Evaluation of a zero-order model to describe ruminal degradation kinetics of whole soybean incubated *in situ*

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Introduction *In situ* incubation of feeds in the rumen serves as a basic procedure in many feed evaluation systems. The formulation of hypotheses concerning underlying biological concepts of ruminal degradability has led to development of different mathematical models describing the resultant time course disappearance curves of feed fractions. The use of models allows comparison of parameter estimates (or combinations thereof), which ideally reflect these biological concepts, between feeds or feeding systems. Among different factors affecting the experimental measurements of *in situ* ruminal disappearance of feeds, less attention has been paid to choice of mathematical model to fit the curves and the goodness-of-fit of the model. The objective of the present work, therefore, was to evaluate the ability of a zero-order mathematical model to describe *in situ* disappearance curves obtained with whole soybean, and to give adequate estimates of the parameters needed to determine extent of ruminal degradation.

Materials and methods Two Iranian cultivars of soybeans (Sahar and Williams) as raw, roasted and steep-roasted were used in this study. Degradability of DM and CP was recorded at each incubation period for each of 6 feeds, yielding a total of 12 disappearance curves, obtained from the following time periods of incubation in rumen: 0, 2, 4, 8, 16, 24, 36, 48 and 72h. The evaluated model was a segmented model with three spline-lines delimited by two nodes or break points, constraining splines 1 and 3 to be horizontal asymptotes, and follows zero-order degradation kinetics (France *et al*., 1990). Fractional degradation rate (/h), disappearance to time t (%) and extent of degradation (%) were calculated using the formulae $\frac{c}{b-c(t-L)}$, $a+c(t-L)$ and $a+\frac{c}{k}\ln\frac{kb+ce^{kL}}{c}-cL$, respectively. L is a discrete lag parameter and was included in the model to represent the time interval before degradation commences and a, b, c and k are rapidly soluble fraction (%), slowly degradable fraction (%), the constant degradation rate (%/h) and fractional passage rate (/h), respectively. The model was fitted to the DM and CP disappearance curves by nonlinear regression using the PROC NLIN of SAS to estimate ruminal degradation parameters. A number of statistics, including mean square prediction error (MSPE), root of MSPE (rMSPE) expressed as a percentage of the observed mean and coefficient of determination (R-square) were used to evaluate general goodness-of-fit (quality of prediction) of model to each curve.

Results The results for parameters estimated, MSPE and R-square calculated for the model are shown in Table 1. The value of rMSPE was not significantly different between non-lagged and lagged version of model for both DM and CP components and was sufficiently small to show both forms were able to estimate model parameters accurately. Moreover, decomposition of MSPE gave similar values of ECT (error in central tendency), ER (error due to regression) and ED (error due to disturbance) for both versions, and was mainly dominated by the disturbance component, which indicates that ruminal degradation of DM and CP of samples was well represented by both lagged and non-lagged versions.

Table 1 Parameter estimates for lagged and non-lagged versions of model (SE in parentheses) and statistics calculated for comparison of the two equations

	Lagged version		Non-lagged version	
Item	DM	CP	DM	CP
Parameter estimates[1]				
a	50.27 (2.523)	43.64 (4.686)	47.96 (1.464)	43.07 (3.737)
b	45.95 (2.753)	50.72 (1.828)	47.72 (2.645)	51.35 (2.525)
c	0.012 (0.0027)	0.013 (0.0030)	0.015 (0.0078)	0.016 (0.092)
U	3.79 (2.241)	5.64 (3.606)	4.32 (1.423)	5.58 (3.084)
L	1.30 (2.195)	0.0 (8.2×10^{-7})	…	…
E (*k* = 0.06)	73.40 (4.206)	69.31 (6.584)	74.06 (4.820)	70.68 (8.658)
E (*k* = 0.08)	70.50 (4.223)	66.22 (6.624)	71.18 (4.734)	67.62 (8.719)
R-square (%)	98.79 (2.250)	97.06 (3.82)	97.40 (0.782)	96.32 (2.613)
rMSPE	4.17 (1.341)	5.36 (1.795)	4.36 (0.666)	5.66 (1.894)
MSPE analysis (%MSPE)				
ECT	0.16 (0.209)	5.74 (6.411)	0.01 (0.012)	4.31 (7.647)
ER	1.49 (2.202)	1.11 (1.755)	0.03 (0.009)	4.69 (8.048)
ED	98.35 (2.263)	93.15 (7.140)	99.96 (0.020)	91.00 (15.687)

[1]*a*, rapidly soluble fraction (%); *b*, slowly degradable fraction (%); *U*, undegradable fraction (%), calculated as (1 - *a* - *b*); *L*, lag time (h); *E*, extent of degradation (%); *k*, fractional passage rate (/h).

Conclusion The results showed that the three-piece linear model was suited to describing the degradability patterns of whole raw and roasted soybeans.

Reference

France, J., Thornley, J. H. M., Lopez, S., Siddons, R. C., Dhanoa, M. S., and Van Soest, P. J. 1990. Journal of Theoretical Biology 146, 269-287.