fiber pool (raft) is governed by an age-dependent fractional transference rate of particles from the raft to an escapable pool ($\boldsymbol{\lambda_r}$) and that this escapable fiber pool is governed by an age-independent fractional passage rate ($\boldsymbol{k_e}$). The com-