CHAPTER IV

EXPERIMENT 2: EFFECTS OF SOLUBLE PROTEIN AND SUGAR CONCENTRATION ON RUMINAL FERMENTATION AND NUTRIENTS DIGESTIBILITY IN CROSSBRED STEERS

4.1 Introduction

Protein and carbohydrates are the major nutrients, both in quantity and degradability, required by rumen microbes for optimal microbial protein synthesis (Hoover and Webster, 1998; Sinclair et al., 1995). Optimum utilization of dietary crude protein (CP) requires a selection of complementary feed protein sources that provide the proteins, peptides, amino acids, and ammonia that constitutes rumen degradable protein (RDP) and meets the specific nitrogen requirement of rumen microbes. Soluble protein (SP) is the portion of the RDP that is presumed to be immediately available for utilization by rumen microbes (NRC, 2001). The supply of SP can result in ammonia nitrogen (NH_3-N) that escapes microbial capture, depending on the availability of readily fermentable carbohydrates. Therefore, carbohydrate availability for ruminal fermentation is the key factor for improving the efficiency of ruminal ammonia utilization and critically important in overall dietary nitrogen (N) utilization in ruminants. Feeding supplementary sugar has been shown to decrease ruminal ammonia and increase fiber digestibility (Sannes et al., 2002; Vallimont et al., 2004). Hall and Herejk (2001) found that sucrose induced rapid *in vitro* microbial growth; in order of substrate mediated microbial growth induction, sucrose was followed by pectin, starch and isolated neutral detergent fiber. Moreover, the Cornell Net Carbohydrate and Protein System (NRC, 1996) has indicated that the organisms that ferment soluble sugar could contribute approximately 18 % more of the microbial protein synthesis than those organisms that ferment starch. Several researchers have studied the effects of adding sugar to the diet of lactating cows on fermentation products (McCormick et al., 2001; Sannes et al., 2002; Broderick et al., 2008; Penner and Oba, 2009), in which the sugar added was in proportions not exceeding 3 to 8.4% of the dietary dry matter (DM). Buaphan et al. (2008) reported that replacing cassava with sugar at a 25% level improved the DM and NDF digestion linearly on *in vitro* study. If sugars improve microbial growth and fiber digestibility through a better synchronization between the rapidly available nitrogen and carbohydrate, then SP and sugar may be used at higher levels and feather enhance nutrient digestion and utilization in ruminants fed low-quality roughage. The objective of this study was to investigate the effects of varying the concentrations of SP and sugar on the dry matter intake (DMI), ruminal fermentation, blood metabolites, and total tract digestibility of nutrients in crossbred Thai native steers.

4.2 Materials and methods

4.2.1 Animals, experimental design and diets

Four crossbred steers (Thai Native × Brahman, average age 24 ± 2 months, 241 ± 26 kg of body weight) fitted with ruminal cannulae were used in a 4 × 4 Latin square design. The steers were treated for internal and external parasites at the beginning of the experiment and kept in individual pens of approximately nine m^2. Body weights (BW) were measured on the start and end of each period to compute BW change. Treatments diets (Table 1) were in a 2 × 2 factorial arrangement, with the main effects being the levels of SP (8.0 or 11.0% of diet DM; 60.0 or 80.0% of the total CP) and the levels of sugar (11.0 or 22.0% of diet DM), with similarly calculated total CP (14% of DM) and total digestible nutrient (TDN; 70% of the DM) contents by using KCF 2006 Program (Pattarajinda and Duangjinda, 2006). Cane sugar powder waste, the by-product of fruit-flavored instant drink mix (Kraft Foods, Thailand), was used as the main source of sugar. It was 98.0% DM, approximately 96.0% sugar, consisting mostly of sucrose. Urea the main source of N in this study (2.4 and 3.6% of diet DM); and increased the percentage of SP in the diet with its inclusion in the TMR. These SP and sugar level adjustments yielded four treatment rations: low SP-low sugar (L-SP-L-SU), low SP-high sugar (L-SP-H-SU), high SP-low sugar (H-SP-L-SU), and high SP-high sugar (H-SP-H-SU). The experiment was conducted for 72 days (d) (divided into 4 periods). Each experimental period was run for 18 d: 11 d for adaptation and 7 d for data collection and sampling. Steers were individually fed *ad libitum* intake, twice daily at 0800 and 1600 h. Diets were fed as a total mixed rations (TMR), in which rice straw and concentrate (previously mixed) were weighed and mixed before feeding. The orts were collected and weighed once daily, and diets were adjusted daily to yield orts of approximately 5 to 10% of the total feed offered. Steers had free access to clean drinking water.

Table 4.1 Ingredients of the feed and the chemical compositions of the experimental diets[a]

	L-SP		H-SP	
Item	L-SU	H-SU	L-SU	H-SU
Ingredient, % of DM				
Rice straw	30.0	30.0	30.0	30.0
Cassava chips	40.2	27.7	49.0	36.5
Ground corn	5.0	5.0	5.0	5.0
Soybean meal	11.0	11.5	1.0	2.5
Sugarcane powder waste	11.0	22.0	11.0	22.0
Urea, 46% N	2.4	2.4	3.6	3.6
Vitamins and minerals	0.4	0.4	0.4	0.4
Analyzed content, % of DM				
DM	92.13	92.91	92.32	93.82
OM	90.29	90.98	91.36	91.55
CP	13.71	13.48	13.52	13.03
NDF	28.32	28.85	28.85	26.64
EE	1.22	1.15	1.14	1.06
ADF	20.11	18.51	18.27	18.04
NFC[b]	47.81	48.04	48.51	51.35
SP	8.28	8.25	11.10	11.07
SP, % of total CP	60.39	61.20	82.10	84.96
Total sugar	11.96	22.60	11.33	21.97
SP:sugar ratio	1:1.44	1:2.74	1:1.02	1:1.98

[a] SP, soluble protein; L-SP, low soluble protein; H-SP, high soluble protein; L-SU, low sugar; H-SU, high sugar.

[b] NFC, non-fiber carbohydrate = 100- (% CP + % NDF + % EE + % Ash).

4.2.2 Samples collection and analysis

Feed samples were pooled within each collection period, dried in a forced-air oven at 60°C for 48 h, and ground through a 1-mm screen. Samples were analyzed for DM, organic matter (OM), CP, ash and ADF (AOAC, 1990), SP (Krishnamoorthy et al., 1982), sugar (AOAC, 2000), and NDF, as determined using heat-stable, α-amylase and sodium sulfite (Van Soest et al., 1991). On day 12 of each experimental period, the ruminal content was obtained at 0, 2, 4, and 8 h after the morning feeding and was subsequently strained through 2 layers of cheesecloth. The pH was measured immediately by using a pH meter (Electrochemical Analyzer, Consort model C933P). The ruminal fluid was preserved by adding 5 ml of 1*M* H_2SO_4 to 45 ml of rumen fluid and stored at - 20°C for the analysis of ammonia nitrogen (NH_3-N) and volatile fatty acids (VFA). Samples were thawed and centrifuged at 3,500 rpm for 15 minutes at 4°C; the NH_3-N was analyzed by using the micro-Kjeldahl method, and the VFA level (samples of 4 h post feeding) was analyzed by using an HPLC (Instruments by controller water model 600E; water model 484 UV detector), according to the method of Zinn and Owens (1986). Blood samples were collected at 0, 1, 2 and 4 h after feeding on day 12 from the jugular vein of each steer. Blood samples were collected into 10 ml serum tubes and allowed to clot for 60 min and then centrifuged at 2,500 rpm for 15 min. Serum aliquots were stored at - 20°C until further analysis for blood urea-N (BUN) and blood glucose (BG) concentrations with the Automated Chemistry analyzer (HITACHI, 912). The total tract digestibility of the DM, OM, CP, ADF and NDF was determined during the last week (day 13 to day 18) of each period. Chromium oxide (Cr_2O_3) was used as digestibility marker. The TMR diets were mixed to contain 1 g chromium oxide/kg DM and fed to the steers for 4 consecutive days before collecting feces samples every four hours, daily. The Cr was measured by atomic absorption spectrometry at a wavelength of 357.9 nm, using potassium dichromate as a standard. The total tract digestibility was calculated using the concentrations of the nutrients and chromium oxide in the diet and feces (Maynard et al., 1979).

4.2.3 Statistical analyses

The dry matter intake, nutrient intake, weight change, VFA and total tract digestibility of nutrients were analyzed using the SATTHERH model statement in the MIXED procedure of SAS (SAS, 1996) for a 4 × 4 Latin square design with a 2 × 2 arrangement of treatments. The model included effects for the SP and sugar level and the interaction between these factors with repeated experimental periods. Mean separations were determined using the PDIFF statement in PROC MIXED. Treatment differences were considered to be significant when $P<0.05$ and were considered to indicate a trend at $0.05<P<0.10$. The statistical model was the following:

$$Y_{ijkl} = \mu + \pi_i + P_j + \delta_k + \alpha_l + \delta\alpha_{kl} + \varepsilon_{ijkl}$$

Where:

Y_{ijkl} = the measured variable,

μ = the overall mean,

π_i = the random effect of the steer (i = 1, 2, 3, 4),

P_j = the fix effect of the period (j = 1, 2, 3, 4),

δ_k = the fix effect of the SP level (k = 1, 2),

α_l = the fix effect of the sugar level (l = 1, 2),

$\delta\alpha_{kl}$ = the interaction term of SP and sugar level,

ε_{ijkl} = residue error.

The rumen fluid pH, NH_3-N, BUN, and BG concentration data collected over time were analyzed using the MIXED procedure of SAS (SAS, 1996) with the model described above, except the 'repeated' option was used for 'time after feeding' instead of 'period'.

4.3 Results and Discussion

Ingredient and nutrient composition of diets are shown in Table 4.1. Diets were formulated to be isonitrogenous (14% CP), however, analyses ranged from 13.0% - 13.7% CP. Soluble protein (SP) increased as a percent of CP from 60.8 ± 0.6% for low SP and 83.5 ± 0.2% for high SP when urea was added to the diets. The diets with low or high sugar content were 11.7 ± 0.4%, or 22.3 ± 0.4% (DM basis). The CP content was lower, however, SP, and sugar content were higher than that calculated values; there were many factors that affect chemical compositions including uniform and variety of feed ingredients.

4.3.1 Intake, total tract digestibility, and performance

Nutrients intake and steer performance are presented in Table 4.2. No interaction was detected between SP and sugar concentration for nutrient intake and steer performance. The intake of SP was significantly greater ($P<0.05$) in steers consuming high-SP level diet (Table 4.2) compared to steer fed low-SP level diet. Intake of sugar was greater ($P<0.05$) for steers consuming high-sugar level diet. There were not differences ($P>0.05$) in daily OM intake. However, DMI was tentatively lower ($P<0.10$) for steers fed high-SP diet. This study urea was the main source of N, there was tendency for urea to decrease in DM intake as % of BW ($P<0.10$) when it was used to increase SP in rations. Some researchers suggested that decreased DM intake was likely a result of the bitter taste of the urea (Huber and Kung, 1981). Casper and Schingoethe (1986) have reported that the lowest DMI were found in cow fed urea, and Milton et al. (1997) have reported that a maximal DMI was observed in steers that consumed only 1.1% urea. The trend for decreased DMI was also reflected in daily intake of CP, NDF, or ADF for steers fed high-SP diet ($P<0.05$). When feeding urea, a substantial amount of excess nitrogen not utilized in rumen can be excreted. Slow-release urea and related products attempt to achieve a slower rate of nitrogen release in the rumen allowing more time for microbes to use nitrogen more efficiently while also preventing ammonia toxicity and eliminating negative effects on DM intake (Galo et al., 2003). However, the mechanism of intake depression with urea supplementation is not completely understood. Moreover, the lower intake may have been associated with increased ruminal starch (Milton et al., 1997). In contrast, sugar has been reported improve DMI. Broderick and Radloff (2004) fed dried molasses at 0, 4, 8, or 12% (2.6, 4.2, 5.6, or 7.2% total sugar, respectively) in replacement for high-moisture corn grain, and found increased DMI of lactating Holsteins with additional sugar. In Penner and Oba (2009) study found that cows fed high sugar (8.4% of DM) had increased DMI compared with those fed low sugar (4.7% of DM) (18.3. vs. 17.2 kg/d; $P<0.05$). Some studies have reported increased NDF passage to the omasum with increased dietary sucrose concentration (Broderick et al., 2008); whereas others have reported increases in the solid or liquid passage rates with sucrose, then enhance DMI (Rooke et al., 1987; Sutoh et al., 1996). However, this study DMI did not alter by increasing sugar level may possible due to short time period.

Steers fed low-SP (8% of DM) diets showed a tendency for improved total digestibility of DM and OM (P<0.10) and had higher values of total tract apparent ADF digestibility (P<0.05; Table 4.2), as compared with steers fed high-SP (11.0% of the DM) diets. The decrease in the ADF digestibility with high-SP diet may have been affected by the diet containing low amounts of true protein, or there may have been too much protein substrate, which was supplied more quickly than the microbes could utilize. Merry et al. (1990) and Griswold et al. (1996) have been reported that the digestibility of ADF was observed to increase with a true protein source, as compared with a diet of 100 % urea in an *in vitro* study. Moreover, Russell and Sniffen (1984) have reported that the addition of branched-chain volatile fatty acids (BCVFA) enhanced cellulose digestion. Another study reported that the addition of sucrose caused BCVFA to decrease linearly (Ribeiro et al., 2005). Cows consuming diets containing glucose, sucrose and lactose have lower ruminal concentrations of BCVFA than do diets containing more starch (Sannes et al., 2002; DeFrain et al., 2004; Hristor et al., 2005). It is possible that the BCVFA are converted to branched chain fatty acids by sugar-utilizing microbes (Lee et al., 1999). This use of BCVFA by sugar-utilizing has potential to affect other microbial populations like fiber digesters the require BCVFA for protein synthesis. However, in present study, there was found that sugar level had no significant effect on fiber (NDF and ADF) digestion.

Table 4.2 Effects of SP and sugar concentration in TMR diets[a] on the nutrient intake, total tract digestibility, and performance in crossbred steers

	L-SP		H-SP			P-value		
Item	L-SU	H-SU	L-SU	H-SU	SEM	SP	SU	SP×SU
Intake, kg/d								
DM	7.41	7.37	7.13	6.84	0.20	0.08	0.43	0.54
OM	6.69	6.70	6.51	6.26	0.19	0.14	0.53	0.48
CP	1.01	0.99	0.96	0.89	0.03	0.02	0.11	0.36
NDF	2.10	2.13	2.06	1.82	0.06	0.02	0.11	0.42
ADF	1.49	1.36	1.30	1.23	0.03	<0.01	0.03	0.45
SP	0.61	0.61	0.79	0.76	0.02	<0.01	0.44	0.57
Sugar	0.89	1.66	0.81	1.50	0.04	0.03	<0.01	0.34
DM intake, % of BW	2.79	2.79	2.66	2.59	0.14	0.08	0.70	0.66
Digestibility, %								
DM	89.35	89.42	88.79	88.12	0.44	0.07	0.50	0.41
OM	91.19	91.03	90.66	90.23	0.34	0.08	0.39	0.69
CP	91.56	90.10	90.67	90.53	0.37	0.56	0.08	0.14
NDF	77.15	77.35	76.90	74.08	1.14	0.16	0.27	0.21
ADF	76.69	75.99	74.10	71.39	1.41	0.02	0.21	0.44
Steer performance								
Initial weight, kg	267.3	265.8	269.0	266.0	14.43	0.45	0.11	0.56
Final weight, kg	285.5	283.8	284.5	282.5	15.60	0.61	0.41	0.95
Weight change, kg	18.3	18.0	15.5	16.5	1.57	0.11	0.75	0.60
ADG[b], kg/d	1.01	0.99	0.86	0.92	0.09	0.11	0.76	0.57

[a] SP, soluble protein; SU, sugar; L-SP, low soluble protein; H-SP, high soluble protein; L-SU, low sugar; H-SU, high sugar.

[b] ADG, average daily gain.

There were no differences in weight change among treatments (P>0.05) (Table 4.2). These findings were similar to the results of Chizzotti et al. (2008), in which no differences were found with ADG among steers (Holstein × Nellore crossbred, 350 ± 20 kg of BW) fed diets containing non-protein nitrogen (NPN) up to 66.3% of the total nitrogen (urea up to 2% of DM). This experiment was conducted for 99 d. Additionally, Glehorn et al. (2004) found no differences in the ADG (1.71, 1.67, and 1.64) among finishing beef steers (British × Continental, 305 - 357kg of initial BW) fed TMR diets (90% of concentrate) for 56 d, containing different CP concentration (11.5, 13.0, or 14.5% of dietary CP) and degradability (100:0, 50:50, or 0:100% of urea: cottonseed meal, respectively). In the current study, the concentration of SP was 60.8 or 83.5% of CP, and the NPN from urea was 49.2 and 78.0% of SP for low- or high-SP diets, respectively. This resulted in proportionally higher dietary soluble nitrogen levels in both the low- and high-SP diets, as compared to NRC (1996) recommendations. The intake and weight gain of steers might have been influenced more by the relatively high level of SP rather than increase in dietary sugar level.

4.3.2 Ruminal fermentation and blood metabolites

In this study, there were no SP and sugar interaction for ruminal pH, NH_3-N, VFAs production, and the main effect data are presented in Table 4.3. Penner et al. (2007) were of the view that the inclusion of higher levels of sugar in a ruminant diet might promote and lead to acidosis. Surprisingly, the daily mean data of the ruminal pH did not differ among the dietary treatments in the current study. The average daily pH across treatments ranged from 6.4 - 6.7, which is generally considered suitable for fiber digestion (Mould and Ørskov, 1983). Zinn (1995) attributed the response to increase in ruminally pH during the first hour after starting feeding that urea may serve as a buffer. Penner et al. (2009) reported that the ruminal pH for ruminally cannulated lactating Holstein cows (163±55 DIM) fed high- sugar (5.7%) diets was higher than those fed low- sugar (2.8%) diets, and this may have indicated that the rapid disappearance of sugar from the rumen did not result in a sustained increase in fermentation acid production in the rumen. It is also possible that bacteria convert soluble dietary sugar to glycogen as a short-term storage of energy that can be utilized later, thereby temporarily reducing fermentation acid production (Hall and Weimer, 2007). Furthermore, Hoover and Webster (2001) suggested that a high proportion of sucrose leaves the rumen with liquid fraction before fermentation, and Henning et al. (1993) have reported that the disappearance rate of sugar was 69%/h. However, if sucrose supplementation increased microbial-cell yield, the ruminally degraded OM available for fermentation, acid production would be reduced (Allen, 1997). In contrast, Khalili and Huhtanen (1991) found pH decreased, and lactic acid increased three fold when diets contained 16% of sucrose and were fed (6.3 kg/d) to male Friesian cattle. However, at 8 h post feeding steers fed low-SP and high-sugar diet trend to lower in ruminal pH ($P<0.10$, Table 4.3), may possible due to accumulative of organic acid in the rumen. Lactic acid production was observed for the first period of the present study in steers fed the high-sugar diet, 2.3 m*M* on average, and it remained at a normal range (0 - 5 m*M*) (Nagaraja and Titgemeyer, 2007). The increases in lactate production with high sugar diet is in accord with reports that, in some microbial species (*Streptococcus bovis*, *Selenomonas ruminantium*), rapid growth at high sugar concentration results in fermentation product shifts toward lactic acid production (Russell and Hino, 1985; Melville et al., 1988). However, Penner et al. (2009) reported that there were no detectable treatment effects (high-sugar, 5.7% vs.) low-sugar, 2.8% diets) on the bacteria profile as determined through PCR-coupled denaturing gradient gel electophoresis analysis.

Satter and Slyter (1974) reported that when NH_3-N concentration exceeds 5 mg/dl, microbial efficiency was maximized in continuous-culture. Hoover and Webster (2001) have stated that this level of NH_3-N is greatly influenced by the level of readily fermentable carbohydrates present. In the present study, at 0, 2, or 4 h post feeding of NH_3-N concentration were not significantly different among dietary treatments ($P>0.05$) Moreover, daily mean concentrations of rumen NH_3-N were above this level for all of the diets. The steers fed low-sugar level diet had lower in NH_3-N at 8 h post feeding compared to steers fed high-sugar level diet ($P<0.01$). Excess NH_3-N in the rumen fluid is absorbed through the rumen wall and transported to the liver, where it is metabolized to urea.

There were no statistically significant differences among treatments for total VFA, molar proportion of propionate, butyrate and A: P ratio ($P<0.05$; Table 4.3). However, it was observed that feeding a high-SP diet tended to cause the molar proportion of acetate to decrease, as compared to steers fed low-SP diet; this might have been due to the decreased ADF digestibility in the current study. Therefore, a TMR diet that contains 8.0% of SP (60% of the CP) and 11.0% of sugar may be a viable strategy for improving the intake, ruminal fermentation, digestibility and performance of steers.

Table 4.3 Effects of SP and sugar concentration in TMR diets[a] on the ruminal pH and NH_3-N

	L-SP		H-SP			P-value		
Item	L-SU	H-SU	L-SU	H-SU	SEM	SP	SU	SP×SU
Ruminal pH								
0 h before feeding	6.82	6.78	6.80	6.77	0.16	0.94	0.85	0.40
2 h post feeding	6.87	6.45	6.60	6.77	0.20	0.90	0.53	0.17
4 h post feeding	6.58	6.39	6.36	6.60	0.24	1.00	0.92	0.40
8 h post feeding	6.37	6.01	6.36	6.45	0.13	0.09	0.29	0.09
pH mean[b]	6.65	6.40	6.53	6.65	0.17	0.67	0.71	0.23
NH_3-N, mg/dl								
0 h before feeding	15.97	10.31	17.96	15.30	2.68	0.20	0.14	0.56
2 h post feeding	31.28	28.28	26.28	20.95	2.92	0.07	0.19	0.70
4 h post feeding	21.96	24.62	18.96	25.62	3.62	0.74	0.15	0.51
8 h post feeding	22.62	26.28	19.63	32.94	3.48	0.43	<0.01	0.07
NH_3-Nmean[c]	22.96	22.37	20.71	23.70	2.09	0.75	0.40	0.22
Total VFA, m*M*	97.20	97.95	91.24	82.45	5.87	0.12	0.52	0.45
Individual VFA, molar proportion								
Acetate	65.48	64.11	57.53	53.41	4.91	0.07	0.52	0.79
Propionate	18.57	20.37	21.56	16.47	3.05	0.87	0.56	0.24
Butyrate	12.80	13.46	12.15	12.57	1.31	0.60	0.71	0.93
A:P ratio[d]	3.94	3.19	2.94	3.35	0.61	0.32	0.79	0.27

[a] SP, soluble protein; SU, sugar; L-SP, low soluble protein; H-SP, high soluble protein; L-SU, low sugar; H-SU, high sugar.

[b] Treatment × time interaction (*P* = 0.02).

[c] Treatment × time interaction (*P* = 0.02).

[d] Acetate:propionate.

Table 4.4 Effects of SP and sugar concentration in TMR diets[a] on blood metabolite levels

	L-SP		H-SP			P-value		
Item	L-SU	H-SU	L-SU	H-SU	SEM	SP	SU	SP×SU
Blood urea N, mg/dl								
0 h before feeding	12.56	14.24	11.92	16.40	1.60	0.60	0.14	0.40
1 h post feeding	14.55	14.07	15.23	16.94	1.62	0.33	0.73	0.53
2 h post feeding	15.10	14.46	16.76	16.69	1.38	0.23	0.83	0.83
4 h post feeding	19.84	15.83	16.81	19.89	1.28	0.68	0.91	0.05
Blood urea N mean[b]	15.51	14.65	15.18	17.48	1.12	0.29	0.54	0.18
Blood glucose, mg/dl								
0 h before feeding	42.28	37.75	31.21	47.26	7.69	0.95	0.43	0.20
1 h post feeding	53.00	46.53	54.24	48.47	7.89	0.83	0.33	0.89
2 h post feeding	51.96	44.22	58.39	54.17	5.73	0.08	0.20	0.62
4 h post feeding	67.91	51.77	66.88	60.44	5.20	0.20	0.01	0.15
Blood glucose mean[c]	53.29	45.07	52.68	52.58	5.94	0.45	0.36	0.37

[a] SP, soluble protein; SU, sugar; L-SP, low soluble protein; H-SP, high soluble protein; L-SU, low sugar; H-SU, high sugar.

[b] Treatment × time interaction ($P = 0.40$).

[c] Treatment × time interaction ($P = 0.11$).

In this study, there was SP and sugar interaction for BUN at 4 h post feeding, steers fed low-SP and high-sugar level diet had lower in BUN compared with steers fed other diets ($P<0.10$; Table 4.4). The increased intake of SP did not affect the BUN concentration at 0, 1, or 2 h post feeding (Table 4.4); it appears that the NH_3-N concentration in the rumen was not high enough to elevate the BUN levels. However, this lack of BUN response may be due to the high level of sugar in the diets. Sannes et al. (2002) have reported that sucrose tended to reduce ($P<0.10$) total urinary N excretion and milk urea nitrogen (MUN) of lactating Holstein cows and decreased plasma urea nitrogen (PUN) in sheep (Obara and Dellow, 1993). These findings suggest a potential for improved nitrogen utilization by adding sucrose. In this study, however, an effect on NH_3-N by the diet sugar levels was observed only at 8 h post feeding. It is possible that the concentration of the dietary SP might be above the requirement of the ruminal microbes; therefore, the BUN seemed to increase with time after feeding (Fig. 4.1c). The BG concentrations are presented in Table 4.4. Increasing the sugar intake decreased the BG concentration at 4 h post feeding ($P<0.05$); however, daily mean of BG was not significantly different among dietary treatments; it remained within a normal range (45-75 mg/dl; Kaneko et al., 1997). The changes of ruminal pH, NH_3-N, BUN, and BG within time of sampling are shown in Figure 4.1 a, b, c, and d, respectively.

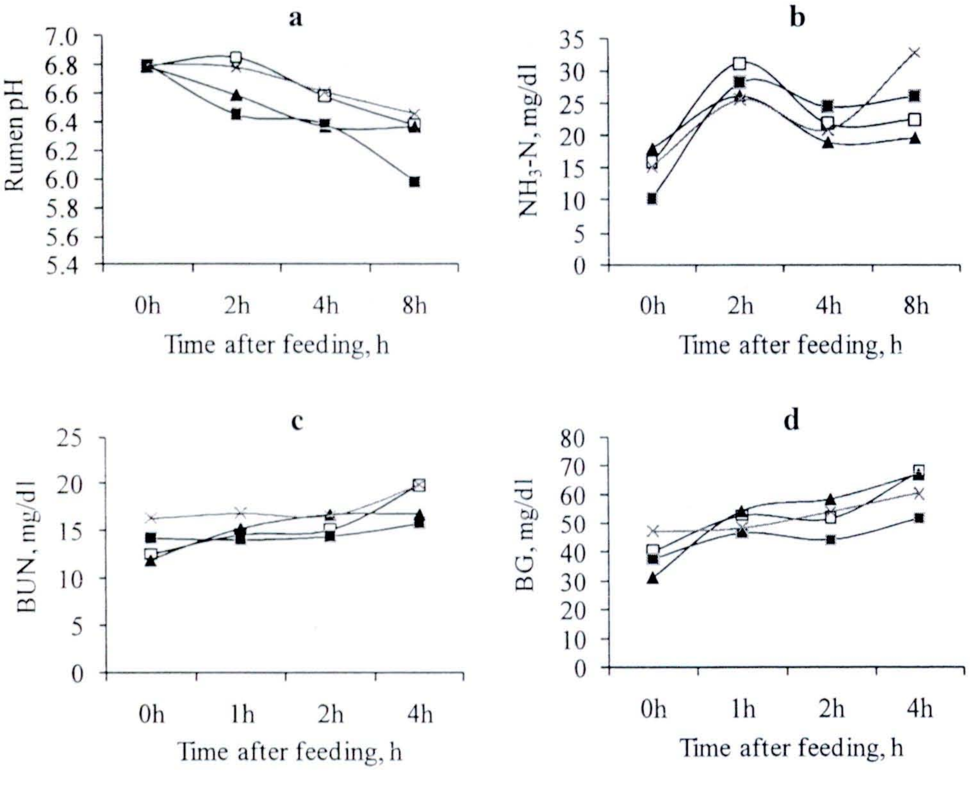

Figure 4.1 Effects of SP and sugar concentration on rumen pH (a), NH_3-N (b), BUN (c), and BG (d) of crossbred steers. Line highlighted by □ designates the L-SP-L-SU treatment diet, ■ designates the L-SP-H-SU treatment diet, ▲ designates the H-SP-L-SU treatment diet, and × designates the H-SP-H-SU treatment diet

4.4 Conclusions

The results of the present study demonstrate that the SP has more of an influence on the intake, digestibility, and performance of steers than the sugar level in the diet. The findings suggest that dietary SP (up to 60% of the CP) can be fed to crossbred Thai steers receiving sugar at a level of 11.0% of the DM. Feeding excess SP (>60% of CP) did not improve animal performance. At lower levels of SP than 60% of CP may be more effective and source of BCVFA should be also considered in future research testing. However, with a proper ratio of SP and sugar, the urea and sugar ingredients can be used at higher levels to reduce the feed cost. The results of the current study indicate that the productivity of steers fed low-quality roughage can be improved when the SP: sugar ratio is 1:1.4, as a percentage of the DM.