EFFECTS OF VARYING DIETARY LEVELS OF TOTAL DIGESTIBLE NUTRIENTS, PROTEIN AND FIBER ON THE GROWTH OF CROSSBRED HOLSTEIN HEIFERS FED UREA-TREATED RICE STRAW DIETS UNDER TWO FEEDING SYSTEMS

S. Promma[1], S. Tuikumpee, P. Jeenkum and T. Indratula

National Dairy Training and Applied Research Institute
Chiangmai 50000, Thailand

Summary

This experiment was carried out to examine the effects of urea-treated rice straw feeding on the growth performance of crossbred Holstein heifers under different feeding conditions. In the first experiment, the animals were given diets having 2 levels of TDN and CP and 3 levels of crude fiber (22, 30 and 36%) which were formulated with urea-treated rice straw and concentrates. Daily weight gain of heifers was not different between 22% and 30% CF diets, but the reduction of TDN or CP level to 90% of the requirements decreased the weight gain. Fiber content of 36% also reduced the body weight gain. The reduction of TDN significantly reduced DM intake and increased feed conversion ratio. Feed cost per kg weight gain was significantly increased by an increase in CF to 36%. In the second experiment, separate feeding and total mixing feeding were compared. There were no significant differences between the two feeding systems in body weight gain although the possibility of superiority in SF to TMF remained. DM intake was not affected by the feeding system, but 30% CF diet gave higher DM intake. Feed cost per kg weight gain was lower in the 30% CF diet.

(**Key Words**: Digestibility, Fiber Level, Urea-treated Rice Straw, Growth Performance, Crossbred Holstein Heifer, Feeding System)

Introduction

Rice straw represents the major crop residue in the developing countries. Treatment of rice straw with urea has been proved for increasing organic matter digestibility (Wanapat et al., 1982) as well as supporting productivity of cattle (Promma et al., 1988). The benefit of urea-treated rice straw feeding also showed economic value with growing cattle and milking cows (Promma et al., 1985). Feeding of urea-treated rice straw needs concentrate supplements when satisfactory performances are required (Promma et al., 1983; Wanapat et al., 1986). The report of Promma et al. (1982) showed that the supplementation of concentrates (65% TDN and 14.8% CP) at the rate of 1.5 kg/day for crossbred Holstein heifers fed on *ad libitum* urea-treated rice straw supported weight gain of 431 g/day.

For effective feeding management, the nutrient requirements recommended by NRC (1988) or ARC (1980) are used. Since information of nutrient requirements on crossbred dairy cattle is limited, nutritionists still use the same recommendation as given for the purebred cattle. Patle and Mudgal (1975) indicated that non-lactating crossbred dairy cattle required less energy and protein than those recommended by NRC. When the levels of nutrients was reduced to 70% of the NRC recommendation, however, negative responses would be shown (Panichutra, 1982). The fiber content of diet represents an amount of roughage being fed. Fiber fractions as presently be used are crude fiber (CF), acid detergent fiber (ADF) and neutral detergent fiber (NDF). Crude fiber and ADF are the appropriate units for milking cow feeding, the levels being 17% and 19%, respectively (Lofgren and Warner, 1970). According to Promma et al. (1985, 1988), however, feeding urea-treated rice straw with concentrates to meet the required weight gain of cattle normally provides crude fiber in the total

[1]Address reprint requests to Mr. S. Promma, National Dairy Training and Applied Research Institute. 1 Moo 4, Laddaland Road, Chiangmai 50000, Thailand.
Received July 7, 1992
Accepted October 27, 1992

ration from 32.0% to 32.8% on dry matter basis. Therefore, crude fiber level between 17% and 32% in the ration containing urea-treated rice straw should be investigated with the crossbred Holstein heifers. For applying NDF unit in feed formulation for cattle especially when by-products are fed, more experiments will be required.

Feeding dairy cattle is based on two feeding systems: concentrates and roughages separately (SF), and total mixed rations (TMR). Feeding high producting cows has been achieved with the TMR system (Rakes, 1969). TMR feeding provides a desired amount of forage relative to the amount of concentrates offered and improves feed efficiency (Lawrence, 1990). The separate feeding system is conventionally used by farmers in developing countries and has been used for urea-treated straw feeding experiments by many researchers (Promma et al., 1982; Wanapat et al., 1982; Cheva-Isarakul and Potikanond, 1985).

The objectives of this experiment were to examine the effect of three different fiber levels as well as energy and protein levels on growth of crossbred Holstein heifers fed a urea-treated rice straw diet, and also to compare the SF system with the TMR system on growing heifers.

Materials and Methods

Urea-treated rice straw was prepared by adding the straw with water and urea at the ratio of 100 : 100 : 6 on weight basis under the air-tight condition by covering the heap of exposed straw with polythene sheets overlapping and left for at least 21 days. Treated straw was removed daily and chopped into 15 cm prior to feeding. The treated straw was fed as fresh form without aeration.

This experiment composed of 2 trials, one was for examining the levels of TDN, CP and crude fiber in the diets, and another for comparing the feeding systems. The experimental design, animals and diets used were as follows: Trial 1: This experiment was planned to study the effect of TDN, CP and crude fiber (CF) levels on the growth of heifers. Eighteen 12-14 month-old crossbred Holstein heifers (75% Holstein blood) having similar previous growth records were used in this experiment. They were randomly arranged into 6 treatments of 3 animals each. Treatments were 1TDN-1CP-22CF, 1TDN-1CP-30CF, 1TDN-0.9CP-30CF, 0.9TDN-1CP-30CF, 0.9TDN-0.9CP-30CF and 1TDN-1CP-36CF, where, 1TDN, 1CP and 22CF represent 100% of TDN, 100% of CP, both recommended by NRC, and 22% of crude fiber level, respectively. All animals were dewormed prior to the experiment. The heifers were individually tethered in stalls with *ad libitum* access to water. The animals were given experimental diets for 112 days, and the body weight was measured every 2 weeks throughout the experimental period. Feed ingredients used in this experiment were urea-treated rice straw (UTS), soybean meal (SBM) and ground corn (GC) as sources of fiber, protein and energy, respectively. Each ingredient was analyzed every 2 weeks and experimental diets were formulated using these data to meet the NRC requirements (1988). The diets were supplemented with a mineral mixture and vitamins so as to meet the requirements recommended by NRC. For the formulation of the diets, a computer program developed by Promma et al. (1990) was employed. The ranges and mean values of chemical composition of each ingredient are shown in table 1. The experimental diets were divided into 2 parts, one being UTS and another mixed concentrates of SBM, GC, mineral mixture (Ca 17.5%, P 7.2%, S 1.9% and adequate amounts of trace minerals) and vitamins (A 10^6 IU/kg, D 300,000 IU/kg and E 80 g/kg). Urea-treated rice straw and concentrates were separately given twice a day. All animals completely consumed the given diets except the group given high fiber diet (1TDN-1CP-36CF), in which case UTS residues were weighd next day before feeding.

Trial 2: This experiment was conducted to study the effect of 2 dietary fiber levels in association with 2 feeding systems (SF and TMR) on growth of growing heifers. Twenty 18-21 month-old crossbred Holstein growing heifers with similar blood level were randomly divided into 4 groups of 5 heifers each. Treatments were designed as 22CF-SF, 22CF-TMR, 30CF-SF and 30CF-TMR. All animals were similarly maintained as Trial 1. The experiment was carried out for 238 days. Diets for each treatment were prepared using the same roughage and concentrates as shown in Trial 1. Amounts of feed were calculated using the computer program to meet the requirements at 1TDN and 1CP levels. Feeding

management of SF was the same as Trial 1, and that of TMR was such that all ingredients including urea-treated rice straw were mixed together with some additional amount of water in a plastic container prior to the feeding time.

Feed samples were weekly collected and dry matter (DM), crude ash (CA), crude protein (CP), ether extract (EE), crude fiber (CF) and nitrogen free extract (NFE) were analyzed by standard method of AOAC (1975). Crude protein of urea-treated straw was analyzed using fresh samples. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) of the feed ingredients were analyzed by the method of Goering and Van Soest (1970).

Determination of digestibility and TDN of urea-treated rice straw was done by using four 12 month-old male crossbred bulls. The animals were given UTS for 7 days as a preliminary period followed by 14 days of collection period. Feces from each animal were weighed and checked on DM content every day. Fecal samples for the chemical analysis were obtained from the pool of daily specimen which were kept refrigerated. Urea-treated rice straw was given at the constant amount (2.2% of body weight, BW). Feed and fecal samples were analyzed on DM, CA, CP, EE, CF and NFE. The digestibility and TDN of GC and SBM were determined by the difference method of Church and Pond (1988) using UTS as the basal diet (2% of BW) plus the test feed (1% of BW).

Feed cost was calculated using the feed prices at the time of experiment; (in Baht/kg FM) UTS 0.67, GC 3.8, SBM 11.5, mineral mixture 7 and Vitamins 400.

Data of weight gain, feed intake, feed conversion ratio (FCR) and feed cost were analyzed statistically using analysis of variance in a completely random design (Trial 1) and in a 2 × 2 factorial design (Trial 2). The difference between treatment means was tested by Duncan's new multiple range test (Steel and Torrie, 1960).

Results and Discussion

The chemical composition of feeds used in the experiments showed that crude protein of the fresh urea-treated rice straw was 7.7-8.5% (table 1). These values were much higher than the value (3.5%) of untreated rice straw reported by Wanapat et al. (1982). The composition of other components were not so much different from those of untreated straw. Digestibilities of nutrients and TDN values of each ingredient are indicated in table 2. Digestibilities of DM and CF of UTS were 59.4% and 72.7%, respectively, and these values were similar to those in sheep reported by Chevalsarakul and Cheva-Isarakul (1992). TDN of UTS was 54.1% on dry matter basis, and again it was higher than the average value of untreated straw, being 44.7% reported by Promma et al. (1985). This was due to the

TABLE 1. DRY MATTER BASIS COMPOSITION OF UREA-TREATED RICE STRAW AND CONCENTRATES USED IN THE EXPERIMENT

Composition (DMB)	UTS		Ground corn		Soybean meal	
	range	(mean)	range	(mean)	range	(mean)
Dry matter, fresh (%)	48.0-69.8	(58.6)	86.3-89.6	(88.2)	87.5-89.0	(88.4)
Crude ash (%)	14.3-18.2	(16.5)	1.3- 1.6	(1.5)	6.0- 8.1	(7.0)
Crude protein (%)	7.7- 8.5	(8.0)	7.7-10.3	(8.9)	41.2-45.4	(43.3)
Ether extract (%)	1.8- 2.1	(1.9)	3.9- 5.2	(4.6)	2.0- 3.3	(2.4)
Crude fiber (%)	36.7-42.1	(39.3)	3.4- 8.5	(5.5)	6.1- 9.8	(7.9)
NFE (%)	33.2-35.8	(34.3)	77.5-82.4	(79.5)	35.0-39.5	(39.1)
NDF (%)	71.5 84.2	(78.0)	5.4-13.1	(8.7)	10.9-17.8	(14.5)
ADF (%)	50.7-68.0	(59.1)	4.8- 8.6	(6.5)	8.6-13.1	(10.9)
ADL (%)	4.5- 5.8	(5.2)	2.0- 2.9	(2.5)	–	(–)

UTS: Urea-treated rice straw.
NDF, ADF: Neutral or acid detergent fiber.
ADL: Acid detergent lignin.

TABLE 2. DIGESTIBILITY OF NUTRIENTS AND TDN VALUES IN EACH FEED INGREDIENT

(in %)	UTS	GC	SBM
DM	59.4 ± 1.4[1]	84.8 ± 1.8	87.3 ± 0.8
CP	41.6 ± 1.2	86.9 ± 1.0	95.2 ± 1.2
EE	46.3 ± 0.7	90.8 ± 0.7	86.6 ± 1.0
CF	72.7 ± 1.0	27.3 ± 0.8	87.4 ± 0.9
NFE	55.0 ± 1.6	87.6 ± 1.0	94.9 ± 1.0
TDN	54.1 ± 0.8	89.5 ± 1.1	88.1 ± 1.5

[1] SE, replication is 4.

higher digestibility of cell wall component as reported by Wanapat et al. (1982) and Cheva-Isarakul and Cheva-Isarakul (1992). Digestibilities and TDN of GC and SBM were almost similar to the previously reported data (NRC, 1988).

Effects of different levels of TDN, crude protein and crude fiber on the growth performance of heifers were shown in table 3. Feed intake of DM basis was significantly lower in the 0.9TDN-1CP-30CF and 0.9TDN-0.9CP-30CF groups than in the other groups. As expected, TDN intake was lower in the 0.9TDN groups. CP intake was also lower in the 0.9CP groups, but the 0.9TDN-1CP-30CF and 1TDN-1CP-36CF groups consumed small amounts of CP because of low body weight. The ratio of CP/TDN was 17.2-18.0% in the 1TDN-1CP and 0.9TDN-0.9CP groups, and 16.1% and 19.3% in the 1TDN-0.9 CP and 0.9TDN-1CP groups, respectively, since the diets were formulated to be so. When the DM intake was calculated as % of body weight, the 1TDN-1CP-30CF group consumed more DM than the 1TDN-1CP-22CF group because of higher fiber content. Although the diets for the 0.9TDN groups contained 30% CF, these groups consumed less DM due to less supply of ground corn. The 36CF group consumed more DM to cover the TDN requirement since the fiber content was very high in this diet. Nevertheless, TDN and CP intake of heifers offered 1TDN and 1CP levels were reach their requirements. CF intake was just as expected in all cases.

When the animals were fed the diets containing 1TDN and 1CP, average daily gain was not

TABLE 3. GROWTH PERFORMANCE OF CROSSBRED HOLSTEIN HEIFERS IN TRIAL 1 (REPLICATION 3)

	TDN	1	1	1	0.9	0.9	1	
Levels	CP	1	1	0.9	1	0.9	1	SEM
	CF	22	30	30	30	30	36	
Initial weight (kg)		140.7	148.3	132.8	127.3	116.3	134.0	8.4
Weight gain (WG) (kg)		62.5[c]	56.5[c]	46.7[b]	32.5[a]	42.6[ab]	32.8[a]	9.7
Daily gain (g)		583[c]	505[c]	417[b]	290[a]	380[ab]	293[a]	41
Feed intake (kg/d)								
DM		3.92[b]	4.51[b]	4.02[b]	3.44[a]	3.29[a]	4.27[b]	0.74
TDN		2.82	2.83	2.52	2.16	2.07	2.40	0.14
CP		0.49	0.50	0.41	0.42	0.36	0.43	0.02
CP/TDN (%)		17.2	17.7	16.1	19.3	17.5	18.0	0.35
CF		0.88	1.40	1.25	1.07	1.02	1.60	0.20
DM intake, % of BW		2.36[a]	2.68[b]	2.75[b]	2.49[a]	2.56[b]	3.08[c]	1.51
FCR, kg feed/kg gain		6.7[a]	9.0[a]	9.7[a]	12.1[b]	8.9[a]	15.2[b]	0.4
Feed cost, Baht/kg WG		21.2[a]	19.0[a]	18.6[a]	29.3[b]	19.1[a]	22.0[b]	0.5

[1] For TDN and CP, 1 and 0.9 represent 100% and 90% of the NRC requirements, respectively, and figures in CF show % of crude fiber in the diet.

Means of the same row with different superscripts differ at $p < .05$.

different between the groups fed 22% and 30% fiber, being 583 and 505 g/day, respectively. When the animals were fed the 0.9CP diet, the weight gain significantly decreased to 417 g/day, and the reduction was much higher when the 0.9TDN diet was fed, daily gain being 290 g. The effect of reducing both protein and energy to 0.9 was in between the effects of single redution of TDN and CP. It means that the decrease in energy level showed more negative effect on growth of heifers than the decrease in protein level. The result of this experiment is not in agreement with the report of Mudgal and Ray (1965) who found no effect on growth of Sahiwal calves when dietary protein was reduced from the standard by 20%. Such an unsimilarity may be due to the property of crude protein in the roughages used; since most of crude protein of UTS are in the form of ammonia nitrogen with a small amount of natural protein. Therefore, the role of protein fractions should be further studied, particulary in the straw treated with urea.

As stated previously, fiber levels of 22% and 30% did not show significant differences in weight gain, but the growth rate was significantly depressed by feeding the 36% CF diet. It may be due to the longer retention time of the high fiber diet in rumen in association with low soluble carbohydrates since no ground corn was given in this group. The present result well demonstrates that the fiber content should not be higher than 30% and TDN and CP should not be lower than the recommendation of NRC (1988), if more than 500 g of daily weight gain is required. Reflecting the feed intake and body weight gain, the feed conversion ratio (FCR) was higher in the 0.9 TDN- 1CP-30CF and 1TDN-1CP-36CF groups. Although not significant, the 22CF group showed better FCR than the 1TDN-1CP-30CF and 1 TDN-0.9CP-30CF groups and the 36CF group showed the worst FCR.

Although the feed cost for 1 kg body weight gain was not significantly different between the 22% and 30% fiber diets, it seemed that the 30% fiber diet would reduce the feed cost. The diet containing 36% crude fiber significantly increased the feed cost. Again, 10% reduction in the requirement of CP alone or of both CP and TDN did not cause any effect on feed cost, however, single reduction of TDN by 10% significantly increased feed cost for body weight gain.

Average nutrient contents of the diets were calculated from the data and the results are given in table 4. Compared with the NRC recommendation, TDN content was higher in the 22CF diet and lower in the 36CF diet, and the other diets were almost the same as the NRC recommendation. The CP content of the 1TDN-1CP-22CF and 0.9TDN-1CP 22CF diets was similar to that of the NRC recommendation, but the CP content of the 1TDN-1CP-30CF and 0.9TDN-0.9CP-30CF diets was 1% lower and that of the 1TDN-0.9CP-30CF and 1TDN-1CP-36CF diets was 2% lower than the NRC recommendation. Crude fiber, NDF and ADF contents were extremely higher in all cases. These figures would by the characteristics of the roughage used in this experiment.

Effects of feeding systems on growth of cross-bred Holstein growing heifers are shown in table 5. Since the interaction of fiber content and feeding system was not significant, only the main effects of CF level and feeding system could be discussed. The P values of the fiber effects for weight gain and DM intake were 0.06 and 0.05, respectively. When the DM intake was expressed as % of body weight, it was significantly higher in the 30% CF diet. It might be said that 22%

TABLE 4. NUTRIENT CONTENTS OF RATIONS CONSUMED BY HEIFERS (% DM BASIS)

Levels	TDN	1	1	1	0.9	0.9	1	NRC
	CP	1	1	0.9	1	0.9	1	
	CF	22	30	30	30	30	36	
TDN		71.9	62.8	62.8	62.7	62.8	56.1	61
CP		12.4	11.1	10.0	12.1	11.0	10.1	12
CF		22.4	31.1	31.1	31.2	31.1	37.5	15
NDF		43.5	61.3	61.1	61.5	61.2	74.3	25
ADF		32.9	46.4	46.3	46.6	46.4	56.3	19

TABLE 5. GROWTH PERFORMANCE OF CROSSBRED HOLSTEIN HEIFERS IN TRIAL 2 (REPLICATION 5)

CF level (%)	22	22	30	30	SEM	P value[2]		
Feeding system[1]	SF	TMR	SF	TMR		Fiber	System	Intac
Initial weight (kg)	194.8	199.6	181.5	192.2	11.5	–	–	–
Weight gain (kg)	165.3	140.2	138.8	128.6	9.4	–	–	–
Daily gain (g)	695	589	583	540	40	0.06	0.08	0.44
Feed intake (kg/d)								
DM	5.60	5.44	6.22	5.76	0.28	0.05	0.20	0.50
TDN	4.03	3.91	3.91	3.62	0.22		-	–
CP	0.63	0.60	0.60	0.55	0.02	–	–	–
CP/TDN (%)	15.6	15.4	15.3	15.3	0.1	–	–	–
CF	1.25	1.22	1.93	1.79	0.23	–		–
DM intake, % of BW	2.25	2.27	2.55	2.56	2.03	0.02	0.60	0.74
FCR, kg feed/kg gain	8.28	9.23	10.71	10.68	0.51	<0.01	0.34	0.31
Feed cost, B/kg gain	16.64	16.19	11.47	10.99	0.47	<0.01	0.34	0.98

[1] SF: Separate feeding system, TMR: Total mixed rations system.

[2] Level of significance. Fiber, System and Intac. show the effects of fiber content, feeding system and interaction.

CF give better growth performance of heifers since the growth rate was also higher in Trial 1 although no significant difference was shown statistically. Although DM intake was higher in the 30% CF diet than the 22% CF diet, but the intake of TDN and CP were not so much different and the CP/TDN ratio was also very similar. On the contrary, CF intake was about 50% higher in the 30% CF group than in the 22% CF group. This indicates that too high fiber feeding might give heifers a somewhat deteriorative effect. For the feeding system, P value of the DM intake was 0.20 and it might be said that no difference was shown between the 2 systems, but the P value of the weight gain was 0.08. Therefore, there was a possibility that the SF system was better than the TMR system. The lower weight gain by the TMR system as seen in this experiment might be due to the uncontinuing feed consumption. Animals fed by the TMR system ate over the total amount of feed within 1-2 hours, whereas the animals fed by the SP system consumed the treated straw slowly and finished it 4-6 hours later than the TMR system animals. Hence, by having continuous feed entering the rumen, microorganisms could get regular substrates and develop their population effectively. Accordingly, the synthesis of bacterial protein and VFA production in the rumen might be better in the SF system.

The FCR and feed cost were not different between the systems but different between fiber levels with a high possibility. The heifers fed the 22% CF diet consumed more concentrates and less UTS, and consequently the FCR was better in the 22% CF diet, but cost of production could be reduced by feeding the 30% CF diet. It can be said from the results obtained here that fiber content of 30% is more favorable than 22% from the economical point of view.

Acknowledgements

The authors sincerely acknowledge Prof. Dr. Iwao Tasaki, Faculty of Agriculture, Kyushu Tokai University, Japan for his advice on this experiment and the correction of the manuscript. The assistance of R. Wilairat, B. Nukchob, U. Tumprasen throughout the experimental period is greatly appreciated.

Literature Cited

AOAC. 1975. Official Methods of Analysis (12th ed.). AOAC, Washington. D.C.

ARC. 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureaux, Slough, England.

Cheva-Isarakul, B. and N. Potikanond. 1985. Performance of growing cattle fed diets containing

Untreated rice straw and Leucaena leaves compared to urea-treated rice straw. The Utilization of Fibrous Agricultural Residues as Animal Feeds. (Ed. P. T. Doyle). IDP, Canberra. pp 140-144.

Cheva-Isarakul, B. and B. Cheva-Isarakul. 1992. Urea-molasses multinutrient block 1. Supplementary effect on straw digestibility. Proc. 30th Kasetsart University Conf. Anim. Sci. pp. 275-286.

Church, D. C. and W. G. Pond. 1988. Basic Animal Nutrition and Feeding (3rd ed.) John Wiley & Sons, Inc., New York.

Goering, H. K. and P. J. Van Soest. 1970. Forage Fiber Analysis. USDA ARS Handbook No. 379.

Lawrence, D. M. 1990. Individual concentrate feeding and total mixed rations in meeting nutritional needs of dairy cows. Proc. Dairy Feeding Systems. Symp. NRAES, New York. pp. 113-124.

Lofgren, P. A. and R. G. Warner. 1970. Influence of various fiber sources and fractions on milk fat percentage. J. Dairy Sci. 53:296-304.

Mudgal, V. D. and S. N. Ray. 1965. Studies on the nutrients required for growth. I. Effect of feeding different levels of protein on growth of Sahiwal calves. Indian. J. Dairy. Sci. 18:21-30.

NRC. 1988. Nutrient Requirements of Dairy Cattle (6th ed.) National Academy Press. Washington, D.C.

Panichutra, C. 1982. Influence of feeding three planes of nutrition on growth, feed efficiency and reproduction of dairy heifers. M. Sc. Thesis, Kasetsart University, Bangkok.

Patle, B. R. and V. D. Mudgal. 1975. Maintenance requirement for energy in cross-bred cattle. Brit. J. Nutr. 33:127-134.

Promma, S., A. Ratnawanija, S. Tuikampee, N. Vidhayakorn and A. Suvapap. 1982. Effect of Feeding treated rice straw as the main roughage for crossbred Holstein Friesian heifers. Paper presented in 20th Conf. Anim. Sci. Kasetsart Univ. Bangkok.

Promma, S., S. Tuikampee, N. Vidhayakorn and A. Ratnavanija. 1983. A study on feeding beef cattle with treated rice straw. Paper presented in 21st Conf. Anim. Sci. Kasetsart Univ. Bangkok.

Promma, S., S. Tuikampee, N. Vidhayakorn and R. W. Froemert. 1985. The effects of urea-treated rice straw on growth and milk production of crossbred Holstein Friesian dairy cattle. The Utilization of Fibrous Agricultural Residues as Animal Feeds. (Ed. P. T. Doyle). IDP, Canberra. pp. 88-93.

Promma, S., N. Vidhayakorn, S. Tuikampee and A. Suvapap. 1988. Supplements of concentrates Leucaena or molasses/urea for untreated or urea-treated straw diets for growth of crossbred Holstein Friesian heifers. Ruminant Feeding systems Utilizing Fibrous Agricultural Residues-1987. (Ed. R. M. Dixon). IDP. Canberra. pp. 233-238.

Promma, S., P. Jeenklum and T. Indaratula. 1990. Development of the XRATION computer program for dairy cattle ration formulation. Annual Report of Animal Production Research Department of Livestock Development. Bangkok. pp. 257-279.

Rakes, A. H. 1969. Complete rations for dairy cattle. J. Dairy Sci. 52:870-875.

Steel, R. G. D. and J. H. Torrie. 1960. Principle and Procedures of Statistics. McGraw-Hill Book Co. New York.

Wanapat, M., S. Prasertsuk, S. Chanthai and S. Sivapraphagon. 1982. Effects on rice straw utilization of treatment with ammonia released from urea and/or supplementation with cassava chips. The Utilization of Fibrous Agricultural Residues as Animal Feeds. (Ed. P. T. Doyle). IDP, Canberra. pp. 95-101.

Wanapat, M., S. Duanchan, S. Pongpairote, T. Anakewit and P. Tongpanung. 1986. Effects of various levels of concentrate fed with urea-treated rice straw for purebred American Brahman yearling cattle. Ruminant Feeding System Utilizing Fibrous Agricultural Residues-1986. (Ed. R. M. Dixon). IDP, Canberra. pp. 149-153.