Autocatalytic models describing ruminal in situ digestion

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Ann Zootech (1994) 43, 275

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Digestion of particulate matter in the rumen is a microbial enzymatic process and probably depends on both substrate and enzyme availability. Although microbes can be considered the cause of digestion, they are also the result of digestion, being one of the digestion end-products. Thus, digestion partially is an autocatalytic process.

In the classical digestion model (model 1), rate of digestion (dS/dt) is proportional only to the concentration of potentially digestible substrate *(S)*. The effect of other factors affecting digestion is represented by the fractional digestion rate, which is assumed to be constant (k_d). To account for time-varying effects of microbes (or enzymes) on digestion of substrate, 2 models are proposed which are based on a non-constant fractional digestion rate *(Z)*, such that $dS/dt = -ZS$:

1. $dZ/dt = 0$; $Z = 0$ for $t \leq t_l$ and $Z = k_d$ for $t > t_l$
2. $dZ/dt = (Z_i - Z)Z$ with $Z_0 \neq 0$; $Z = Z_i Z_0/(Z_0 + (Z_i - Z_0)\exp(-Z_i t))$
3. $dZ/dt = (Z_i - Z)k_z$ with $Z_0 = 0$; $Z = Z_i (1 - \exp(-k_z t))$

which yield for *Y*, the total quantity of substrate remaining (Stf_i):

1. $Y = f_d + f_i$ for $t \leq t_l$; $S = f_d \exp(-k_d(t - t_l)) + f_i$ for $t > t_l$
2. $Y = f_d Z_i/(Z_0\exp(Z_i t) + Z_i - Z_0) + f_i$
3. $Y = f_d \exp(Z_i(1 - k_z t - \exp(-k_z t))/k_z) + f_i$

where t is the incubation time (h), f_d the potentially digestible fraction (g/g), f_i the indigestible fraction (g/g), k_d the fractional digestion rate constant (1/h), t_l the discrete lag time (h), Z_0 the initial value of Z (1/h), Z_i the asymptotic value of Z (1/h), and k_z the fractional rate of change of Z (1/h). The models were evaluated by fitting the equations to *in situ* data of 4 roughages.

Microbes involved in digestion of substrate are either synthesized within the system (*in situ* bag) or originate from the environment (rumen fluid surrounding *in situ* bags). Model 2 (*Y* is the logistic function) is based on the conversion of substrate into microbes (or enzymes), but does not account for exchange of microbes between the system and its environment. Model 3 assumes that the effect of microbes on digestion is time-dependent. Although it does not explicitly account for the origin of microbial mass, it has properties that cannot be included in model 1 (*eg*, $Z_0 = 0$).

The residual standard deviation (RSD) and estimates for f_d and f_i were generally similar between models. The Z_i (representing the fractional digestion rate after infinite incubation) for model 3 was of a similar magnitude to k_d in model 1. However, Z_i for model 2 was 35 to 95% higher than k_d. The t_l, Z_0 and k_z are difficult to compare between models because they are based on different concepts. Parameter estimates for orchard grass hay are given in table I as an example. Both models are suitable alternatives to the classical model.

Table I. Digestion kinetic parameters for orchard grass hay.

	Model 1	*Model 2*	*Model 3*
RSD (g/g)	0.023	0.024	0.021
f_d	0.597	0.615	0.604
f_i	0.227	0.237	0.230
k_d or Z_i	0.034	0.047	0.036
t_l	4.61	–	–
Z_0	–	0.023	–
k_z	–	–	0.198