Model Prediction of Nutrient Supply to Ruminants from Processed Field Tick Beans

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ABSTRACT : The objective of this study was to compare the Dutch DVE/OEB system and the NRC-2001 model in the prediction of supply of protein to dairy cows from processed field tick beans. Comparisons were made in terms of 1) ruminally synthesized microbial CP, 2) truly absorbed protein in the small intestine, and 3) degraded protein balance. The results showed that the predicted values from the DVE/OEB system and the NRC-2001 model had significant correlations with high R (>0.90) values. However, using the DVE/OEB system, the overall average microbial protein supply based on available energy was 16% higher and the truly absorbed protein in the small intestine was 9% higher than that predicted by the NRC-2001 model. The difference was also found in the prediction of the degraded protein balances (DPB), which was 5% lower than that predicted based on data from the NRC-2001 model. These differences are due to considerably different factors used in calculations in the two models, although both are based on similar principles. It need to mention that this comparison was based on the limited data, the full comparison involving various types of concentrate feeds will be investigated in the future. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 12 : 1674-1680)***

Key Words : Field Tick Bean, NRC-2001 Model, DVE/OEB System, Feed Processing, Protein Evaluation, Ruminants

INTRODUCTION

Field tick beans are particularly high in protein and starch contents as potential sources for ruminants. Despite the fact that field tick bean have high protein and starch content, their use in dairy cow feeding is inefficient. The major reasons are that rumen degradation of protein is rapid and rumen effective degradability is high, which causes an imbalance between feed protein breakdown and microbial protein synthesis, resulting in unnecessary nutrient loss from the rumen (Yu et al., 1999). Dry roasting is a relatively simple, safe and economical procedure to reduce rumen degradation and increase intestinal availability of protein or starch. Little systematic research has been done on quantitative prediction of nutrient supply from field tick bean affected by different combinations of heating temperature and duration with a model.

There are several sophisticated models such as ARC, NRC, NKJ-NJF, PBI and DVE/OEB (Tamminga et al., 1994) existed, which can be used to quantitatively predicted such protein nutrient supply to dairy cows, both in the rumen and intestines (Yu et al., 2003). Based on principles in existing models, modern protein evaluation systems: the Dutch DVE/OEB system (Tamminga et al., 1994) and NRC-2001 dairy model (NRC, 2001) have been developed. These two models consider the strong elements (such as truly absorbed protein in the small intestine) of other recently developed protein evaluation systems such as ARC and they also introduce new elements, such as the role of energy balance in intestinal protein supply. Both models provide equations to predict nutrient supply from a feedstuff to dairy cattle in terms of 1) digestible true protein escaping rumen degradation; 2) digestible true microbial protein synthesized in the rumen, and 3) endogenous protein in the digestive tract. Both models can also estimate the rumen degraded protein balance value of feeds, which considers the balance between microbial protein synthesis potentially possible from available rumen degradable protein and that potentially possible from the energy extracted during anaerobic fermentation in the rumen. Although the principles of these two models are similar, some of the factors used in quantifying calculations and some concepts differ. For example, in the DVE/OEB system, 150 g of microbial protein CP is assumed to be synthesized per kg fermented OM. But in the NRC-2001 model, it is assumed that 130 g of microbial protein CP is synthesized per kg TDN.

Comparison of the NRC-2001 model with the Dutch system (DVE/OEB) in the prediction of nutrient supply to dairy cows from forages has been made and published in Journal of Dairy Science (Yu et al., 2003). The objective of this study was to use the DVE/OEB system and the NRC-2001 model to predict potential nutrient supply to dairy cows from the heat processed field tick beans, which is one of three major legume seeds in Australia. The field tick beans have been systematically investigated previously on the effects of roasting at various temperatures (110, 130 or 150°C) and times (15, 30 or 45 min) on chemical composition, *in situ* rumen degradation characteristics , ADG and feed efficiency (Yu, 1999; Yu et al., 2002).

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MATERIALS AND METHODS

Field tick bean and technological treatment

The Field tick beans were roasted at 3 different temperatures (110, 130, 150°C) for 15, 30 and 45 min, which result in 10 treatments which were the control, T1 (110/15), T2 (110/30), T3 (110/45), T4 (130/15), T5 (130/30), T6 (130/45), T7 (150/15), T8 (150/30), and T9 (150/45) (Yu, 1999). The chemical compositions are presented in Table 1.

Estimation of total digestible nutrient and energy values

Based on chemical composition data in Table 1 (Yu, 1999), a summative approach was used to derive the total digestible nutrient (TDN_{1x}) (NRC, 2001). In this approach, the concentrations (%DM) of truly digestible nonfiber carbohydrate, crude protein (CP), NDF and fat acid (FA) were estimated (Weiss et al., 1992) according to the equations in the NRC dairy model (2001). The energy values of DE_{3X}, ME_{3X}, NE_{L3X} (standing for Digestible, Metabolizable and Net energy for lactation at production level of intake (3X) estimated from NRC dairy model 2001, respectively) were estimated using summative approach from the NRC dairy (NRC, 2001) and of ME, NE_m and NE_g were estimated from the NRC beef (NRC, 1996).

The DVE/OEB system

Calculation of FOM and RUP^{DEV} : Bypassing rumen

Table 1. Chemical composition, *in situ* rumen degradation characteristics and energy value of processed field tick bean[1]

Treatment[2]	Control	T1	T2	T3	T4	T5	T6	T7	T8	T9
Chemical composition	---------------------(g/kg DM)---------------------									
DM (g/kg)	885.9	895.6	900.7	910.2	919.0	920.6	923.4	924.1	935.3	941.0
Ash	34.7	34.2	33.8	33.4	33.7	34.2	34.4	35.2	34.0	34.2
CP	317.3	317.5	319.9	318.8	323.1	324.2	318.2	322.0	320.4	310.4
EE	20.4	19.9	18.7	17.1	18.2	16.3	16.0	16.2	14.6	14.0
CHO	627.6	628.4	627.6	630.7	625.0	625.2	631.4	626.6	631.1	641.4
Starch	411.0	415.1	412.1	420.5	404.5	402.1	407.7	401.2	395.1	400.7
ADF	90.4	96.8	99.5	95.5	90.6	88.7	84.7	99.2	88.2	99.8
NDF	195.0	216.3	196.5	191.7	190.0	196.8	208.6	257.9	309.1	440.2
Hemicellulose	104.6	119.5	97.0	96.2	99.4	108.1	123.9	158.7	220.8	340.4
Lignin	4.5	6.3	3.2	6.2	5.8	6.6	5.5	4.9	5.7	5.9
ADIN (g/kg N)	11.2	11.1	10.9	11.2	10.7	10.7	11.4	10.8	10.6	10.6
NDIN (g/kg N)	59.3	64.9	62.8	58.1	63.6	70.6	85.4	97.1	137.4	296.7
Ratio (NDIN/ADIN)	5.3	5.9	5.8	5.2	5.9	6.6	7.5	9.0	13.0	28.0
In situ rumen degradation characteristics of crude protein (by the Øskov model)										
S (%)	49.0	57.6	56.1	55.1	45.0	47.1	41.7	36.3	35.7	26.3
D (%)	50.7	42.1	43.3	44.3	54.7	52.6	58.3	63.6	64.3	73.7
U (%)	0.2	0.3	0.6	0.7	0.3	0.3	0.0	0.1	0.0	0.0
Kd (%/h)	21.44	23.49	24.22	22.71	20.70	19.38	15.99	16.71	10.42	4.26
RUP (%)	11.3	8.9	9.2	9.9	12.5	12.8	15.9	16.9	23.5	43.1
RDP (%)	88.7	91.1	90.8	90.1	87.5	87.2	84.1	83.1	76.5	56.9
In situ rumen degradation characteristics of starch (by the DVE/OEB system)										
S (%)	50.1	53.7	52.0	52.5	42.4	40.5	36.1	30.8	25.5	18.2
D (%)	49.9	46.3	48.1	47.6	57.6	59.5	63.9	69.2	74.5	81.8
Kd (%/h)	9.82	9.88	10.97	10.96	10.14	10.03	9.04	8.54	7.05	4.21
RUST (%)	23.9	22.9	22.2	22.1	25.6	26.3	29.1	31.6	36.8	49.9
RUST (g/kg DM)	98.4	94.9	91.4	92.8	103.7	105.8	118.7	126.9	145.4	200.0
RDST (%)	76.1	77.1	77.8	77.9	74.4	73.7	70.9	68.4	63.2	50.1
RDST (g/kg DM)	312.6	320.2	320.7	327.7	300.7	296.3	289.0	274.3	249.7	200.8
Energy value[3]										
TDN_{1X} (g/kg DM)	827.7	817.3	828.4	820.5	823.7	818.1	817.5	807.3	794.7	772.8
	---------------------(Mcal/kg DM)---------------------									
DE_{3X} (NRC 2001 dairy)	3.59	3.55	3.60	3.56	3.58	3.56	3.55	3.52	3.47	3.37
ME_{3X} (NRC-2001 dairy)	3.17	3.13	3.18	3.15	3.17	3.15	3.14	3.10	3.05	2.95
NE_{L3X} (NRC-2001 dairy)	2.04	2.01	2.05	2.02	2.04	2.02	2.01	1.99	1.95	1.89
ME (NRC-1996 beef)	3.20	3.17	3.21	3.18	3.20	3.18	3.17	3.14	3.09	3.01
NE_m (NRC-1996 beef)	2.20	2.17	2.20	2.18	2.19	2.18	2.17	2.15	2.11	2.04
NE_g (NRC-1996 beef)	1.52	1.49	1.52	1.50	1.51	1.50	1.49	1.47	1.44	1.38

[1] Data source from Yu (1999).

[2] T1-T9 were treatments of field tick bean roasted at the temperature of 110, 130 or 150°C for 15, 30 or 45 min, respectively, which were T1 (110/15), T2 (110/30), T3 (110/45), T4 (130/15), T5 (130/30), T6 (130/45), T7 (150/15), T8 (150/30) and T9 (150/45).

[3] TDN_{1X} and energy value were estimated according to equations in NRC (2001) based on chemical composition data.

microbial degradation of feed protein (RUP^{DEV}) was calculated as: RUP^{DEV} (g/kg DM)=1.11×CP (g/kg DM)×% RUP. The factor 1.11 was taken from the French PDI-system (Verite et al., 1987). The content of OM fermented in the rumen (FOM) was calculated as: FOM (g/kg DM)=DOM-EE-RUP-FP, where, digested OM (DOM), EE, and RUP in g/kg DM; FP: Fermentation products for conserved forages (g/kg DM) (assumed to be zero for field tick beans).

Microbial protein synthesis in the rumen : Microbial protein synthesized in the rumen based on rumen fermented organic matter (MCP_{FOM}) was estimated as: MCP_{FOM} (g/kg DM)=0.15×FOM. The factor 0.15 means that per kg FOM, 150 g of microbial protein CP was assumed to be synthesized (Tamminga et al., 1994).

The content of true protein supplied to the small intestine (TPSI) was calculated as: TPSI (g/kg DM)=RUP^{DEV}+0.75×MCP_{FOM}, where, the factor 0.75 means that 75% of microbial N was present in amino acids with the remaining N originating from in nucleic acids.

Intestinal digestion of feed and microbial protein

The previously discussed RUP^{DEV} and TPSI must be corrected for incomplete digestion and endogenous secretions. A correction was needed for protein losses due to incomplete digestion and from endogenous secretions. True digestibility of microbial protein was assumed to be 85% (Egan et al., 1985) and therefore the amount of truly absorbed rumen synthesized microbial protein in the small intestine ($AMCP^{DVE}$) was estimated as: $AMCP^{DVE}$ (g/kg DM)=0.85×0.75×MCP_{FOM}. For feed ingredients, the content of truly absorbed bypass feed protein in the small intestine ($ARUP^{DVE}$) was calculated as: $ARUP^{DVE}$ (g/kg DM)=% dRUP×RUP^{DVE}.

Endogenous protein losses in the small intestine

The endogenous protein losses in the digestive tract (ENDP) are related to the amount of undigested DM (UDM) excreted in the feaces. According to the DVE/OEB system, 75 g of absorbed protein per kg undigested DM in fecal excretion was required to compensate for the endogenous losses. Therefore endogenous protein losses in the digestive tract are estimated as: ENDP (g/kg DM)=75×undigested DM (UDM, g/kg DM), where, UDM= UOM+undigested inorganic matter (UASH), where, UOM= OM×(100-% dOM), and UASH=ASH×% 50 (CVB, 1996).

Truly digested and absorbed protein in the small intestine

Truly digested and absorbed protein in the small intestine (DVE value) are contributed by 1) feed protein escaping rumen degradation (RUP^{DVE}), 2) microbial protein synthesized in the rumen (MCP_{FOM}), and 3) a correction for endogenous protein losses in the digestive tract (ENDP). Therefore the DVE value was estimated as: DVE (g/kg DM)=$ARUP^{DVE}$+$AMCP_{FOM}$-ENDP.

Degraded protein balance

The degraded protein balance was balance between microbial protein synthesis from rumen degradable CP and that from the energy extracted during anaerobic fermentation in the rumen. Therefore the DPB^{OEB} value (g/kg DM) was estimated as: $MCP_{RDP}{}^{DVE}$-MCP_{FOM}, where, $MCP_{RDP}{}^{DVE}$=CP-1.11×% RUP. When the Degraded Protein Balance is positive, it indicates the potential loss of N from the rumen. When negative, microbial protein synthesis may be impaired, because of a shortage of N in the rumen. The optimum value of the DPB^{OEB} in a ration is therefore zero or slightly above (Tamminga et al., 1994).

The NRC-2001 model

Calculation of RDP^{NRC} and RUP^{NRC} : The ruminally undegraded feed CP was calculated as: RUP^{NRC} (g/kg DM)=CP×% RUP; the rumen degraded feed protein was calculated as: RDP^{NRC}=CP×% RDP, where, a Kp was 6%/h..

Rumen microbial protein synthesis : Ruminally synthesized microbial CP was calculated as: MCP^{NRC} (g/kg DM)=0.13×TDN, when RDP^{NRC} exceeded 1.18×TDN-predicted MCP (MCP_{TDN}). When RDP^{NRC} was less than 1.18×TDN-predicted MCP (MCP_{TDN}), then MCP^{NRC} was calculated as 0.85 of RDP^{NRC} (MCP_{RDP}). The factor 0.13 means that per kg TDN, 130 g of microbial protein CP is assumed to be synthesized.

Intestinal digestion of feed and microbial protein : Digestibility and true protein of ruminally synthesized microbial CP are assumed to be 80%, therefore the amount of truly absorbed MCP^{NRC} was estimated as: $AMCP^{NRC}$ (g/kg DM)=0.80×0.80×MCP^{NRC}.

For feed ingredients, truly absorbed rumen undegraded feed protein in the small intestine ($ARUP^{NRC}$) was calculated as: $ARUP^{NRC}$ (g/kg DM)=% dRUP×RUP^{NRC}.

Rumen endogenous protein in the small intestine : Rumen endogenous CP (g/kg DM) according to the NRC model (2001) can be calculated as: ECP (g/kg DM)=6.25×1.9×DM (g/kg). Assuming that 50% of rumen endogenous CP passes to the duodenum and 80% of rumen endogenous CP is true protein (NRC, 2001), the truly absorbed endogenous protein in the small intestine (AECP) was estimated as: AECP (g/kg DM)=0.50×0.80×ECP.

Total metabolizable protein : Metabolizable protein in the NRC dairy model (NRC, 2001) is contributed by 1) digestible RUP^{NRC}, 2) digestible MCP^{NRC}, and 3) ECP, calculated as: MP (g/kg DM)=$ARUP^{NRC}$+$AMCP^{NRC}$+AECP.

Degraded protein balance : Based on the data from the NRC dairy model (NRC, 2001), the degraded protein balance (DPB^{NRC}, g/kg DM) can be calculated. It reflects the difference between the potential microbial protein synthesis based on ruminally degraded feed crude protein (RDP^{NRC}) and that based on energy (TDN) available for microbial fermentation in the rumen, calculated as: RDP-1.18 MCP_{TDN}, where, the DPB^{NRC} value is in g/kg DM.

Statistical analysis

The PROC CORR and PROC REG (SAS, 1991) was used for linear correlation and regression analysis between predicted values from the DVE/OEB system and the NRC-2001 model (MCP_{FOM} vs. MCP_{TDN}; MCP_{RDP}^{DVE} vs. MCP_{RDP}^{NRC}; DVE vs. MP; and DPB^{OEB} vs. DPB^{NRC}. Linear regression equation and residual standard deviation are presented.

RESULTS AND DISCUSSION

Chemical composition, *in situ* rumen degradation characteristics and energy value of the processed field tick beans

Chemical composition and *in situ* rumen degradation characteristics of CP and starch have been reported (Table 1) (Yu, 1999). Based on the basic data (Table 1) (Yu, 1999), a summative approach was used to derive the TDN_{1X} value (NRC, 2001). In this approach, the concentrations of truly digestible non-fiber carbohydrate (tfNFC), CP (tfCP), fat acid (tfFA) and NDF (tfNDF) for each treatment were estimated from Weiss's equations (Weiss et al., 1992). The result show that with increase temperature and times, the predicted TDN_{1X} and energy values were generally decreased (Table 1). Compared with the control, the TDN_{1X}, DE_{3X}, ME_{3X}, NEL_{3X}, ME, NE_m and NE_g values of the treatment of 150°C for 45 min were decreased by 6.6, 6.1, 6.9, 7.4, 5.9, 7.3 and 9.2%, respectively.

Prediction of nutrient supply to ruminants using the DVE/OEB system

Using the DVE/OEB system, the nutrient supply to dairy cows from processed field tick beans are presented in Table II. The most important values are DVE (=AMCP+ ARUP-ENDP) and the DPB^{OEB} values. The DVE value was generally increased from 109.7 to 197.2 g/kg DM (1.8 times) and DPB^{OEB} value was generally decreased from 157.3 to 71.8 g/kg DM (2.2 times). The increased DEV value was mainly due to highly increasing absorbed RUP in the intestine although the absorbed MCP was decreased (Table 2). The predicted DPB^{OEB} value was highly reduced but was not to the level of negative in the heated treatments (Table 2). This indicated that potential microbial protein

Table 2. Using the Dutch DVE/OEB system to predict the potential nutrient supply to dairy cattle from the processed field tick bean[1]

Treatments[2]	Control	T1	T2	T3	T4	T5	T6	T7	T8	T9
Truly digested and absorbed rumen synthesized microbial protein in the small intestine (g/kg DM)										
FOM	801.0	813.6	819.5	818.3	795.9	795.0	771.2	758.2	718.1	600.6
RDP^{DVE}	277.4	286.2	287.4	283.7	278.1	278.3	262.0	261.5	236.8	161.9
MCP_{RDP}^{DVE}	277.4	286.2	287.4	283.7	278.1	278.3	262.0	261.5	236.8	161.9
MCP_{FOM}	120.1	122.0	122.9	122.7	119.4	119.3	115.7	113.7	107.7	90.1
$AMCP^{DVE}$	76.6	77.8	78.4	78.3	76.1	76.0	73.7	72.5	68.7	57.4
Truly digested and absorbed rumen undegraded protein in the small intestine (g/kg DM)										
TPSI	130.0	122.8	124.7	127.1	134.5	135.3	143.0	145.8	164.3	216.0
RUP^{DVE}	39.9	31.3	32.5	35.1	45.0	45.9	56.2	60.5	83.6	148.5
dRUP (%)	87.4	86.1	87.2	89.0	88.3	88.9	88.8	89.2	91.8	95.1
$ARUP^{DVE}$	34.9	26.9	28.3	31.2	39.7	40.8	49.9	53.9	76.7	141.3
Endogenous protein losses in the digestive tract (g/kg DM										
DOM	959.7	959.6	962.1	963.3	962.8	963.1	962.1	961.8	961.6	963.1
UOM	5.6	6.2	4.1	3.3	3.5	2.7	3.6	3.0	4.4	2.7
UAsh	17.4	17.1	16.9	16.7	16.9	17.1	17.2	17.6	17.0	17.1
UDM	23.0	23.3	21.0	20.0	20.3	19.8	20.8	20.6	21.4	19.8
ENDP	1.7	1.7	1.6	1.5	1.5	1.5	1.6	1.5	1.6	1.5
Total truly digested and absorbed protein in the small intestine (g/kg DM)										
DVE[3]	109.7	103.0	105.1	108.0	114.3	115.3	122.1	124.9	143.7	197.2
Degraded protein balance in the DVE/OEB-system (g/kg DM)										
DPB^{OEB} [4]	157.3	164.2	164.5	161.0	158.7	159.1	146.3	147.8	129.1	71.8

[1] The potential nutrient supply to dairy cattle was predicted using the Dutch DVE/OEB system based on the our basic data in Yu (1999).

[2] T1-T9 were treatments of field tick bean roasted at the temperature of 110, 130, or 150°C for 15, 30 or 45 min, respectively, which were T1 (110/15), T2 (110/30), T3 (110/45), T4 (130/15), T5 (130/30), T6 (130/45), T7 (150/15), T8 (150/30), and T9 (150/45).

[3] DVE=truly digested and absorbed protein in the small intestine (g/kg DM), contributed by 1) feed protein escaping rumen degradation (RUP^{DVE}), 2) microbial protein synthesized in the rumen (MCP_{FOM}), and 3) a correction for endogenous protein losses in the digestive tract (ENDP), calculated as: DVE=$ARUP^{DVE}$+$AMCP^{DVE}$-ENDP (DVE/OEB system: Tamminga et al., 1994).

[4] Degraded protein $balance^{OEB}$ (g/kg DM), reflecting the difference between the potential microbial protein synthesis based on degraded feed crude protein and that based on energy available for microbial fermentation in the rumen, calculated as: MCP_{RDP}^{DVE}-MCP_{FOM} (DVE/OEB-system: Tamminga et al., 1994).

synthesis might not be impaired due to the sufficient N supplied in the rumen, but the high positive DPB^{OEB} values in the most treatments except of 150°C for 45 min indicated that there was still the large amount of N loss in the rumen. In term of achieving target values for potential high net absorbable protein in the small intestine while holding any N loss in the rumen to a low level, the treatment of 150°C for 45 min was the best among the treatments.

Prediction of nutrient supply to ruminants using the NRC-2001 model

Using the NRC-2001 model, the nutrient supply to dairy cows from processed field tick beans are presented in Table 3. Results show that total MP, contributed from $AMCP^{NRC}$, $ARUP^{NRC}$, and AECP, was generally increased (from 98.9 to 190.8 g/kg DM) and the predicted DPB^{NRC} was highly decreased (from 164.7 to 67.8 g/kg DM).

Comparison of predictions from the DVE/OEB system and the NRC-2001 model

The linear relationship of the predicted nutrient supply from processed field tick bean, using the DVE/OEB system and the NRC-2001 model, in terms of 1) potential microbial protein supply based on available energy and ruminally degraded feed protein, 2) total truly absorbed protein in the small intestine, and 3) degraded protein balance, are presented in Table 4.

Using the DVE/OEB system, the overall mean for microbial protein supply based on energy, or based on ruminally degraded protein were higher (+18 and +34 g/kg DM, respectively), the total absorbed protein in the small intestine was higher (+11 g/kg DM), but the degraded protein balance values were lower (-7 g/kg DM) in comparison to that predicted by the NRC-2001 dairy model.

Linear regression of the predicted nutritional values between the DVE/OEB system and the NRC-2001 model for the processed field tick beans are as follow:

$MCP_{FOM}=4.71\times MCP_{TDN}-341.3$,
where, $R^2=0.9251$, $p<0.0001$, RSD=2.92.

$MCP_{RDP}^{DVE}=1.30\times MCP_{RDP}^{NRC}-32.80$,
where, $R^2=0.9999$, $p<0.0001$, RSD=0.32.

$DVE=0.94\times MP-17.30$,
where, $R^2=0.9996$, $p<0.0001$, RSD=0.53.

$DPB^{DVE}=0.87\times DPB^{NRC}-13.18$,
where, $R^2=0.9994$, $p<0.0001$, RSD=0.76.

The principles of the two models for predicting metabalizable protein value are similar. However, some concepts and factors used for calculation of data are different, such as RUP and endogenous protein, MCP `(based on available N and based on available energy TDN or FOM), absorbed MCP. All contribute to the differences

Table 3. Using the NRC-2001 model to predict the nutrient supply to dairy cattle from the processed field tick bean[1]

Treatments[2]	Control	T1	T2	T3	T4	T5	T6	T7	T8	T9
Truly digested and absorbed rumen synthesized microbial protein in the small intestine (g/kg DM)										
TDN_{1x} (%DM)	76.01	75.05	76.08	75.36	75.64	75.13	75.07	74.14	72.98	70.98
MCP_{TDN}	98.8	97.6	98.9	98.0	98.3	97.7	97.6	96.4	94.9	92.3
RDP^{NRC}	281.4	289.3	290.6	287.2	282.5	282.9	267.6	267.5	245.1	176.6
MCP_{RDP}^{NRC}	239.1	245.9	247.0	244.1	240.1	240.5	227.4	227.4	208.3	150.1
MCP^{NRC}	98.8	97.6	98.9	98.0	98.3	97.7	97.6	96.4	94.9	92.3
$AMCP^{NRC}$	63.2	62.4	63.3	62.7	62.9	62.5	62.5	61.7	60.7	59.1
Truly digested and absorbed rumen undegraded protein in the small intestine (g/kg DM)										
RUP^{NRC}	36.0	28.2	29.3	31.6	40.5	41.3	50.6	54.5	75.3	133.8
$ARUP^{NRC}$	31.4	24.2	25.5	28.1	35.8	36.8	45.0	48.6	69.1	127.3
Truly digested rumen endogenous protein in the small intestine (g/kg DM)										
ECP	10.5	10.6	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.2
AECP	4.2	4.3	4.3	4.3	4.4	4.4	4.4	4.4	4.4	4.5
Total truly digested and absorbed protein in the small intestine (g/kg DM)										
MP[3]	98.9	90.9	93.1	95.1	103.1	103.6	111.8	114.7	134.2	190.8
Degraded protein balance in the NRC-2001 (g/kg DM)										
DPB^{NRC} [4]	164.7	174.2	173.9	171.6	166.5	167.6	152.4	153.8	133.1	67.8

[1] The potential nutrient supply to dairy cattle was predicted using the NRC-2001 model based on the our previous basic data in Yu (1999).

[2] T1-T9 were treatments of field tick bean roasted at the temperature of 110, 130 or 150°C for 15, 30 or 45 min, respectively, which were T1 (110/15), T2 (110/30), T3 (110/45), T4 (130/15), T5 (130/30), T6 (130/45), T7 (150/15), T8 (150/30) and T9 (150/45).

[3] MP=metabolizable protein, defined as the true protein that is digested postruminally and the component AA absorbed by the intestine) contributed by 1) ruminally undegraded feed crude protein (RUP^{NRC}), 2) ruminally synthesized microbial crude protein (MCP^{NRC}) and 3) endogenous CP (ECP), calculated as: $MP=ARUP^{NRC}+AMCP^{NRC}+AECP$ (NRC, 2001).

[4] Degraded protein balance ^{NRC} (g/kg DM) reflecting the difference between the potential microbial protein synthesis based on ruminally degraded feed crude protein (RDP^{NRC}) and that based on energy (available TDN) available for microbial fermentation in the rumen, calculated as: $RDP^{NRC}-1.18\ MCP_{TDN}$ (NRC, 2001).

Table 4. Comparison of the NRC-2001 Model with the DVE/OEB system in the prediction of nutrient supply to dairy cows from the relationship of the predicted nutrient supply from processed field tick bean, using the DVE/OEB system and the NRC-2001 model, in terms of 1) potential microbial protein supply based on available energy and ruminally degraded feed protein, 2) total truly absorbed protein in the small intestine, and 3) degraded protein balance

Items	Overall mean	Linear Regression			
		Equation (Y=a (±SE)×X+b (±SE)	R square	RSD[1]	P
Microbial protein supply based on available energy (g/kg DM)					
MCP_{FOM} (±SD)	115.4±10.1				
Range	97.0-122.9				
MCP_{TDN} (±SD)	97.0±2.1	MCP_{FOM}=4.71 (±0.47)×MCP_{TDN}-341.3 (±45.96)	0.9251	2.92	<0.0001
Range	92.3-98.9				
Microbial protein supply based on ruminally degraded feed protein (g/kg DM)					
MCP_{RDP}^{DVE} (±SD)	261.4±38.2				
Range	161.9-287.4				
MCP_{RDP}^{NRC} (±SD)	227.0±29.5	MCP_{RDP}^{DVE}=1.30 (±0.004)×MCP_{RDP}^{NRC}-32.80 (±0.82)	0.9999	0.32	<0.0001
Range	150.1-247.0				
Truly absorbed protein (g/kg DM) in the intestine					
DVE (±SD)	124.3±28.2				
Range	103.0-197.2				
MP (±SD)	113.6±30.0	DVE=0.94(±0.006)×MP-17.30 (±0.70)	0.9996	0.53	<0.0001
Range	90.9-190.8				
Degraded protein balance (g/kg DM)					
DPB^{OEB} (±SD)	146.0±28.2				
Range	71.8-164.5				
DPB^{NRC} (±SD)	152.6±32.4	DPB^{DVE}=0.87(±0.008)×DPB^{NRC}-13.18 (±1.21)	0.9994	0.76	<0.0001
Range	67.8-174.2				

[1] RSD=Residual standard deviation.

between the two models in prediction of amount of total truly absorbed protein in the small intestine (DVE vs. MP) (Yu et al., 2003).

In this study, using the DVE/OEB system, the overall average microbial protein supply based on available energy-rumen FOM was 16% higher, microbial protein supply based on ruminally degraded feed protein was 13% higher, and the truly absorbed protein in the small intestine was 9% higher than that predicted by the NRC-2001 model. The difference was also found in the prediction of the degraded protein balance, which was 5% lower than that based on the data from the NRC-2001 model. These differences are due to the factors used in quantifying calculations rather than the difference in principles upon which the two systems are based. The most important outputs (net results), the DVE in the DVE/OEB system vs. the MP in the NRC-2001 model, were 11 g/kg DM difference on average. However, the comparisons were based on the predicted values from the processed tick beans. The full comparison involving various types of concentrate feeds between the two models will be investigated.

CONCLUSIONS

The predicted protein values of the processed field tick bean from the DVE/OEB system and the NRC-2001 model had significant correlations with high R values (>0.90). However, using the DVE/OEB system, the microbial protein supply based on available energy was 16% higher, the degraded protein balance was 5% lower, and total truly absorbed protein in the small intestine was 9% higher than that predicted using the NRC-2001 model. However, this comparison was based on the limited data, the full comparison involving various types of concentrate feeds will be investigated in the future

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