Protein Evaluation of Dry Roasted Whole Faba Bean (*Vicia faba*) and Lupin Seeds (*Lupinus albus*) by the New Dutch Protein Evaluation System: the DVE/OEB System

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ABSTRACT : The effects of dry roasting (110, 130, 150℃ for 15, 30, 45 min) on potential ruminant protein nutritional values in terms of: a), rumen bypass protein (BCP); b), rumen bypass starch (BST); c), fermented organic matter (FOM); d), true absorbed bypass protein (ABCP); e) microbial protein synthesized in the rumen based on available energy (E_MP); f), microbial protein synthesized in the rumen based on available nitrogen (N_MP); g), true protein supplied to the small intestine (TPSI); h), true absorbed rumen synthesized microbial protein (AMP); i), endogenous protein losses (ENDP); j), true digested protein in the small intestine (DVE); k), degraded protein balance (OEB) of whole lupin seeds (WLS) and faba beans (WFB) were evaluated by the new Dutch DVE/OEB protein evaluation system. Dry roasting significantly increased BCP, BST, TPSI, ABCP, DVE ($p<0.001$) and decreased FOM, E_MP, AMP, N_MP and OEB ($p<0.001$) with increasing temperatures and times except that when temperature was at 110℃. The values of BCP, BST, TPSI, ABCP and DVE at 150℃/45 min for WLS and WFB were increased 2.2, 3.7; -, 2.0; 1.7, 1.7; 2.3, 3.7 and 1.7, 1.7 times and the values of FOM, E_MP, AMP, N_MP and OEB at 150℃/45 min for WLS and WFB were decreased by 15.3, 25.8; 18.1, 25.8; 18.7, 25.8; 54.6, 41.6 and 82.3%, 54.7%, respectively, over the raw WLS and WFB. The results indicated that though dry roasting reduced microbial protein synthesis due to reducing FOM, TPSI didn't decrease but highly increased due to increasing BCP more than enough for compensation of the microbial protein decreasing. Therefore the net absorbable DVE in the small intestine was highly increased. The OEB values were significantly reduced for both WLS and WFB but not to the level of negative. It indicated that microbial protein synthesis might not be impaired due to the sufficient N supplied in the rumen, but the high positive OEB values in the most treatments except of 150℃ for 30 and 45 min of WLS (The OEB values: 54.8 and 26.0 g/kg DM) indicated that there were the large amounts of N loss in the rumen. It was concluded that dry roasting at high temperature was effective in shifting protein degradation from rumen to intestines and it increased the DVE values without reaching the negative OEB values. No optimal treatment was found in WLS due to the too high OEB values in all treatments. But dry roasting at 150℃ for 30 and 45 min might be optimal treatments for WLS due to the very lower OEB values. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 6 : 871-880)*

Key Words : Protein Evaluation, DVE, OEB, Faba Bean, Lupin Seeds, Dry Roasting, Cows

INTRODUCTION

Whole lupin (*Lupinus albus*) seeds (WLS) and whole faba (*Vicia faba*) beans (WFB) with high protein contents appear to be the protein sources as a potential use as protein supplements in ruminal diets. The CP contents of WFB and WLS were 281.2 (Yu, 1998a) and 388.8 g/kg DM (Yu, 1998b).

But their rapidly extensive microbial degradation, resulting in imbalance between feed breakdown and microbial protein synthesis and causing unnecessary N-loss from rumen, make them in unsuitable to be used in the unprocessed form in ruminal diets. The protein degradability of WFB and WLS were 89% (Yu, 1996) and 95% (Cros, 1991). Thus there were no more protein left in the rumen bypassing to the small intestine. But the protein becomes available to the animal only after digestion in and absorption from the small intestine (Hvelplund, 1992).

Dry roasting reduced the rumen protein degradation and increased rumen bypass protein with increasing temperature and time (Yu, 1998a). But the optimal heating conditions have not been found for such legume seeds and the total evaluation of protein of such feeds after dry roasting (e.g. total absorbable protein (DVE) in the small intestine and degraded protein balance (OEB) have not been done yet).

The Dutch new protein evaluation system: the DVE/OEB system (Tamminga, 1994) developed recently can give such information on the quantitative aspects of both ruminal and post-ruminal feed protein digestion in ruminants. The basic concept of the system is that protein supply is estimated as the amount of protein absorbed from the small intestine, and which is the sum of feed protein bypassing degradation in the rumen and microbial protein formed and subsequently released to the lower tract, both corrected with an appropriate factor for intestinal digestion (van Straalen, 1994).

The OEB value shows the imbalance between microbial protein synthesis potential possible from

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available rumen degradable CP (N_MP) and that potential possible from the energy extracted during anaerobic fermentation in the rumen (E_MP). When OEB is positive, it indicates the 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 OEB value in a ration is therefore zero or slightly above (Tamminga, 1993).

The objectives of this study were to use the advanced protein evaluation system: the DVE/OEB system to totally evaluate the effects of dry roasting on WLS and WFB in terms of: a), rumen degradation characteristics (RDC) and the rumen bypassing degradation protein (BCP) and starch (BST); b), fermented organic matter (FOM); c), microbial protein synthesized in the rumen based on available energy (E_MP) and that based on nitrogen (N_MP); d), true protein supplied to the small intestine (TPSI); e), absorbable microbial protein (AMP); f), endogenous protein (ENDP); g), absorbable rumen bypass feed protein (ABCP); h), feed rumen degradation production; i), the DVE values, and j), the OEB values to give the quantitative aspects of how the dry roasting affected the protein degradation and digestion in detail and to give information for ration formula and the decision for the optimal treatment conditions in dairy industry.

Table 1. List of abbreviations

ABCP	: True absorbed bypass protein in the small intestine
AMP	: Truly absorbed rumen synthesized microbial protein in the small intestine
BCP	: Bypassing rumen microbial degradation of feed protein (BCP)
%BCP	: Fraction of bypassing rumen degradation of protein
BST	: Bypassing rumen microbial fermentation of feed starch (BST)
%BST	: Fraction of bypassing rumen degradation of starch
CFAT	: Crude fat
D	: Insoluble but potential degradable fraction in the in sacco incubations
dASH	: Digestibility of inorganic matter
dBCP	: Digestibility of bypass protein in the small intestine
DOM	: Digested organic matter
DVE	: True digested protein in the small intestine
ENDP	: Endogenous protein losses in digestion
FOM	: Organic matter fermented in the rumen
FP	: Fermentation products
Kd	: The rate of degradation of D fraction
Kp	: Passage rate
E_MP	: Microbial protein synthesized in the rumen based on available energy
N_MP	: Microbial protein synthesized in the rumen based on available nitrogen
OEB	: Degraded protein balance
RDC	: Rumen degradation characteristics
RWFB	: Raw whole faba beans
RWLS	: Raw whole lupin seeds
S	: Soluble fraction in the in sacco incubations
T0	: Lag time in which no degradation takes place
TPSI	: True protein supplied to the small intestine
U	: Undegradable fraction in the in sacco incubations
UASH	: Undigested inorganic matter
UDM	: Undigested dry matter
UOM	: Undigested organic matter
WFB	: Whole faba beans
WLS	: Whole lupin seeds

MATERIALS AND METHODS

Feedstuffs

WFB and WLS were obtained from a commercial feed company (Peter Gibbs Stock Feeds in Australia).

Technological treatments

RWFB and RWLS were dry roasted at 3 different temperatures (110, 130, 150℃) for 15, 30 and 45 min in a complete block design (with A and B series for WLS) as shown in table 2. The A, B series were used to test whether the conditions of dry roasting

Table 2. Treatments and the dry roasting conditions of WFB and WLS

Temp. (℃)	Time (min)	Dry Roasting					
		Temp. (℃)	SD	Temp. (℃)	SD	Temp. (℃)	SD
Raw		RWFB (control)		RWLS, A (control)		RWLS, B (control)	
110	15	110.0	0.0	110.0	1.0	111.0	1.0
110	30	111.3	1.2	109.5	0.5	111.0	0.0
110	45	110.9	1.6	109.5	0.5	111.0	1.0
130	15	130.0	0.0	129.5	0.5	130.0	0.0
130	30	129.8	0.5	130.0	0.0	130.5	0.5
130	45	130.0	0.0	131.0	1.0	130.5	0.5
150	15	149.5	0.7	150.0	0.0	150.0	0.0
150	30	150.0	0.0	149.5	0.5	150.0	0.0
150	45	150.0	0.0	149.5	0.5	150.0	0.0

Note: Each treatment was measured at least 5 times.

were kept constantly and reliable.

RWFB and RWLS were used as controls. For each treatment, about 1.5 kg was roasted in a lab oven (Qualtex Solidstat. universal series 2,000 designed in Australia by Watson Victor LTD). The conditions of processing are shown in table 2. After roasting, the samples were allowed to cool down to ambient temperature and were ground through a 3 mm screen (Hammer mill AEG TYP AM80N*2).

Animal and diets

Measuring RDC and rumen degradability by *in sacco* method for WFB and WLS were carried out in different dairy research centers and used different dairy cows.

For WFB rumen incubation, six dry Holstein-Friesian cows, of average weight 620 kg previously equipped with a rumen cannula with an internal diameter of 10 cm (Silicon rubbers, handmade, Kyabram Dairy Center, Victoria, Australia) were used at Kyabram Dairy Center (Victoria, Australia) in the feedlot. All these cows received a diet consisting of 3.5 kg/day commercial pelleted concentrate (Barastoc Hi-LAC-Hi-E Dairy Pellets, Ridley Agriproducts PTY. LTD), chemical analysis of which are shown in table 3 and 5.4 kg/day (83.7% DM) sub-clover hay (from Goulburn Valley, Australia).

Table 3. The chemical analysis* of commercial pelleted concentrate of dairy cows

Composition	Content (%)
DM	87.6
CP	12.0
Non protein N	1.3
Urea	0.5
CFAT	2.0
Crude fibre	15.0
Added salt	1.0
Fluorine	0.02
Vitamin A (IU/kg)	6,000
Vitamin D_3 (IU/kg)	500

* The date provided by manufacturer, Ridley Agriproducts PTY. LTD, except DM content.

Water was always available. The cows were individually fed twice daily at 08:00 and 16:00, 2.7 kg sub-clover and 1.75 kg pellets. The feeding level was according to the dairy cow requirements calculated by Rumnut 3.3 (Dept. of Agriculture, Reading University, UK). A 12 day period of adaptation was allowed.

For WLS rumen incubation, six dry Holstein Friesian cows (table 4), of average weight 580 Kg previously equipped with a rumen cannula with an internal diameter of 10 cm were group-fed in the grass land of Ellinbank Dairy Center. The cows received a diet consisting of crushed barley and oaten hay, chemical analysis of which are shown in table 5. Water was always available. The cows were fed twice daily at 08:30 and 16:30. A two week period of adaptation was allowed.

Table 5. The chemical analysis of crushed barley and oaten hay

Composition	Barley	Oaten hay
DM (%)	89.5	85.0
NIRSa, CP (%)	14.6	5.2
Ash (%)	2.6	-
NDF (%)	20.0	63
Total P (%)	0.28	-
Total K (%)	0.58	-
Total S (%)	0.13	-
Total Na (%)	0.04	-
Total Ca (%)	0.04	-
Total Mg (%)	0.12	-
Total B (mg/kg)	3	-
Total Fe (mg/kg)	82	-
Total Mn (mg/kg)	16	-
Total Cu (mg/kg)	5	-
Total Zn (mg/kg)	15	-
NIRS, ME (% DM)	12.6	7.8
NIRS, Digestibility (%)	85.0	60.0

Notes: The date provided by Ellinbank Dairy Center (Victoria, Australia); a: NIRS= Near Infra-Red Reflectance Spectroscopy.

Table 4. Basic data of the dry Holstein-Frisian dairy cows used for the rumen incubation

	Cow 1	Cow 2	Cow 3	Cow 4	Cow 5	Cow 6
Cow No.	307	330	348	344	338	304
Weight (kg)	629	549	577	591	550	602
Birth Year	1993	1993	1993	1993	1993	1993
No. Lactation	2	2	2	2	3	2
Fat Yield (kg)	239	242	220	242	193	282
Protein Yield (kg)	168	162	162	183	152	223
Milk Yield (kg)	4160	5131	4832	5729	4801	6200
Last Insemination day	14/11/96	30/12/96	30/11/96	2/11/96	6/1/97	1/2/97

Notes: The data provided by Ellinbank Dairy Center (Victoria, Australia).

***In sacco* protein degradation**

The RDC of protein in the rumen were determined using the in sacco method. Incubations of all treatments in the rumen were with 5 g DM in nylon bags (10 cm*17 cm) with the pore size of approximately 44 m (Switzerland 1807710014 I 044 Nytal ASTM 325-44) as described by Tamminga (1990). The rumen incubations were performed according to the 'gradual addition/all out' schedule. Incubations were carried out for 24, 12, 8, 4 and 2 h; bags were inserted at 20:00, (next day) 08:00, 12:00, 16:00 and 18:00 and removed at 20:00 h, respectively. The 48 h rumen incubation were carried out from 20:00 till 20:00 two days later. All treatments were randomly allocated over all cows and the whole incubation period. After the incubation, the bags containing the residues were rinsed under a cold stream of tap water to remove excess ruminal contents and microbes on the surface to stop microbial activity, washed with cool water without detergent in a commercial washing machine (Fisher & Paykel, Smart Drive 500) for 55 min without spinning and subsequently dried at 60℃ for 24 h in an oven. The 0 h incubation samples were only put in the washing machine under the same conditions. The samples were stored in a cool room (4℃) until analysis. The residue was ground through a 1 mm screen and analyzed for chemical composition.

Chemical analysis

Dry roasted seeds were analyzed for DM, ash, CP, CFAT, starch (only for WFB) and in sacco rumen residues of 0, 2, 4, 8, 12, 24 and 48 h were analyzed for DM, Ash, Starch (only for WFB) and N. DM, Ash, CFAT were determined by AOAC methods (1984). N was analyzed by NCS instruments (NA 1500 NCS FISONS), and CP content was obtained by N multiplication by 6.25. WFB Starch was determined according to the AGS-DG method (Yu, 1995). There was no starch analysis for WLS due to the very low starch content (1.5%) in kernel (Hove, 1974). The digestibility of WFB and WLS were determined by in vitro method (McLeod and Minson, 1978).

Protein evaluation system: the DVE/OEB system

Rumen protein and starch bypassing microbial degradation: RDC, BCP and BST in the rumen were determined by the internationally accepted technique (Tamminga, 1993) of the in sacco method. In this technique, the results were calculated using the NLIN (non linear) procedure of the statistical package SAS (SAS, 1991) using iterative least squares regression (Gauess-Newton method) by the following the first order kinetics equation: $R(t)=U+D*\exp^{-Kd*(t-T0)}$, (1), where, R(t) stands for residue (in %) of the amount of incubated material after t h of rumen incubation; U and D in %; T0 in h; Kd in %/h.

BCP were calculated as: % BCP=U+D*Kp/(Kp+Kd); (2), BCP=1.11*CP*% BCP/100, (3), where, Kp of 6%/h was adopted based on international data (Tamminga, 1994); BCP and CP in g/kg DM; The factor 1.11 in the formula was taken from the French PDI-system, the regression coefficient of in vivo on in sacco degradation data.

BST were calculated as: % BST=D*Kp/(Kp+Kd)+0.1*S, (4); BST=Starch (g/kg)*% BST/100, (5), where: kp of 6% /h was adopted based on international data (Tamminga, 1994); BST and Starch in g/kg, DM.

Microbial protein synthesis in the rumen: The first factor limiting the microbial protein synthesis in the rumen is energy. This energy is derived from the anaerobic microbial conversion of OM into VFA and fermented gases. Consequently, a reliable estimate of microbial growth requires knowledge on the amount of FOM in the rumen (Tamminga, 1993). The DVE/OEB system relate microbial protein yield to FOM not to OM apparently digested in the rumen (ADOM).

FOM in the rumen was calculated as: FOM=DOM-CFAT-BCP-BST-FP, (6), where, DOM, CFAT, BCP, BST in g/kg DM; FP: Fermentation Products for conserved forages (g/kg DM) not for legume seeds.

Subsequently E_MP was estimated as: E_MP=0.15*FOM, (7), where, E_MP in g/kg DM, the factor 0.15 means that per kg FOM, 150 g of microbial protein crude protein is assumed to be synthesized. TPSI was calculated as: TPSI=BCP+0.75 MP, (8), where, factor 0.75 means that 75% of microbial N is present in amino acids, the remaining part of N in nucleic acids.

Intestinal digestion of feed and microbial protein: The previously discussed BCP and TPSI did not give exact enough information on the amount of amino acids absorbable from the small intestine. A correction is needed for protein losses due to incomplete digestion and resulting from endogenous excretion. True digestibility of microbial protein is assumed to be 85% and therefore the amount of AMP can be estimated as: AMP=0.85*0.75*0.15*FOM, (9), where, AMP in g/kg DM. For feed ingredients, ABCP is calculated as: ABCP=dBCP/100*BCP, (10).

In DVE/OEB system, ENDP in the intestine is related to the amount of dry matter excreted in the feaces. According to DVE/OEB, 75 g of absorbed protein per kg dry matter in feacal excretion is required to compensate for endogenous losses. Therefore ENDP is estimated as: ENDP=75*UDM, (11), where, UDM and ENDP in g/kg DM; UDM=UOM+UASH (12), where, UOM=OM-DOM; UASH=ASH-ASH*dASH, dASH for both faba beans and lupin seeds are 50% (Tamminga, 1993).

The DVE value was estimated from the total of

ABCP plus AMP minus ENDP as: DVE=ABCP+AMP-ENDP, (13), where, DVE in g/kg DM.

The degraded protein balance: The OEB value shows the imbalance between microbial protein synthesis potentially possible from available rumen degradable CP and that potential possible from the energy extracted during anaerobic fermentation in the rumen. Therefore the OEB value was estimated as: OEB=N_MP-E_MP, (14), where, N_MP=CP-BCP=CP-1.11*%BCP/100; E_MP=0.15*FOM; all parameters in g/kg DM.

Statistical analysis

Statistical analysis were carried out using the statistical package SAS (SAS, 1991). Results of in sacco incubations were calculate using the NLIN Procedure using iterative least squares regression method. Analysis of variance was carried out using Proc GLM: $Y_{ijk}=m+Series_i+Temp_j+Time_k+Temp*Time_{jk}+e_{ijk}$, where, Y=protein degradation and digestion; i=1, 2; j=1, 2, 3, 4; k=1, 2, 3, 4. Comparison of means of dry roasting effects on degradation and digestion were carried out by Tukey Studentized Range Test (HSD or Tukey Test). But since the determination of degradation and digestion yield one result per treatment in WFB, no statistical test was carried out for the RDC results of each combination of time and temperature of dry roasting.

RESULTS

Chemical compositions

The chemical compositions of WLS and WFB is in table 6 and 7. Dry roasting had significantly increased DM contents and decreased CFAT ($p<0.05$). This could be attributed to the water evaporating. But dry roasting did not significantly affected CP, starch (WFB), Ash and ($p>0.05$). The lower CFAT content of dry roasted WLS and WFB agreed with the results observed by others (Cros, 1991; Kibelolaud, 1993). Due to very lower starch content in WLS, no starch

Table 6. Effect of dry roasting on nutritional values (e.g. DVE and OEB) of WLS in dairy cows, calculated according to the new Dutch DVE/OEB protein system

Temp. (℃)		110			130			150		
Time (Min)	Raw	15	30	45	15	30	45	15	30	45
Chemical compositions										
DM (g/kg)	921.26^{ab}	920.95^{b}	930.40^{ab}	933.15^{ab}	928.77^{ab}	927.78^{ab}	931.92^{ab}	932.98^{ab}	935.06^{a}	933.72^{a}
CP (g/kg DM)	386.53^{a}	387.88^{a}	380.64^{a}	377.29^{a}	379.75^{a}	384.94^{a}	380.07^{a}	392.34^{a}	382.06^{a}	386.05^{a}
Ash (g/kg DM)	27.25^{a}	28.32^{a}	26.21^{a}	27.53^{a}	29.40^{a}	26.78^{a}	26.88^{a}	28.30^{a}	26.15^{a}	25.84^{a}
OM (g/kg DM)	972.75^{a}	971.69^{a}	973.79^{a}	972.48^{a}	970.61^{a}	973.22^{a}	973.13^{a}	971.70^{a}	973.86^{a}	974.16^{a}
CFAT (g/kg DM)	53.88^{a}	53.21^{ab}	53.13^{ab}	50.68^{abc}	49.68^{bc}	48.43^{cd}	45.33^{de}	44.06^{e}	43.90^{e}	41.68^{e}
Total tract										
dOM (*in vitro*, %)	98.22^{a}	98.42^{a}	98.49^{a}	98.60^{a}	98.67^{a}	98.58^{a}	98.37^{a}	98.62^{a}	98.44^{a}	98.75^{a}
dASH (%)	50	50	50	50	50	50	50	50	50	50
DOM (g/kg DM)	955.44^{a}	956.33^{a}	959.09^{a}	958.82^{a}	957.70^{a}	959.40^{a}	957.26^{a}	958.29^{a}	958.62^{a}	961.94^{a}
UOM (g/kg DM)	17.32^{a}	15.36^{a}	14.71^{a}	13.66^{a}	12.91^{a}	13.82^{a}	15.87^{a}	13.41^{a}	15.24^{a}	12.23^{a}
UASH (g/kg DM)	13.63^{a}	14.16^{a}	13.11^{a}	13.77^{a}	14.70^{a}	13.39^{a}	13.44^{a}	14.16^{a}	13.08^{a}	12.93^{a}
UDM (g/kg DM)	30.94^{a}	29.51^{a}	27.81^{a}	27.43^{a}	27.61^{a}	27.21^{a}	29.30^{a}	27.56^{a}	28.31^{a}	25.15^{a}
Rumen degradation characteristics of CP										
S (CP) (%)	31.8^{a}	32.01^{a}	31.59^{a}	30.20^{a}	30.08^{a}	27.71^{a}	27.10^{a}	27.60^{a}	28.28^{a}	25.80^{a}
D (CP) (%)	67.41^{a}	67.74^{a}	67.79^{a}	69.80^{a}	69.66^{a}	69.83^{a}	66.23^{a}	59.76^{ab}	43.72^{bc}	35.82^{c}
U (CP) (%)	0.79^{c}	0.27^{c}	0.63^{c}	0.00^{c}	0.27^{c}	2.46^{bc}	6.68^{bc}	12.65^{b}	27.50^{a}	38.44^{a}
Kd (CP) (%/h)	10.21^{a}	9.38^{a}	9.14^{a}	10.48^{a}	9.34^{a}	7.74^{a}	9.87^{a}	8.25^{a}	4.40^{b}	3.56^{b}
%BCP	25.90^{e}	26.70^{de}	27.49^{de}	25.44^{e}	27.54^{de}	33.04^{cd}	31.75^{cde}	37.83^{c}	52.73^{b}	60.69^{a}
BCP (g/kg DM)	111.23^{c}	114.90^{c}	116.05^{c}	106.57^{c}	116.10^{c}	141.31^{bc}	134.05^{bc}	164.55^{b}	223.64^{a}	246.19^{a}
FOM (g/kg DM)	790.33^{a}	788.23^{a}	789.91^{a}	801.57^{a}	791.92^{a}	769.67^{ab}	777.89^{ab}	749.69^{b}	691.08^{c}	659.07^{c}
E_MP (g/kg DM)	118.55^{a}	118.24^{a}	118.49^{a}	120.24^{a}	118.79^{a}	115.46^{ab}	116.68^{ab}	112.46^{b}	103.67^{c}	98.86^{c}
TPSI (g/kg DM)	200.14^{de}	203.58^{de}	204.92^{de}	196.75^{e}	205.19^{de}	227.89^{cd}	221.56^{cde}	248.89^{c}	301.39^{b}	335.34^{a}
AMP (g/kg DM)	75.58^{a}	75.38^{a}	75.54^{a}	76.65^{a}	75.73^{a}	73.60^{ab}	74.39^{ab}	71.69^{b}	66.09^{c}	63.03^{c}
ENDP (g/kg DM)	2.32^{a}	2.22^{a}	2.09^{a}	2.06^{a}	2.07^{a}	2.04^{a}	2.20^{a}	2.07^{a}	2.12^{a}	1.89^{a}
dBCP (*in vitro*, %)	95.39^{a}	96.34^{a}	96.99^{a}	96.22^{a}	95.98^{a}	96.67^{a}	97.11^{a}	96.10^{a}	95.88^{a}	96.03^{a}
ABCP (g/kg DM)	106.04^{de}	110.69^{de}	112.56^{de}	102.49^{e}	111.42^{de}	136.69^{cd}	130.24^{cde}	158.16^{c}	214.47^{b}	250.81^{a}
N_MP (g/kg DM)	275.30^{a}	272.98^{a}	264.62^{a}	270.71^{a}	263.65^{a}	243.63^{ab}	246.02^{ab}	227.79^{b}	158.42^{c}	124.86^{c}
DVE (g/kg DM)	179.29^{d}	183.86^{d}	186.01^{d}	177.09^{d}	185.08^{d}	208.24^{cd}	202.43^{cd}	227.78^{c}	278.43^{b}	311.95^{a}
OEB (g/kg DM)	156.75^{a}	154.75^{a}	146.13^{ab}	150.47^{a}	144.86^{ab}	128.19^{ab}	129.34^{ab}	115.34^{b}	54.75^{c}	26.01^{c}

^{a,b,c} Mens with different superseripts in the same raw are significantly different ($p<0.05$).

chemical analysis results were given.

Protein evaluation by the DVE/OEB system

Whole lupin seeds: The effects of dry roasting on protein degradation and digestion and microbial protein synthesis and digestion of WLS in dairy cows are presented in table 6. Dry roasting had no significant effects on dOM, DOM, UOM, UASH, UDM, S and ENDP ($p>0.05$), but had significant effects on DM ($p<0.05$) and had strongly significant effects on D, U, Kd, %BCP, BCP, FOM, E_MP, TPSI, AMP, ABCP, DVE, N_MP and OEB ($p<0.001$). Dry roasting had strong interaction effects on D, U, Kd, %BCP, BCP, FOM, MP, TPSI, AMP, ABCP, DVE and OEB ($p<0.05$).

Dry roasting had significantly increased BCP at 130 and 150℃ but no at 110℃. BCP was varied from 111.2 in the raw and 114.9 in 110℃/15 min to 246.2 g/kg in 150℃/45 min. BCP of 150℃/45 min was increased 2.2 times compared with the raw. FOM was reduced gradually and varied from 790.3 in the raw to 659.1 g/kg in 150℃/45 min due to increasing BCP. The E_MP value was reduced. Though E_MP decreased, TPSI was increased from 200.1 in the raw to 335.3 g/kg DM in the 150℃/45 min. Based on the

Table 7. Effects of dry roasting on nutritional values (e.g. DVE and OEB) of WFB in dairy cows, calculated according to the new Dutch DVE/OEB protein system

Temp. (℃)		110			130			150		
Time (Min)	Raw	15	30	45	15	30	45	15	30	45
Chemical compositions										
DM (g/kg)	885.90	895.60	900.70	910.20	919.00	920.60	923.40	924.10	935.30	941.00
CP (g/kg DM)	317.33	317.45	319.89	318.82	323.04	324.25	318.19	322.00	320.35	310.37
Ash (g/kg DM)	34.77	34.17	33.75	33.40	33.73	34.22	34.33	35.28	34.00	34.22
OM (g/kg DM)	965.23	965.83	966.25	966.60	966.27	965.78	965.67	964.72	966.00	965.78
CFAT (g/kg DM)	20.42	19.87	18.67	17.12	18.20	16.34	15.98	16.24	14.57	13.98
	410.99	415.14	412.12	420.46	404.46	402.13	407.73	401.15	395.06	400.74
Total tract										
dOM (*in vitro*, %)	99.42	99.36	99.58	99.66	99.64	99.72	99.63	99.69	99.54	99.72
dASH (%)	50	50	50	50	50	50	50	50	50	50
DOM (g/kg DM)	963.58	963.20	965.53	966.30	965.51	965.79	964.72	964.40	963.75	965.09
UOM (g/kg DM)	5.62	6.20	4.07	3.30	3.49	2.71	3.58	3.00	4.45	2.71
UASH (g/kg DM)	17.38	17.08	16.88	16.70	16.87	17.11	17.16	17.64	17.00	17.11
UDM (g/kg DM)	23.00	23.29	20.95	20.00	20.35	19.82	20.75	20.64	21.45	18.82
Rumen degradation characteristics of CP										
S (CP) (%)	49.03	57.56	56.11	55.07	45.02	47.06	41.68	36.25	35.70	26.31
D (CP) (%)	50.73	42.14	43.34	44.27	54.73	52.63	58.82	63.64	64.30	73.69
U (CP) (%)	0.24	0.30	0.55	0.66	0.25	0.31	0.00	0.11	0.00	0.00
Kd (CP) (%/h)	21.44	23.49	24.22	22.71	20.70	19.38	15.99	16.71	10.42	4.26
%BCP	11.33	8.87	9.15	9.91	12.55	12.75	15.91	16.92	23.50	43.09
BCP (g/kg DM)	39.92	31.27	32.51	35.08	45.00	45.90	56.20	60.49	83.55	148.46
Rumen degradation characteristics of Starch (ST)										
S (CP) (%)	50.09	53.72	51.95	52.45	42.42	40.51	36.06	30.81	25.53	18.18
D (CP) (%)	49.91	46.28	48.05	47.55	57.58	59.49	63.94	69.19	74.47	81.82
U (CP) (%)	0	0	0	0	0	0	0	0	0	0
Kd (CP) (%/h)	9.82	9.88	10.97	10.96	10.14	10.03	9.04	8.54	7.05	4.21
%BCP	23.94	22.86	22.18	22.07	25.65	26.32	29.11	31.63	36.79	49.90
BCP (g/kg DM)	98.38	94.89	91.42	92.78	10.73	105.83	118.71	126.89	145.35	199.97
FOM (g/kg DM)	804.86	817.16	822.93	821.32	798.58	797.72	773.83	760.78	720.28	602.67
E_MP (g/kg DM)	120.73	122.57	123.44	123.20	119.79	119.66	116.07	114.12	108.04	90.40
TPSI (g/kg DM)	130.46	123.20	125.09	127.48	134.84	135.64	143.26	146.08	164.58	216.26
AMP (g/kg DM)	76.96	78.14	78.69	78.54	76.36	76.28	74.00	72.75	68.88	57.63
ENDP (g/kg DM)	1.73	1.75	1.57	1.50	1.53	1.49	1.56	1.55	1.61	1.49
dBCP (*in vitro*, %)	89.04	88.56	92.11	87.69	88.46	90.87	87.89	88.91	91.42	87.99
ABCP (g/kg DM)	35.54	27.69	29.94	30.76	39.80	41.71	49.40	53.78	76.38	130.63
N_MP (g/kg DM)	277.41	286.19	287.38	283.74	278.04	278.35	261.98	261.51	236.80	161.91
DVE (g/kg DM)	110.78	104.09	107.06	107.80	114.64	116.50	121.84	124.98	143.65	186.78
OEB (g/kg DM)	156.69	163.61	163.94	160.54	158.26	158.69	145.91	147.40	128.76	71.51

consumption of true digestibility of microbial protein as 85%, AMP reduced from 75.6 in the raw to 63.0 g/kg DM in 150℃/ 45 min. For ENDP, dry roasting did not significantly change its content (p>0.05). The ENDP value in the raw was 2.32 g/kg DM. ABCP in the small intestine was increased significantly from 106.0 in the raw to 250.8 g/kg DM in 150℃/45 min.

Therefore the DVE value was increased with increasing temperatures and items as shown in figure 1. Compared with the raw, it was increased from 179.3 in the raw to 312.0 in 150℃/45 min.

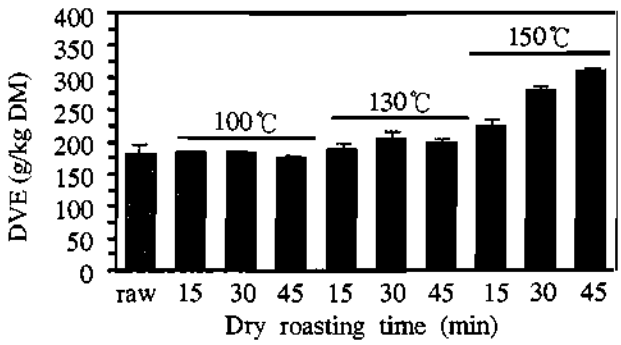

Figure 1. Effect of dry roasting n the DVE values of WLS in dairy cows

As to the OEB value, it was reduced sharply at 150 C as shown in figure 2. Compared with the raw (156.8 g/kg DM), it reduced 6 times in 150℃/45 min but no to the level of negative (figure 2).

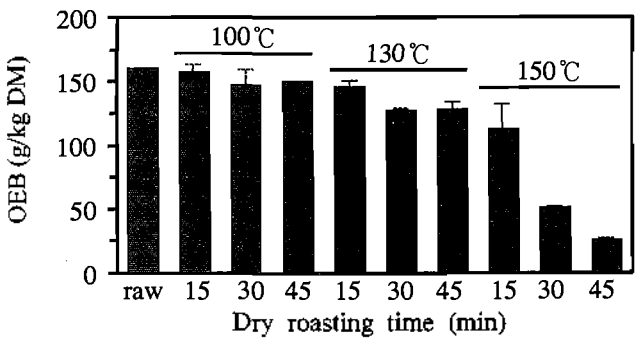

Figure 2. Effect of dry roasting on the OEB values of WLS in dairy cows

Whole faba beans: The effects of dry roasting on protein degradation and digestion and microbial protein synthesis and digestion of WFB in dairy cows were similar to the WLS as presented in table 7.

Dry roasting had effects on D, S, U, Kd (Yu, 1998a; Yu, 1998c) and increased BCP, BST at 130 and 150℃ but not at 110℃. BCP was varied from 39.9 in the raw and 31.3 in 110℃/15 min to 148.5 g/kg DM in 150℃/45 min. It was decreased by 17% at 110℃ and then increased by 23% at 130℃. When temperature was 150℃, it increased by 144%. The BCP value of 150℃/45 min was increased 3.7 times compared with the raw. The important results were that BCP had an initial decline and then little changed until 150℃ for 30 or 45 min. For BST, dry roasting had same pattern as BCP. It was increased at higher temperature of 130 and 150℃. It was varied from 98.4 in the raw to 200.0 g/kg DM in 150℃/45 min. FOM was reduced from 804.9 in the raw to 602.7 in 150℃/45 due to increasing BCP and BST. Therefore, the E_MP value was reduced from 120.7 in the raw to 90.4 in 150℃/45 min. Thus AMP was reduced too. Due to increasing BCP in all treatments, ABCP was increased from 35.5 in the raw to 130.6 in 150℃/45 min.

Based on the above results, the DVE value was increased from 110.8 in the raw to 186.8 in 150℃/45 min as shown in figure 3. The OEB value as shown in figure 4 was reduced from 156.7 in the raw to 71.5 in 150℃/45 min. But it was higher than WLS under the same dry roasting conditions.

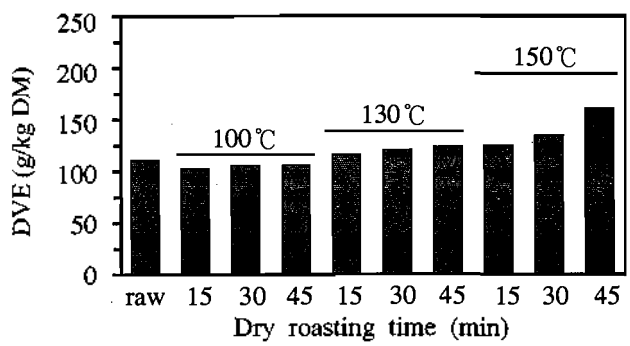

Figure 3. Effect of dry roasting on the DVE values of WFB in dairy cows

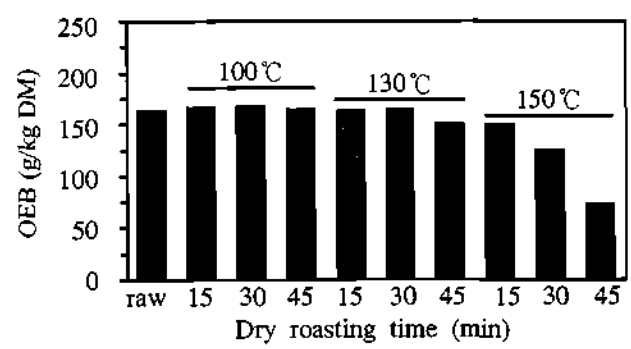

Figure 4. Effect of dry roasting on the OEB values of WFB in dairy cows

DISCUSSION

The DVE/OEB system

The Dutch new protein evaluation DVE/OEB

system (Tamminga, 1994) has been developed recently. It can give information on the quantitative aspects of both ruminal and post-ruminal feed protein digestion in ruminants. For a long time, widely used protein evaluation in ruminants have been either crude protein or digested crude protein. More recently systems based on protein truly or apparently absorbed from intestine have been developed such as ARC (1984), NJK (1985), PDI (INRA, 1987), AP (NRC, 1985) and DVE/OEB (1994).

In the DVE/OEB system, each feed has a DVE value composed of the digestible true protein contributed by feed protein escaping rumen degradation; microbial protein synthesised in the rumen and a correction for endogenous protein losses in the digestive tract. Each feed also has a OEB value reflecting the difference between the potential microbial protein synthesised based on degraded feed crude protein and that based on energy available for microbial fermentation in the rumen.

In this system, it considers the strong elements of other recently developed protein evaluation systems and it also introduces new elements, including undegraded bypass starch, fermentation products in ensiled feeds, the role of energy balance in protein supply and the way in which requirements change in the course of lactation. This system make it possible to feed protein more accurately according to the real demands of the dairy cow and prevent unnecessary losses of nitrogen (Tamminga, 1994).

The DVE/OEB system has its own characteristics. It accepts Kp as 5 to 8%/h for concentrate ingredients and 3 to 5%/h for long forages in the rumen. For microbial protein synthesis in the rumen, the DVE/OEB system relate microbial protein yield to FOM. It bases on the theory that the first factor limiting the microbial protein synthesis in the rumen is energy. This energy is derived from the anaerobic microbial conversion of OM into VFA and fermented gases. Consequently, a reliable estimate of microbial growth requires knowledge on the amount of FOM in the rumen. In some system a fixed ratio, usually 0.65, between total (DOM) and organic matter apparently digested in the rumen (ADOM) is accepted. The difference between FOM and ADOM is microbial organic matter, which is included in FOM but not in ADOM. Therefore the DVE/OEB system is more reasonable. In the DVE/OEB system, FOM is equal DOM minus CFAT, BCP and BST. With conserved forages (silage) a further correction is made from FP resulting from the ensiling process. The latter correction is based on the assumption that FP is not a suitable source of energy for microbial growth. But in PDI system, there is not correction for BST.

In DVE/OEB system, it is assumed that the N loss is compensated for by N recycled to the rumen via saliva or directly by diffusion from the blood; per kg of FOM, 150 g microbial protein is to be synthesis; only 75% of microbial N is present in amino acids, the remaining part as N in nucleic acids; true digestibility of microbial protein is 85%. Therefore truly absorbed microbial protein can be calculated as AMP=0.85*0.75*0.15*FOM.

In the DVE/OEB system, it accepts a different value for each individual feedstuff. But in some new protein evaluation system assume a constant apparent absorption regardless of the origin of the protein supplied to the small intestine. In the DVE/OEB system, estimates of these individual values are usually based on the measurements using mobile nylon bag technique (Tamminga, 1993). ENDP in the intestine, in this system, is related to the amount of dry matter excreted in faeces not related to the dry matter intake. A figure of 75 g not 90 g (NRC, 1988) of absorbed protein per kg dry matter in faeces excretion is required to compensate for endogenous losses. In DVE/OEB system, the OEB value is recommended not to become negative. The risk of a shortage of N for the microbes is considered too high. In that case the calculated value of absorbed microbial protein may not achieved. This risk is particularly apparent at higher levels of feed intake, normally found in early lactation combined with infrequent feeding (Tamminga, 1994).

Availability of BCP

The results of the absorbed the bypassing rumen degradation protein were estimated as: ABCP=BCP* dBCP. The digestibility of BCP could be measured by in vivo, mobile bag technique or in vitro method. But determination of the digestibility in vivo and mobile bag technique are very expensive and laborious. The surgical cannulated animals are required and are not suitable for routine screening of feedstuffs. Therefore the earliest times of research in animal nutrition, efforts have been made to develop simpler and quicker laboratory methods as alternatives to in vivo and mobile bag trials. Therefore the lab in vitro methods which could predict the digestibility routinely and accurately is essential. *In vitro* McLeod and Minson (1978) method provide possibility.

In the WFB and WLS, dry roasting did not significantly alter the digestibility of BCP. These results were similar to published observations carried out with lupin and faba beans subject to different protective methods involving heating. Kibelolaud (1993) reported that extrusion of white lupin seeds decreased the degradability of CP with a corresponding increase in the amount digested in the post-ruminal sections and availability of BCP and the whole tract digestibility were generally unchanged. Cros (1991) found that extrusion at 120, 150 and 195 C appeared to have potential for decreasing ruminal degradation

without reducing intestinal digestibility of WLS protein.

The DVE and OEB values of WFB and WLS

The protein evaluation results by DVE/OEB indicated though dry roasting at 130 and 150℃ reduced microbial protein synthesis due to reducing FOM and reducing rumen protein degradation, the DVE value didn't decrease but highly increased due to increasing BCP more than enough for compensation for microbial protein decreased. Therefore the net absorbable DVE value in the animal was highly increased.

For WFB, the DVE value had an initial decline and then little change until 130℃ for 45 min and 150℃ for 15, 30 and 45 min. For WLS, the DVE value increased with increasing times and temperatures. It had significantly increased at 150℃ with the DVE values of 227.8 in 150℃/15 min, 278.4 in 150℃/30 min and 312.0 g/kg DM in 150℃/45 min.

The OEB value shows the imbalance between microbial protein synthesis potentially possible from available rumen degradable CP and that potentially possibly from the energy extracted during anaerobic fermentation in the rumen. When the OEB value is positive, it indicates the loss of N from the rumen. When the OEB value is negative, microbial protein synthesis may be impaired due to a shortage of N in the rumen. The optimum OEB value in a ration is therefore zero or slightly above (Tamminga, 1993).

In present study, dry roasting significantly reduced the OEB values for both WLS and WFB but not to the level of negative. It indicated that microbial protein synthesis might not be impaired due to sufficient N supplied in the rumen. But high positive values of OEB for most treatments except of 150℃/30 min (OEB of 54.7 g/kg DM) and 150℃/45 min (OEB of 26.0 g/kg DM) in WLS indicated that there were still quite large amount of N loss in the rumen. Compared WLS with WFB, the OEB values in RWLS and RWFB were similar, 156.8 and 156.7 g/kg DM. But after dry roasting, the OEB values of the roasted WFB were quite higher (147.4, 128.8 and 71.5 g/kg DM in 150℃ for 15, 30 and 45 min) than that of the roasted WLS. It might suggest that dry roasting at 130, 150℃ of WFB were not sufficient method to protect the N loss in the rumen. But for WLS, dry roasting at 150℃ for 30 or 45 min might efficiently protect the N loss in the rumen. Because the OEB values in the treatments of 150℃ for 30 or 45 min were slightly above zero, not too high.

It was concluded that dry roasting at higher temperature was effective in shifting protein degradation from rumen to intestine and increased the DVE value with increasing temperatures and times without reaching the negative OEB value. But dry roasting at 110, 130℃ for both WFB and WLS and 150℃ for WFB did not prevent unnecessary N loss from rumen due to the high OEB values, though it reduced rumen degradation of protein and increasing true absorbed protein in the small intestine. No optimal treatment was found in WFB due to the too high OEB values in all treatments. But for WLS, the treatments of dry roasting at 150℃ for 30 and 45 min might be optimal treatments due to the very lower OEB values.

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