Journal of Animal and Veterinary Advances 8 (7): 1279-1284, 2009
ISSN: 1680-5593

Effect of Fodder Tree as Fiber Sources in Total Mixed Ration on Feed Intake, Nutrient Digestibility, Chewing Behavior and Ruminal Fermentation in Beef Cattle

[1]S. Chumpawadee and [2]O. Pimpa
[1]Unit of Animal Feed Resource and Animal Nutrition Research, Division of Animal Science, Faculty of Veterinary and Animal Sciences, Mahasarakham University, Mahasarakham 44000, Thailand
[2]Faculty of Science and Industrial Technology, Prince of Songkla University Surat Thani Campus, Thailand

Abstract: The objective of this study, was to determine the effect of fodder tree as fiber sources in a total mixed ration on feed intake, nutrient digestibility, chewing behavior and ruminal fermentation. Four Brahman-Thai native crossbred steers with an average initial body weight of 233.3+13.09 kg were randomly assigned in a 4×4 Latin Square Design. During each of four 21 days periods, the animals were fed 4 Total Mixed Rations that varied in the fiber sources: Corn cob as fiber sources (C-TMR, control), Burma padauk leave as fiber source (B-TMR), Rain tree leave as fiber source (R-TMR) and Siamese rough bush leave as fiber source (S-TMR). The results showed that feed intake, crude protein digestibility, chewing time and ruminal fermentation were significantly different among treatments ($p<0.05$). Dry matter intake of animal fed R-TMR, B-TMR had higher than S-TMR and C-TMR (control). In this study, R-TMR had lowest crude protein digestibility. The number of chewing had highest when animals fed B-TMR. At 2 h post feeding C-TMR had the highest NH_3-N, when compared with other TMRs. The fodder tree as a fiber source in the total mixed ration has positive effect on feed intake and chewing behavior. Therefore, fodder trees can be use as fiber sources in TMR, especially when acute shortage of conventional fiber sources.

Key words: Leaves, fiber source, total mixed ration, nutrient digestibility, chewing behavior, beef cattle

INTRODUCTION

In recent years, feeding a Total Mixed Ration (TMR) for cattle has become widely accepted. The benefits of a TMR include increased milk production, enhanced use of low cost alternative feed ingredients, ability to control the forage concentrate ratio, lower incidence of metabolic and digestive disorders and reduced labor input for feeding (Spahr *et al*., 1993; Everson *et al*., 1976). Fiber source of TMR is very importance, because it can be affected feed intake, chewing activity, digestibility and production (Chumpawadee and Pimpa, 2008). Generally, silage, forage, rice straw, corn cop and hay are conventional roughages found in TMR. Due to the dry season have shortage fiber source for mixed TMR. Therefore, non-conventional roughage such as fodder tree is needed for fiber source in TMR. Although, they have the crucial parameters affecting fodder utilization, such as tannins saponin and non protein amino acids, which are toxic to rumen microbes or to the animal (Lowry *et al*., 1996). However, leaves of fodder trees should be used as fiber sources in TMR. Because of their feed are high content of protein, minerals and vitamins (Baloyi *et al*., 1997) and availability in the dry season. In addition, the toxic substance in leaves can be reducing by sun dry.

With respect to fodder trees, limited information is available on its use as a fiber source of TMR. The aim of this study, was to investigate feed intake, nutrient digestibility, chewing behavior and ruminal fermentation in beef cattle fed different fiber sources.

MATERIALS AND METHODS

Preparation of TMRs: The burma padauk (*Plerocarpus Indicus*), rain tree (*Samanea Saman* (*Jacg.*) *Merr*) and siamese rough bush (*Streblus Asper*) leaves and corn cop were used in this study. They were collected from the Mahasarakham province area in the Northeast of Thailand. Fresh samples were dried in a hot, dry air force oven at 65°C for 72 h and weighed. All feed samples were ground to pass through a 1 mm screen for chemical analysis. The feedstuff samples were analyzed for Dry

Corresponding Author: Songsak Chumpawadee, Faculty of Veterinary and Animal Sciences, Mahasarakham University, Mahasarakham, 44000, Thailand

Table 1: Feed formulation and chemical composition of dietary treatments

	Dietary treatments[1]			
Ingredients	C-TMR	B-TMR	R-TMR	S-TMR
Corn cop	30.0	-	-	-
Burma padauk leave	-	40.0	-	-
Rain tree leave	-	-	40.0	-
Siamese rough bush leave	-	-	-	40.0
Leuceana meal	10.0	10.0	15.0	4.5
Cassava chip	40.5	27.5	24.5	21.0
Cane molasses	8.0	5.0	7.0	6.0
Rice pollard	7.0	15.0	12.3	25.8
Urea	3.0	1.4	0.1	1.3
Salt (NaCl)	0.5	0.5	0.5	0.5
Mineral mixed	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.5	0.1	0.1	0.7
Total	100.0	100.0	100.0	100.0
Chemical composition				
DM (%)	86.3	89.0	90.5	88.4
Ash (%)	9.3	9.0	9.9	12.0
CP (%)	15.8	15.0	13.6	13.9
NDF (%)	53.9	54.3	50.0	58.4
ADF (%)	35.6	36.0	40.7	48.7
ADL (%)	4.7	6.0	11.1	2.8
Total digestible				
Nutrient (TDN) (%)	63.5	60.4	63.3	60.1
Calcium (Ca) (%)	0.4	0.9	0.5	0.4
Phosphorus (P) (%)	0.2	0.2	0.2	0.3

[1]C-TMR = Corn cob as fiber source, B-TMR = Burma padauk leave as fiber source, R-TMR = Rain tree leave as fiber source, S-TMR = Siamese rough bush leave as fiber source

Matter (DM), Crude Protein (CP) and ash (AOAC, 1990), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) (Van Soest *et al*., 1991), the data used for feed formulation. Four TMRs were formulated, to have similar Total Digestible Nutrient (TDN), CP, NDF, ADF, but differ in fiber source (Table 1).

Animals and feeding: Four Brahman-Thai native crossbred steers an initial body weighs of 233.3 + 13.09 kg were used. The animals were dewormed using ivermectin and injected with AD3E vitamin-complex prior to undertaking the experiment. They were housed individuals pens and fed *ad libitum* at 7.00 and 19.00 h. Drinking water and mineral lick were offered and available at all time. Animals were randomly allocated to one of four treatments in 4×4 Latin Square Design with 21 days periods. The dietary treatment were Corn cob TMR (C-TMR, control), Burma padauk leave TMR (B-TMR), Rain tree leave TMR (R-TMR) and Siamese rough bush leave TMR (S-TMR). The experimental was carried out at the Division of Animal Science, Faculty of Veterinary and Animal Sciences, Mahasarakham University, Thailand. The animals were weighed at the beginning and end of each period.

Sample collection and preparation: The TMRs were randomly collected and composite prior to analyses. Composite samples of TMR were ground to pass through a 1 mm screen and the analyzed for DM, ash and CP (AOAC, 1990) NDF, ADF, ADL (Van Soest *et al*., 1991) and Acid Insoluble Ash (AIA) (Van Keulen and Young, 1977).

Fecal samples were collected by rectal sampling at 10.00 h for 3 consecutive days and composted. The feces were placed into an oven at 65°C for 72 h, weighed and ground to pass through a 1 mm screen and the analyzed for DM, ash CP, NDF, ADF and AIA. The AIA content in feed and fecal were used to calculated digestibility (Schneider and Flatt, 1975).

Rumen fluid (100 mL) was collected at the end of each sampling period at 0, 2, 4 and 6 h post feeding by stomach tube connected with a vacuum pump. Ruminal pH was measured immediately after sampling using pH meter (Handy Lab 1, CG842 Schott). Rumen fluid samples were then filtered through 4 layers of cheesecloth. Fifty milliliter of rumen fluid was acidified with 5 mL of 6 N HCl and centrifuged at 16,000 g for 15 min and the clear supernatant was stored in plastic tubes at -20°C prior to ammonia nitrogen (NH_3-N) analysis using the micro Kjeldahl methods.

Blood samples were collected from the jugular vein at the same time as rumen fluid sampling, using 10 mL heparinised vacutainers. The tube was gently inverted a couple of times and then kept in an ice box and later centrifuged at 5,000 g for 10 min. The plasma was then transferred into storage tube and labeled with date and animal identification and stored at -20°C until analysis of Blood Urea Nitrogen (BUN) using the Stanbio Urea Nitrogen (SUN) (Liqui-UV® Procedure No.2020).

On day 18 and 19 of each period, chewing behaviors were monitored visually at all time. Total chewing time was calculated by the sum of eating time and ruminating time. Eating chew and Ruminating chew were measured by counting.

Statistical analysis: All data obtained from the trials were subjected to the general linear models procedure of Statistical Analysis System (SAS, 1996) according to a 4×4 Latin Square Design. Means were separated by Duncan New's Multiple Range Test. The level of significance was determined at $p<0.05$.

RESULTS AND DISCUSSION

Feed intake and nutrient digestibility: Chemical composition analyses of the 4 TMRs are presented in Table 1. TMRs contained similar concentrations of DM, ash and CP. However, NDF and ADF content in S-TMR were slightly higher than others TMRs. Table 2 shows the feed intake and nutrient digestibility of TMRs. Dry matter

Table 2: Feed intake and nutrient digestibility in beef cattle fed difference TMRs

	Dietary treatments[1]				
Parameters	C-TMR	B-TMR	R-TMR	S-TMR	SEM
Dry matter intake					
Kg day^{-1}	4.5^{b}	5.9^{a}	5.9^{a}	4.8^{b}	0.26
BW (%)	1.9^{c}	2.4^{ab}	2.6^{a}	2.1^{bc}	0.11
g kg^{-1} BW$^{0.75}$	76.7^{c}	95.3^{ab}	101.3^{a}	80.4^{bc}	4.30
Nutrient digestibility					
DMD	63.7	61.0	62.7	60.3	0.99
OMD	69.1	65.2	65.5	62.5	1.28
CPD	74.5^{a}	71.9^{a}	65.8^{b}	70.8^{a}	1.07
NDFD	54.3	53.5	52.5	54.9	2.03

a, b, c: Means within a row different superscripts differ ($p<0.05$), [1] C-TMR = Corn cob as fiber source, B-TMR = Burma padauk leave as fiber source, R-TMR = Rain tree leave as fiber source, S-TMR = Siamese rough bush leave as fiber source

Table 3: Eating and ruminating behavior in beef cattle fed difference TMRs

	Dietary treatments[1]				
Parameters	C-TMR	B-TMR	R-TMR	S-TMR	SEM
Chewing time (min day^{-1})					
Eating	138.5^{b}	230.0^{a}	185.5^{ab}	185.0^{ab}	14.85
Rumination	197.6^{a}	222.0^{a}	238^{a}	148.0^{b}	25.80
Total	336.1^{b}	452.0^{a}	396.5^{a}	333.0^{b}	52.8
Chewing time (min kg^{-1} NDF intake)					
Eating	61.1^{b}	90.5^{a}	62.2^{b}	67.9^{b}	6.71
Rumination	74.3	86.6	79.8	55.4	10.04
Total	135.4^{b}	177.4^{a}	142.6^{b}	123.4^{b}	11.79
Eating rate, g DM min^{-2}	35.4	27.3	33.5	29.4	2.87
Rumination efficiency, g DM min^{-3}	71.5^{a}	29.6^{c}	26.8^{c}	45.58^{b}	10.55

a, b, c: Means within a row different superscripts differ ($p<0.05$), [1]C-TMR = Corn cob as fiber source, B-TMR = Burma padauk leave as fiber source, R-TMR = Rain tree leave as fiber source, S-TMR = Siamese rough bush leave as fiber source [2] = DM intake (g day^{-1})/eating time (min day^{-1}). [3] = DM intake (g day^{-1})/rumination time (min day^{-1})

intake was significant different ($p<0.05$) among treatments. Many dietary factors may influence dry matter intake in ruminant such as physical characteristics, ingredient and nutrient composition. In this study, dry matter intake was influenced by fiber source in TMRs. Dry matter intake of animal fed R-TMR, B-TMR had higher than S-TMR and C-TMR (control), respectively. This is due to fodder tree TMR had palatability and good physical characteristics than corn cob TMR. Additionally, the animals fed C-TMR and S-TMR had lower chewing time when compared with the B-TMR and R-TMR (Table 3). It is demonstrate that burma padauk leave, rain tree leave and siamese rough brush leave can be used as fiber source in TMRs.

Digestibility of DM, OM and NDF were not significantly difference ($p>0.05$) between the treatments. The current finding disagree with *in vitro* studies on the affect of fodder tree as fiber source in TMRs (Chumpawadee and Pimpa, 2009), who found that IVDMD and IVODM were significantly different ($p<0.05$) among treatment. The S-TMR gave the highest IVDMD and IVOMD. It was probably different condition on *in vitro*

Table 4: Eating, ruination chews ruminated boli and boli characteristics in beef cattle fed difference TMRs

	Dietary treatments[1]				
Parameters	C-TMR	B-TMR	R-TMR	S-TMR	SEM
No. of chews day^{-1}					
Eating	8437.0	10680.0	10622.0	9454.0	635.2
Rumination	9338.0	11291.0	11151.0	6762.0	1297.1
Total	17775.0	21971.0	21773.0	16216.0	1752.3
No. of chews kg^{-1} NDF intake					
Eating	3694.8	4238.3	3560.0	3458.3	301.9
Rumination	3553.0	4429.0	3739.0	2525.0	519.6
Total	7247.8	8667.3	7299	5983.3	628.1
No. of chews min^{-1} eating time	62.5	44.9	58.02	54.9	3.02
No.of chews min^{-1} rumination time	43.1^{b}	52.5^{a}	46.5^{ab}	43.4^{b}	1.7
Ruminated boli, no/day	136.8	229.3	228.5	138.8	26.23
Ruminated boli, no./kg NDF intake	50.5	90.8	76.3	51.8	9.89
No. of chews bolus^{-1}	44.4	51.6	50.17	43.7	2.7
No. of boli min^{-1} rumination time	1.0	1.02	0.95	1.02	0.04

a, b: Means within a row different superscripts differ ($p<0.05$), [1]C-TMR = Corn cob as fiber source, B-TMR = Burma padauk leave as fiber source, R-TMR = Rain tree leave as fiber source, S-TMR = Siamese rough bush leave as fiber source

and *in vivo*. However, crude protein digestibility was significant different ($p<0.05$) between treatment. Many factors may influenced crude protein digestibility; protein levels in the ration (Kawashima *et al.*, 2003), protein source and nature of protein source providing the rumen undegradable protein (Milis and Liamadis, 2007) and protein fraction (Chumpawadee *et al.*, 2007). Fernandez *et al.* (2003) reported protein source in TMRs was affected protein digestibility. In this study, R-TMR had lowest crude protein digestibility, it was possibly due to protein fraction of R-TMR have less proportion of non protein nitrogen, especially urea in the ration (Table 1).

Chewing behavior: Chewing behaviors variables are shown in Table 3 and 4. Chewing time was significantly different ($p<0.05$) among treatment. The animals consumed B-TMR and R-TMR had high chewing time. In contrast, animals consumed C-TMR and S-TMR had low chewing time. The incidence, probably due to C-TMR and S-TMR are small particle size and less physical effective NDF that may affect chewing time. Generally, total chewing time decreases as dietary forage NDF decreased (Beauchemin, 1991) or particle size decreases (Grant *et al.*, 1990). Additionally, chewing time and rumination times approximated the lower values reported by Yang and Beauchemin (2006) and Oshita *et al.* (2008). When expressed chewing time kg^{-1} of NDF intake, the animal fed B-TMR had highest. The result indicated that chewing time increased as increasing NDF intake.

Table 5: Blood urea nitrogen, ruminal pH and ammonia nitrogen in beef cattle fed difference TMRs

	Dietary treatments[1]				
Parameters	C-TMR	B-TMR	R-TMR	S-TMR	SEM
Blood Urea Nitrogen (BUN) (mg%)					
0 h	8.5	6.5	6.0	7.0	0.40
2 h	9.7[a]	7.8[b]	5.5[c]	7.8[b]	0.42
4 h	9.0	8.3	6.5	9.0	0.43
6 h	9.5[a]	8.0[a]	6.3[b]	8.8[a]	0.35
Average	9.0	8.2	7.7	6.4	0.33
pH					
0 h	6.8	6.8	7.0	6.9	0.06
2 h	6.7	6.9	6.6	6.7	0.11
4 h	6.4	6.7	6.7	6.4	0.07
6 h	6.3	6.7	6.7	6.4	0.10
Average	6.6	6.7	6.8	6.6	0.07
Ammonia nitrogen (NH_3-N) (mg%)					
0 h	8.2	6.9	10.4	10.8	0.85
2 h	22.2[a]	19.5[b]	15.6[c]	19.3[b]	2.26
4 h	19.1	19.5	9.9	5.6	2.64
6 h	8.6	10.6	12.2	12.3	2.55
Average	14.5	14.1	12.0	12.0	2.48

[a, b, c]: Means within a row different superscripts differ ($p<0.05$), [1]C-TMR = Corn cob as fiber source, B-TMR = Burma padauk leave as fiber source, R-TMR = Rain tree leave as fiber source, S-TMR = Siamese rough bush leave as fiber source

Number of chews, number of chews per kg NDF intake, number of chew per eating time, ruminated boli, ruminated boli per kg NDF intake, number of chews per bolus and number boli per rumination time was not significantly affected by fiber sources in TMR (Table 4), except for number of chews per rumination time. The number of chewing had highest when animals fed B-TMR. However, chewing time and number of chewing are in the normal range. The result suggested that fodder tree was not negatively affect chewing activity, when use as fiber sources in TMR. Generally, chewing activity was affected by effective fiber in the ration (NRC, 1989). Fodder trees are high in effective fiber; they therefore, not affect chewing activity.

Ruminal fermentation and blood urea nitrogen: Concentrations of NH_3-N and pH in rumen fluid were used to monitor the ruminal fermentation pattern (Table 5). The pH was not altered by fiber source in TMRs ($p>0.05$). When monitoring pH pattern at 0, 2, 4 and 6 h post feeding, the pH values were relatively stable at 6.3-7.0 and all treatment means were within the normal range that has been reported as optimal pH (6.0-7.0) for microbial digestion of protein (Hoover, 1986) and fiber digestion (Theodorou and France, 1993). Generally, rate and extent of carbohydrates degradation are influenced ruminal pH (Nocek and Russell, 1988). The large amount of soluble carbohydrate may reduce the pH of rumen fluid and this can affect the rate of fermentation of structural carbohydrate (Sutton and Alderman, 2000). In addition, ruminal pH was partly regulated by the NH_3-N concentration (Chanjula *et al*., 2004) and VFA concentration in the rumen (Stokes *et al*., 1991). In spite of, the NH_3-N in the rumen at 2 h post feeding was increased of all treatment (Table 5), but it did not alter ruminal pH. It was possibly, the buffering capacity can maintained the ruminal pH. The current results are in agreement with *in vitro* studies (Chumpawadee and Pimpa, 2009) that observed pH was not markedly affected by fiber sources in TMRs. Generally, fodder tree have high effective fiber. It was expected that they positively affect chewing activity and leading to normal rumen condition and digestion.

Ammonia nitrogen concentration was significantly different ($p<0.05$) among treatments at 2 h of sampling. The results are in agreement with *in vitro* studies (Chumpawadee and Pimpa, 2009) that observed an NH_3-N concentration was influenced by fiber source in TMRs. The difference in NH_3-N concentrations among treatments may have been related directly to urea and degradability of protein in the TMRs. However, NH_3-N concentration was in the optimal range for rumen ecology, microbial activity (Perdok and Leng, 1990; Wanapat and Pimpa, 1999). At 2 h post feeding C-TMR had the highest NH_3-N, when compared with other TMRs. When ammonia nitrogen is high it indicates that the soluble fraction of protein is also high. There was highly correlated between BUN and NH_3-N concentration in the rumen (Church, 1972). Thus, animals fed C-TMR were also high BUN (Table 5). It was possibly protein degradation is more rapidly than synthesis or imbalance of fermentable energy and nitrogen available, so ammonia will accumulate in the rumen fluid and absorbed in to the blood, carried to the liver and converted to urea.

CONCLUSION

Based on this study, it can be conclude that the fodder tree as fiber sources in TMRs have been affected feed intake, crude protein digestibility, chewing behavior and ruminal fermentation. The animals fed fodder tree TMR had positive affect on feed intake, chewing activities and ruminal fermentation. Therefore, burma padauk leave, rain tree leave and siamese rough bush leave can be use as fiber sources in TMR, especially when acute shortage of conventional fiber sources.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to all staff and my student for their invaluable help on the farm and laboratory. We are grateful to the Division of Animal Science, Faculty of Veterinary and Animal Science, Mahasarakham University for supporting experiment facilities. Financial support was provided by The Thailand Research Fund and Commission on Higher Education under the program 'New Researcher Grant'.

REFERENCES

AOAC, 1990. Official Methods of Analysis Association of Official Analytical Chemist. 15th Edn. Arlington, Virginia. ISBN: 0-935584-42-0.

Baloyi, J.J., N.T. Ngongoni, J.H. Topps and P. Ndlovu, 1997. Chemical composition and degradability of *Brachystegia spiciformis* (Musasa) leaves and stems harvested over 4 months from three site in Zimbabwe. Anim. Feed Sci. Technol., 69: 179-186. DOI: 10.1016/S0377-8401(97)81632-X.

Beauchemin, K.A., 1991. Effects of dietary neutral detergent fiber concentration and alfalfa hay quality on chewing, rumen function and milk production of dairy cows. J. Dairy Sci., 74: 3140-3151. http://jds.fass.org/cgi/reprint/74/9/3140.pdf.

Chanjula, P., M. Wanapat, C. Wachirapakorn and P. Rowlinson, 2004. Effect of synchronizing starch sources and protein (NPN) in the rumen on feed intake, rumen microbial fermentation, nutrient utilization and performance of lactating dairy cows. Asian-Aust. J. Anim Sci., 17: 1400-1410.

Chumpawadee, S., A. Chantiratikul and P. Chantiratikul, 2007. Chemical compositions and nutritional evaluation of protein feeds for ruminant using *in vitro* gas production technique. Int. J. Agric. Technol., 3 (2): 191-202. http://www.ijat-rmutto.com/pdf/Nov_V3_no2_07/4-IJAT2007_25-P%20191-202.pdf.

Chumpawadee, S. and O. Pimpa, 2008. Effect of non forage high fibrous feedstuffs as fiber sources in total mixed ration on gas production characteristics and *in vitro* fermentation. Pak. J. Nutr., 7 (3): 459-464. http://www.pjbs.org/pjnonline/fin944.pdf.

Chumpawadee, S. and O. Pimpa, 2009. Effect of burma badauk (*Plerocarpus indicus*), rain tree (*Samanea saman* (*Jacg.*) *Merr*) and siamese rough bush (*Streblus asper*) leaves as fiber sources in total mixed ration on *in vitro* fermentation. Asian J. Anim. Vet. Adv., 4 (1): 1-8. http://www.scialert.net/gredirect.php?doi=ajava.2009.1.8&linkid=pdf.

Church, D.C., 1972. Digestive Physiology and Nutrition of Ruminants. Practical Nutrition. O and B Books. Inc. Corvallis, Oregon, USA, 3: 351. ISBN: 978088133 603.

Everson, R.A., M.A. Jorgensen, J.W. Crowley, E.L. Jensen and G.P. Barrington, 1976. Input-output of cow feed a complete ration of a constant or variable forage-to-grain ratio. J. Dairy Sci., 59: 1776-1787. http://jds.fass.org/cgi/reprint/59/10/1776.pdf.

Fernandez, C., P. Sanchez-Seiquer and A. Sanchez, 2003. Use of a total mixed ration with three sources of protein as an alterative feeding for dairy goats on southeast of Spain. Pak. J. Nutr., 2 (1): 18-24. http://www.pjbs.org/pjnonline/fin78.pdf.

Hoover, W.H., 1986. Chemical factors involved in ruminal fiber digestion. J. Dairy Sci., 69: 2755-2766. http://jds.fass.org/cgi/reprint/69/10/2755.pdf.

Grant, R.J., V.F. Colenbrander and D.R. Metens, 1990. Milk fat depression in dairy cows: Role of particle size of alfalfa hay. J. Dairy Sci., 73: 1823-1833. http://jds.fass.org/cgi/reprint/73/7/1823.pdf.

Kawashima, T., W. Sumamal, P. Pholsen, R. Chaithang, W. Boonpakdee and F. Terada, 2003. Energy and nitrogen metabolism of Thai native cattle given ruzi grass hay with difference levels of soybean meal. In: Annual Research Report, Division of Animal Nutrition, Department of Livestock development, Ministry of Agriculture and Cooperative, pp: 263-378. http://www.dld.go.th/nutrition/exhibision/RESERCH_research_full/2546/R4627.doc.

Lowry, J.B., C.S. McSweeney and B. Palmer, 1996. Changing perceptions of the effect of plant phenolics on nutrient supply in the ruminant. Aust. J. Agric. Res., 47: 829-842. DOI: 10.1071/AR9960829.

Milis, Ch. and D. Liamadis, 2007. Effect of protein levels, main protein and non forage fiber source on digestibility, N-balance and energy value of sheep rations. J. Anim. Vet. Adv., 6 (1): 68-75. http://www.medwelljournals.com/fulltext/java/2007/68-75.pdf.

National Research Council (NRC), 1989. Nutrient Requirements of Dairy Cattle. 6th Rev. Edn. Natl. Acad. Sci., Washington, DC. ISBN: 0-309-03826-X.

Nocek, J.E. and J.B. Russell, 1988. Protein and energy as on integrated system: Relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. J. Dairy Sci., 71: 2070-2077. http:/jds.fass.org/cgi/reprint/71/8/2070.pdf.

Oshita, T., K. Sudo, K. Nonaka, S. Kume and K. Ochiai, 2008. The effect of feed regimen on chewing time, digesta passage rate and particle size distribution in Holstein non lactating cows fed pasture *ad libitum*. Livest. Sci., 113: 243-250. DOI: 10.1016/j.livsci.2007.04.001.

Perdok, H.B. and R.A Leng, 1990. Effect of supplementation with protein meal on the growth of cattle given a basal diet of untreated or ammoniated rice straw. Asian-Aust. J. Anim. Sci., 3: 269-279.

SAS, 1996. SAS User's Guide: Statistics, Version 6. 12th Edn. SAS Institute Inc. Cary, NC. ISBN: 15554 47627.

Spahr, S.L., R.D. Shanks, G.C. Mccoy, E. Caitz and O. Kroll, 1993. Lactation potential as criterion for strategy of feeding total mixed ration to dairy cows. J. Dairy Sci., 76: 2723-2735. http:/jds.fass.org/cgi/reprint/76/9/2723.pdf.

Schneider, B.H. and W.P. Flatt, 1975. The Evaluation of Feed through Digestibility Experiments. The University of Georgia Press, Athens, USA. ISBN: 0-8203-0378-X.

Stokes, S.R., W.H. Hoover, T.K. Miller and R. Blauweikel, 1991. Ruminanl digestion and microbial utilization of diets varying in type of carbohydrate and protein. J. Dairy Sci., 74: 871-881. http://jds.fass.org/cgi/reprint/74/3871.pdf.

Sutton, J.D. and G. Alderman, 2000. The energy and protein requirements of pregnant and lactating dairy goats: The Agriculture and Food Research Council report. Livest. Prod. Sci., 64: 3-8. DOI: 10.101618031-6226(00)00170-6.

Theodorou, M.K. and J. France, 1993. Rumen Microorganism and Their Interaction. Feeding System and Feed Evaluation Models. In: Theodorou, M.K. and J. France (Eds.). Biddles Ltd., Guidford, UK., pp: 154-164. ISBN: 0-85199-346-X.

Van Keulen, J. and B.A. Young, 1977. Evaluation of acid insoluble ash as a natural marker in ruminant digestibility studies. J. Anim. Sci., 44: 282-287. http:/jds.fass.org/cgd/reprint/74/10/3583.pdf.

Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods for dietary fiber, neutral detergent fiber and Non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597. PMID: 1660498.

Wanapat, M. and O. Pimpa, 1999. Effect of ruminal NH_3-N levels on ruminal fermentation, purine derivatives, digestibility and rice straw intake in swamp buffaloes. Asian-Aust. J. Anim. Sci., 12: 904-907.

Yang, W.Z. and K.A. Beauchemin, 2006. Effects of physical effective fiber on chewing activity and ruminal pH of dairy cows fed diets based on barley silage. J. Dairy Sci., 89: 217-228. http:/jds.fass.org/cgd/reprint/89/1/217.pdf.