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Comparison of mathematical models to evaluate various *in situ* ruminant feed crude protein degradation kinetics

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Introduction

The *in situ* technique is a direct method of measuring the rumen degradation kinetics of a feed. It was suggested to describe the data obtained by this technique by an exponential curve (Ørskov and McDonald, 1979). This first order exponential model is a most common procedure for determining crude protein and dry matter degradation coefficients. However, very low attention has been paid to the choice of mathematical model to fit the curves and goodness-of-fit of the model. Different mathematical models were evaluated to describe ruminal dry matter (DM) and crude protein (CP) degradation kinetics of various feeds (Lopez *et al.*, 1999; Fathi *et al.*, 2006). In the present study, two different mathematical models of a straight line or a negative exponential (Fathi *et al.*, 2006) were selected to evaluate crude protein (CP) degradation kinetics of various ruminant feeds including alfalfa hay, corn and whole barley silages, barley and corn grains, cottonseed and soybean meals using data obtained from the *in situ* technique.

Material and methods

Samples of various ruminant feeds including alfalfa hay, corn and whole barley silages, barley and corn grains, cottonseed and soybean meals were incubated in the rumen of four Holstein steers (330 ± 15 kg body weight) for 0.0, 2, 4, 8, 16, 24, 48, 72 and 96 h (8 replicates) using polyester nylon bags (10×20 cm, 50 μm pore size). Animals were fed to maintenance body weight with a medium quality alfalfa hay (35%), corn silage (15%), wheat straw (15%) and concentrate (25%) twice a d, at 9:00 and 16:00 h, individually. Data of CP degradation were further adjusted to a segmented linear model [model I, $P = a + ct$, Fathi *et al.*, 2006] or a negative exponential model [model II, $P = a + b(1-e^{-ct})$, Ørskov and McDonald, 1979]; where P = fraction degraded in the time t, a = rapidly degradable fraction, b = slowly degradable fraction, c = fractional degradation rate and t = incubation time. Several statistics, including mean square prediction error (MSPE), root of MSPE (rMSPE) and coefficient of determination (R-square) were used to evaluate goodness-of-fit of each model. After fitting each model to each disappearance curve, statistics were calculated to detect significant differences between models in MSPE, rMSPE and R-square using GLM of SAS (Y= mean + model + parameter + residual).

Results and discussion

The results of CP degradation kinetics of each sample using models I and II are shown in Table 1. In addition, for each model, the MSPE, rMSPE and R-square have been presented. The R-square and MSPE, as indicators of model accuracy, show that model II gave significantly ($P<0.05$) better fits to the feed CP degradation kinetics than model I. However, based on rMSPE, models I and II showed the same fit to the data on CP disappearance. R-square showed that the variation was high for models I compared with model II. Model I is a segmented model and needs a sufficient number of observations in each segment to obtain a consistent solution, and model II is an exponential model which is sometimes inadequate for describing ruminal disappearance curves (Fathi *et al.*, 2006). Lopez *et al.* (1999) pointed out that the disappearance of some feed components, particularly structural carbohydrates, exhibits a larger variety of forms than does CP. In addition, the ruminal CP degradation does not follow a zero order. The results of the present experiment showed that, based on various statistical tests, the negative exponential model is well suited to describing the degradability patterns obtained for CP of the feed samples.

Table 1. In situ *dry matter degradation parameters estimated for various ruminants feed crude protein using model I ($P = a + ct$) and model II ($P = a + b(1-e^{-ct})$).*

	Model I						Model II					
Forages	a	b	c	MSPE	rMSPE^2	R^2	a	b	c	MSPE	rMSPE^2	R^2
Alfalfa hay	0.35	0.47	0.06	0.02	4.12	0.90	0.43	0.49	0.06	0.01	3.99	0.93
Corn silage	0.35	0.33	0.04	0.04	5.71	0.81	0.28	0.33	0.05	0.03	5.50	0.88
Whole barley silage	0.33	0.42	0.04	0.03	5.2	0.89	0.43	0.33	0.02	0.02	4.84	0.94
Barley grain	0.29	0.63	0.07	0.03	4.84	0.90	0.34	0.44	0.06	0.02	4.92	0.97
Corn grain	0.31	0.50	0.06	0.03	4.99	0.81	0.29	0.41	0.05	0.02	5.02	0.91
Cottonseed meal	0.31	0.45	0.07	0.03	5.01	0.79	0.31	0.32	0.04	0.03	5.11	0.94
Soybeanmeal	0.42	0.49	0.09	0.02	4.16	0.89	0.44	0.46	0.09	0.01	3.78	0.97

a = rapidly degradable fraction, b = slowly degradable fraction, c = fractional degradation rate, MSPE = mean square prediction error, rMSPE = root of MSPE expressed as a percentage of the observed mean and R^2 = coefficient of determination.

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