Utilization of Sunnhemp Meal in Beef Cattle Diet Supplemented with Urea-Treated Rice Straw

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ABSTRACT

The objective of this study was to determine the effects of the utilization of sunnhemp (Crotalaria juncea) meal (SM) in beef cattle diet in North-East Thailand. The first experiment was conducted to determine the effects of cutting intervals and height on the yield and nutrient composition of sunnhemp. The experiment was a 3×3 factorial arrangement in a randomized complete block design (RCBD) , in which factor A was the cutting intervals (30, 40 and 50 days) and factor B was the cutting heights (30, 40 and 50 cm) above ground level. It is concluded that a cutting interval of sunnhemp at 50 days achieves greater dry matter and nutrient yields than at 30 days. In terms of nutrient content, there is also a considerable increase in crude fiber, neutral-detergent fiber, acid-detergent fiber, and acid-detergent lignin in sunnhemp. In contrast, the results showed that cutting height at 30, 40 or 50 cm had no effect on the chemical composition values of sunnhemp. The second experiment was to study the effect of SM supplemented with urea-treated rice straw (UTRS) on the growth rate of Brahman×Thai-Native beef cattle. Twelve cattle, averaging 218±14 kg body weight (BW) and approximately 14-17 months' old were stratified randomly and assigned to RCBD in 4 treatments of 3 beef cattle each. The treatments were equal amounts of SM supplement with UTRS at 0, 25, 50 and 75% respectively. There were no significant differences in the live weight change, average daily gain (ADG), dry matter intake and rumen fermentation among treatments of

0, 25 and 50% of SM supplement. However, the BW and ADG significantly decreased at 75% of SM supplement with UTRS.

Keywords: *Crotalaria juncea*, Sunnhemp meal, Beef cattle diet, Urea-treated rice straw

INTRODUCTION

Livestock feed is an important factor in the success of cattle farming. Animal feed costs are usually accounts for 60-70% of animal production (Habtamu, 2014), of which approximately 10 up to 16% are roughage and 65-80% are concentrated feed expenses (Wanapat et al., 2013), depending on the quality of the feed and the feeding method (Seyoum et al., 2007). Supplementing the concentrate from a basal feed diet or grass fortifies nutritional deficiencies. However, fresh grass is only of good quality at an early stage, because the nutritive value of fresh grass may vary throughout the year and its quality gradually decreases with the age of forage harvest and rising temperature (Lee et al., 2017). Therefore, it is necessary to supplement it with high levels of concentrated feed in order for the cattle to receive sufficient nutrients for production, which causes higher production costs for farmers. Concentrated feed consists of 2 types of important nutrients, which are, firstly, a basal diet, such as diets with high carbohydrates which are usually low in price and, secondly, protein supplements. Cattle are usually fed a concentrated diet, which means that they do not often get enough protein to meet their nutrient requirements, especially in steer cattle. The provision of protein supplements mixed with basic feed will increase the protein content for animals. Most protein supplements are derived from the oil extracted or expressed from types of grain, such as palm kernel meal, cotton seed meal (Wanapat and Rowlinson, 2007) and soybean meal (Martens et al. , 2012) , etc. , Although these protein sources are of good quality, more palatable and contain different amounts of protein according to the type of plant, they are expensive. The problem is how to decrease the expensive price of the protein feed for beef cattle to supplement poor quality roughage in order to achieve efficient production. This can be done by adding protein supplements from other plant sources which provide the energy of the basal diet plus the added nutritive value from the feed intake.

Many legume species have the potential to be used as the raw material for animal feed, and widely grown especially in the tropics and subtropical areas of India, Nepal, Srilanka and Southern Africa (Tripathi et al., 2013) . Sunnhemp (*Crotalaria juncea*) is a type of legume plant grown for fiber (Tripathi et al., 2012) that has been mostly used as a green manure (Sarkar and Ghoroi, 2007; Tripathi et al., 2013) to improve soil fertility by nitrogen fixation (Rhizobium), medicinal values (Lawal et al., 2013), local fodder (Sarkar et al., 2015) and is more suitable for use in cattle feed than grasses (Fraser et al., 2004) due to its high protein content (Srisaikham and Lounglawan, 2018). However, we have not been able to find any studies on this in Thailand.

Thai farmers allow a rest period for cultivation which encourages plants to grow, especially sunnhemp, which can be used as cover cropping to improve soil properties, reduce soil erosion, conserve soil water, and recycle plant nutrients (USDA, 1999). However, planting and plowing are generally less useful, although they provide other benefits as sunnhemp can be used as fodder, which may possibly be another way to solve the main problem of feed shortage for ruminant animals by producing a lower cost diet per ton. In addition, sunnhemp leaves can be used in a dried form as the raw materials for animal diet or as a supplement for a poultry diet (USDA, 1999) or African catfish diet (Lawal et al., 2013). Therefore, this study aimed to investigate the utilization of sunnhemp meal (SM) partially supplemented with urea-treated rice straw (UTRS) to investigate the effects on feed intake, growth performance, nutrient digestibility and ruminal fermentation in beef cattle.

MATERIAL AND METHODS

Effects of cutting heights and cutting intervals on the yield and nutrient composition of sunnhemp

The present study formed part of a larger research trial that evaluated the effects of cutting intervals and height on the yield and nutrient composition of sunnhemp, as reported previously (Sumalu et al., 2012), and observed their utilization of SM on the production of Brahman×Thai-Native beef cattle. The experiment was conducted in a 3 x 3 Factorial in a Randomized Complete Block Design (RCBD), in which factor A was the cutting intervals (30, 40 and 50 days of age) and factor B was the cutting heights (30, 40 and 50 cm) with 4 replications giving a total of 36 plots each (3×3 m) at Suranaree University' s Farm. The experimental site located on the GPS co-ordinates of Suranaree University of Technology, Nakhon Ratchasima province, Thailand at 14° 52' 13.49" N latitude and 102° 01' 15.19" E longitude, where the average annual extreme maximum and minimum temperature, total amount of rainfall, number of rainy days and daily maximum ranges between 13. 7 to 40. 1 ºC, 1,179. 5 millimeter, 113.5 day and 104.5 millimeter (Meteorological Department, Ministry of Information and Communication Technology, 2015). The sunnhemp seeds were obtained from the Land Development Station in Nakhon Ratchasima province, Thailand. The soil of the field crops in Suranaree district, Nakhon Ratchasima province was classified in a group of Korat soil series (Korat series: Kt) which have low fertility and are composed of sandy loam. The soil was prepared for planting by plowing in regular furrows twice followed by 1 more tillage subsequently so that the soil was ready for planting. The plot used for planting was 1 m^2 and each plot was divided into 6 rows. The planting space between rows and plants was 50 x 50 cm. 15N-15P-15K chemical fertilizer was used on the soil surface after plowing at the rate of 187. 5 kg per ha with a planting rate of 12.5 kg seeds per ha and irrigation by the drip system. The total amount of fresh sunnhemp harvested from the whole plot yielded a fresh weight of 500 g of sunnhemp. Samples of the harvest were randomly collected from each plot to determine plant height, chemical composition and dry weight per plant.

Feeding of animals and the experimental design

All the procedures involving animals in this study were performed in accordance with the guidelines and ethics standards of the National Requirements of Beef Cattle in Thailand as specified by the working committee of Thai Feeding Standards for ruminants (WTSR) (2008) for the care and use of animals. Twelve Brahman×Thai-Native cattle were divided by BW into 4 treatments of 3 cattle each which were housed in individual pens and their body weight (BW) averaged 218±14 kg and they were approximately 14-17 months old. They were then assigned to the RCBD. All the cattle were fed 1% of their BW or approximately 3 kg/d of 14% CP concentrate with supplements of 0, 25, 50 and 75% of sunnhemp meal (SM) which were used as roughage to substitute for the urea-treated rice straw (UTRS) which was provided twice daily. The treatments were: 1) concentrate and 0% of SM supplement dry matter (DM; the proportion of plant dry mass to fresh mass) (w/ w) together with *ad libitum* UTRS; 2) concentrate and 25% of SM supplement DM (w/w) together with *ad libitum* UTRS; 3) concentrate and 50% of SM supplement DM (w/w) together with *ad libitum* UTRS; and 4) concentrate and 75% of SM supplement DM (w/ w) together with *ad libitum* UTRS. All cattle also had free access to clean water and they were individually housed in a free-stall unit and they were individually fed according to the treatments. The experiment lasted for 60 days with the first 2 periods (14 d) as an adjustment period. Urea-treated rice straw was prepared by using 5 kg urea of fertilizer grade (46% N) plus 100 kg water, sprayed onto 100 kg of the rice straw and then covered up for 10 d before directly before being fed to the animals (Wanapat et al., 2009). A detailed analysis of the dry matter of concentrate, roughage and total intake (kg/d) and the live weight of beef cattle fed 0, 25, 50 and 75% of sunnhemp which was used as roughage to substitute for the urea treated rice straw has been reported previously (experiment 2; Lounglawan et al., 2016).

Measurements and chemical analysis

Collection of the feed samples and rumen fluid for chemical analysis. The feed left after the individual cattle had eaten were collected after a 10 d period and dried at 60 °C for 48 h. At the end of the experiment, feed samples were pooled to make representative samples for proximate and detergent analyses which were repeated three times. Samples were ground through a 1 mm screen and analyzed for dry matter (DM), and then heated in a hot air oven at 60 °C for 48 h. An analysis of the crude protein (CP, Kjeldahl analysis) (AOAC, 1990) and of the ether extract (EE, petroleum ether in a Soxtec System) was then conducted. Fiber fraction, neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the method described by Van Soest et al. (1991), adapted for a Fiber Analyzer. Ash content was determined by ashing in a muffle furnace at 600 °C for 3 h. The chemical analysis was expressed based on the final DM. Cattle were weighed at the start and at the end of the experiment after a fasting period of at least 16 h to calculate the average daily gain (ADG) and the feed intake per BW. Approximately 60 ml of ruminal fluid were collected by using a stomach tube with a strainer and a vacuum pump.

The rumen fluid was immediately used for determining the pH using a digital pH meter (MP 220 pH Meter, Mettler-Toledo Gombh, CH-9603 Schwerzenbach, Switzerland) . The sample was then filtrated through a clean double layer of cheesecloth at 0 and 4 h post morning feeding on 2 consecutive days of the experimental period. The liquid fraction of rumen fluid was divided into two parts, where one part at approximately 20 ml was immediately fixed with 6 N HCl and approximately 5 ml were then centrifuged for 15 min at 3,000 × g. Approximately 15 ml of supernatant of the rumen fluid were kept at -20 ºC for analysis of ammonia-nitrogen (NH_3-N) concentration by distillation according to the Kjeldahl method (AOAC, 1990). The second part from the liquid fraction was acidified with 1M H_2SO_4 (9:1 w/w), centrifuged at 5,000 x g for 15 minutes and stored at -20 ºC for analysis of volatile fatty acids (VFAs) including of acetic acid (C_2), propionic acid (C_3) and butyric acid (C_4) . The supernatant of the rumen fluid was analyzed for concentrations of VFAs which were determined by gas chromatography (GC) (Hewlett Packard GC system HP6890 A; Hewlett Packard, Avondale, PA) equipped with a 30 m × 0.32 mm × 0.15 µm film silica capillary column (HP_Innowax, AB 002, Agient, USA). Injector and detector temperatures were 250 °C. The column temperature was kept at 80 °C for 5 min, then increased from 10 °C/min to 170 °C and then increased again from 30 °C/min to 250 °C and held at 250 °C for 5 min.

Statistical analysis

Measured data of chemical composition and yields (kg/ha) of sunnhemp cut at different ages and heights were analyzed by ANOVA for a 3x3 Factorial in RCBD, whereas the feed intake, BW change, nutrient digestibility, rumen-pH, NH_3-N and VFAs of the cattle were analyzed by ANOVA for RCBD using the Statistical Analysis System (SAS, 2001). Significant differences among treatments were assessed by Duncan' s new multiple range test (DMRT). A significant level of $P<0.05$ was used (Steel and Torries, 1980).

RESULTS

Effects of cutting intervals (30, 40 and 50 d) and cutting height (30, 40 and 50 cm) on the chemical composition of sunnhemp

There was an interactional effect between the cutting intervals and the nutrient content of sunnhemp for DM, CF, NDF ADF and ADL, which increased as the cutting intervals increased from 30, 40 and 50 days respectively, while the CP, ash, EE and NFE showed decreases as the cutting intervals increased. In addition, the results of cutting at different heights (30, 40 and 50 cm) as shown in Table 1 showed significant differences ($P < 0.05$) on CP, EE and ADF. In this case, the mean of CP and EE increased with increased cutting height and, on the other hand, the mean ADF decreased.

Table 1. Chemical composition (%) of sunnhemp (*Crotalaria juncea*) cut at different intervals (ages) and heights. (Mean)

Age (days)	Height	DM[2] (%)	CP[3] (%)	EE[4] (%)	ASH (%)	CF[5] (%)	NFE[6] (%)	NDF[7] (%)	ADF[8] (%)	ADL[9] (%)
30	30 cm	20.31	22.21	3.07	7.66	12.37	34.17	26.36	24.37	4.31
	40 cm	18.89	23.31	3.42	7.97	12.34	34.54	26.54	24.45	3.68
	50 cm	19.72	25.69	3.16	7.39	12.23	32.02	24.80	21.25	3.13
40	30 cm	23.84	20.12	2.71	6.47	18.84	27.89	39.32	33.03	6.53
	40 cm	23.67	20.23	2.66	6.73	18.53	28.60	40.75	31.64	5.56
	50 cm	23.64	21.32	2.96	6.86	17.29	28.10	37.24	31.36	4.83
50	30 cm	23.49	18.82	2.26	6.37	25.76	23.74	54.33	47.19	8.84
	40 cm	23.38	20.29	2.65	6.49	22.98	24.98	44.80	45.36	8.52
	50 cm	23.15	19.81	2.62	6.52	23.17	23.90	50.72	43.95	8.37
SEM[1]		0.45	0.14	0.05	0.07	0.50	0.50	1.03	0.72	0.35
---------- ***P*-value** ----------										
Block		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Age		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Height		0.373	0.0001	0.0007	0.0711	0.8993	0.1094	0.0994	0.0306	0.0650
Age×height		0.5727	0.0001	0.0123	0.0402	0.2976	0.4346	0.0227	0.6507	0.8184

Note: [1] SEM = standard error of mean[2] DM = dry matter; [3] CP = Crude protein; [4] EE = Ether extract; [5] CF= Crude fiber, [6] NFE = Nitrogen Free Extract; [7] NDF = Neutral detergent fiber; [8] ADF = Acid detergent fiber;
[9] ADL = Acid detergent lignin.

Effects of cutting intervals and cutting height on the yield of sunnhemp

The DM yields at different cutting intervals and heights of sunnhemp between harvests are presented in Table 2. Different cutting intervals and heights of sunnhemp harvests resulted in changes in the dry matter yield of sunnhemp, which were characterized by increases the cutting periods from 2,482 kg per ha at 30 days to 13,644 kg per ha at 50 days, and increases in the maximum growth rate of sunnhemp at 50 days as shown in Table 2. The growth rate was higher than the cutting intervals of 30 and 40 days. In terms of the chemical composition, the production per ha showed that the DM, CP, EE, ash, CF, NFE, NDF, ADF and ADL increased significantly ($P < 0.05$) with increasing cutting intervals. In addition, when the cutting height increased from 30, 40 and 50 cm, this resulted in decreases in the CF, NDF, ADF and ADL, with no significant differences for DM, CP, EE, ash and NFE. However, there was a marked interactional effect of cutting intervals and height on CF content yield only.

Table 2. Yields (kg/ ha) of sunnhemp (*Crotalaria juncea*) cut at different intervals (ages) and heights

Age (days)	Height	DM[2]	CP[3]	EE[4]	ASH	CF[5]	NFE[6]	NDF[7]	ADF[8]	ADL[9]
30	30 cm	947	214	30	85	139	380	293	271	48
	40 cm	917	213	32	76	120	328	254	234	36
	50 cm	619	159	19	43	72	187	145	124	13
40	30 cm	2778	559	80	197	573	854	1199	1005	196
	40 cm	2594	525	72	183	503	778	1101	863	150
	50 cm	2378	507	77	172	430	706	937	785	121
50	30 cm	5056	949	137	386	1555	1433	3302	2846	534
	40 cm	4139	841	95	233	824	897	1602	1624	305
	50 cm	4450	880	133	335	1187	1230	2594	2258	431
SEM[1]		436	87	7	24	73	89	179	140	27
***P*-value**										
Block		0.0001	0.0001	0.0001	0.0007	0.0001	0.0009	0.0001	0.0001	0.0001
Age		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Height		0.4290	0.7010	0.2582	0.1601	0.0269	0.1275	0.0457	0.0472	0.0315
Age×height		0.8688	0.9770	0.0804	0.2275	0.0445	0.2876	0.0504	0.0902	0.1095

Note: [1] SEM = standard error of mean [2] DM = dry matter; [3] CP = Crude protein; [4] EE = Ether extract; [5] CF = Crude fiber, [6] NFE = Nitrogen-Free Extract; [7] NDF = Neutral-detergent fiber; [8] ADF = Acid-detergent fiber; [9] ADL = Acid-detergent lignin.

Chemical composition of feed

The nutritive value of the concentrated diet (14% CP), SM and UTRS is indicated in the present study (Table 3) for reference which was reported previously (Lounglawan et al., 2016). The SM was used as the main raw material in the beef cattle diet supplemented with UTRS of which the mean value of DM, CP, EE, ash, CF, NDF, ADF was approximately 90. 62, 19. 61, 2.43, 6.01, 26.80, 53.04, 47.34 and 8.75% of ADL, respectively, while NDF (75.5%) was the main component in UTRS.

Table 3. Chemical composition (% DM) of the concentrate and roughage (Mean±SE[1]) used in the study (n = 2)

Item	Concentrate	Sunnhemp meal	Urea-treated rice straw
	------------------------------ % of DM	-------------------------------	
DM[2]	90.04 ± 0.12	90.62 ± 0.69	66.14 ± 0.30
CP[3]	14.62 ± 1.99	19.61 ± 0.65	7.77 ± 0.10
EE[4]	3.43 ± 0.08	2.43 ± 0.32	0.66 ± 0.64
Ash	5.45 ± 0.57	6.01 ± 1.06	4.29 ± 0.14
CF[5]	12.48 ± 1.05	26.80 ± 2.39	35.80 ± 0.14
NDF[6]	31.67 ± 1.78	53.04 ± 0.30	75.50 ± 0.14
ADF[7]	18.57 ± 0.48	47.34 ± 0.12	51.40 ± 0.18
ADL[8]	5.27 ± 0.53	8.75 ± 0.12	11.18 ± 0.94

Note: [1] SE = standard error, [2] DM = dry matter; [3] CP = Crude protein; [4] EE = Ether extract; [5] CF = Crude fiber, [6] NDF = Neutral-detergent fiber; [7] ADF = Acid-detergent fiber; [8] ADL = Acid-detergent lignin.

Nutrient intake and live weight

The DM intake of roughage decreased with increases in the SM supplement with UTRS as shown in Table 4. Considering the DM intake per BW per day (% BW) and the metabolic weight per day (g/kgBW$^{0.75}$) neither the concentrated diet, roughage or total intake were significantly different (P > 0.05). The mean values of DM intake (% BW) and (g/kgBW$^{0.75}$) in the concentrated diet were 1.09% BW/d and 43.2 g/kgBW$^{0.75}$/d, 2.28% BW/d and 90.7 g/kgBW$^{0.75}$/d in roughage and 3.36% BW/d and 134 g/kgBW$^{0.75}$/d in total intake, respectively. The live weight change (LWC) and ADG of beef cattle that resulted from SM supplemented with UTRS at 25% was higher than that of the cattle which received 50 and 75% (Table 4). The results from before and after SM was supplemented with UTRS at 25, 50 and 75% in ADG showed that the maximum response was observed at the lowest level as the LWC and ADG of cattle decreased when SM was supplemented with increases of UTRS from 542 g per day to 423 and 345 g per day, respectively. However, the average weight at the end of the experiment showed that no remarkable changes were found in the final weights among the treatments (*P* > 0.05).

Table 4. Effect of sunnhemp meal supplemented with urea-treated rice straw on nutrient intake and growth performance of Brahman×Thai-Native cattle.

Item	Sunnhemp meal level				SEM[1]	*P* value
	0%	25%	50%	75%		
Concentrate						
Dry matter intake, kg[2]/d[3]	2.70	2.70	2.70	2.70	-	-
%BW[4]	1.06	1.08	1.09	1.12	0.05	0.67
g[5]/kgBW$^{0.75}$	42.4	42.9	43.5	44.0	0.83	0.28
Roughage						
Dry matter intake, kg/d	6.09^{a}	5.81^{a}	5.40^{ab}	5.31^{b}	0.16	0.05
%BW	2.39	2.32	2.22	2.19	0.11	0.67
g /kgBW$^{0.75}$	95.7	92.41	88.3	86.5	4.56	0.24
Total						
Dry matter of total intake, kg/d	8.79^{a}	8.51^{a}	8.31^{ab}	8.01^{b}	0.15	0.04
%BW	3.45	3.40	3.31	3.31	0.19	0.25
g/kgBW$^{0.75}$	138.1	135.3	131.8	130.5	3.09	0.12
Live weight change						
Initial live weight, kg	225.4	217.6	221.1	219.2	3.2	0.72
Final live weight, kg	254.7	250.1	246.5	239.9	4.8	0.13
Live weight change, g/d	29.3^{ab}	32.5^{a}	25.4^{bc}	20.7^{c}	3.1	0.05
Average daily gain, g/d	488^{ab}	542^{a}	423^{bc}	345^{c}	41.2	0.04

Note: In each row, different superscripts represent significant differences (*P* < 0.05), [1] SEM = standard error of mean, [2] kg = kilogram; [3] d = day; [4] BW = body weight; [5] g = gram.

Nutrient digestibility

The supplemented diets of SM with UTRS in beef cattle had no effect on DM, CP, EE, CF, NDF, ADF and ADL digestibility, the total digestible nutrients, digestibility energy (DE) or metabolisable energy (ME) in all the treatments (Table 5).

Table 5. Effect of sunnhemp meal supplemented with urea-treated rice straw on nutrient digestibility of Brahman×Thai-Native cattle.

Item	Sunnhemp meal level				SEM[1]	*P* value
	0%	25%	50%	75%		
DM[2]	62.76	61.77	59.87	60.71	1.17	0.26
CP[3]	60.72	59.47	63.96	61.96	2.31	0.44
EE[4]	56.19	60.91	55.73	59.73	1.97	0.72
CF[5]	50.01	52.89	55.11	54.9	1.78	0.59
NDF[6]	45.19	42.99	40.55	41.42	1.95	0.29
ADF[7]	26.14	27.74	24.8	25.09	1.07	0.32
TDN[8] (%)	65.56	62.56	63.09	64.8	0.99	0.47
DE[9] (Mcal/kgDM)	3.02	2.92	2.98	2.95	0.08	0.35
ME[10] (Mcal/kgDM)	2.48	2.43	2.45	2.45	0.09	0.29

Note: [1]SEM = standard error of mean, [2]DM = dry matter; [3]CP = Crude protein; [4]EE = Ether extract; [5]CF = Crude fiber, [6]NDF = Neutral-detergent fiber; [7]ADF = Acid-detergent fiber; [8]TDN = Total digestible nutrients, TDN1X (%) = tdNFC + tdCP + (tdFA x 2.25) + tdNDF-7 (NRC, 2001), [9]DE1X (Mcal/kg) = [(tdNFC/100)x4.2]+[(tdNDF/100) x 4.2]+[(tdCP/100) x 5.6]+[(FA/100) x 9.4] –0.3 Discount = [(TDN1X – [(0.18 x TDN1X) – 10.3]) x Intake)]/TDN1X DEP (Mcal/kgDM) = DE1X x Discount [10]MEp = [1.01 x (DEp) – 0.45] + [0.0046 x (EE – 3)]

Rumen-pH, Ammonia Nitrogen (NH_3-N) and Volatile Fatty Acid (VFA)

Rumen-pH variables, NH_3-N and rumen VFA in the concentrated diet of cattle in which SM was supplemented with UTRS at 0, 25, 50 and 75% were not significantly different ($P > 0.05$) among treatments at 0 and 4 h post feeding, and the mean pH values of rumen fluid were 6.86, 6.91, 6.83 and 6.89, respectively (Table 6). These values of ruminal pH were maintained above 5.5 which is within the normal average range reported in the literature for ruminants. The values of NH_3-N were 11.7, 12.88, 10.84 and 9.64 mg%, respectively. SM supplemented with different amounts of UTRS at 0, 25, 50 and 75% had no effect on rumen VFA concentration (molar proportion of acetate (C_2), propionate (C_3), butyrate (C_4) and C_2:C_3 ratio) nor on rumen-pH and NH_3-N (Table 6).

Table 6. Effect of sunnhemp meal supplemented with urea-treated rice straw on rumen-pH, ammonia nitrogen (mg/dl), individual and ratio of volatile fatty acid (mol/100 mol) at 0 h and after 4 h post feeding of Brahman×Thai-Native cattle.

Item	Sunnhemp meal level				SEM[1]	*P* value
	0%	25%	50%	75%		
pH						
Hour 0	6.61	6.74	6.45	6.38	0.07	0.11
Hour 4	6.86	6.91	6.83	6.89	0.32	0.69
NH_3N[2]	**(mg/dl[3])**					
Hour 0	7.01	8.58	7.57	7.27	0.28	0.34
Hour 4	11.71	12.88	10.84	9.64	0.20	0.10
Acetate; C_2	**(mol/100 mol)**					
Hour 0	68.37	69.37	69.67	68.63	0.14	0.72
Hour 4	69.59	70.08	69.57	68.37	0.51	0.45
Propionate; C_3	**(mol/100 mol)**					
Hour 0	20.75	20.91	20.25	21.03	0.47	0.43
Hour 4	20.58	20.43	20.27	20.37	0.53	0.39
Butyrate; C_4	**(mol/100 mol)**					
Hour 0	10.88	9.71	9.90	10.31	0.31	0.31
Hour 4	10.53	9.97	10.20	11.09	0.23	0.92
C_2:C_3						
Hour 0	3.29	3.32	3.44	3.26	0.09	0.47
Hour 4	3.38	3.43	3.43	3.35	0.08	0.50

Note: [1]SEM = standard error of mean, [2] NH_3-N = ammonia nitrogen, [3] mg/dl = milligrams per deciliter.

DISCUSSION

Sunnhemp productivity increased with increased cutting intervals which was partly due to when the sunnhemp was planted and changes characterized by concomitant increases in the accumulation of nutrients from the soil. However, the differences in the yield of each crop in the research study suggested that several factors may have had an impact, for example, the sunnhemp may have been planted with different densities causing differences in growth. In addition, there are other factors that can affect the yield of the sunnhemp crop, such as soil integrity, harvesting, sunnhemp species and environmental conditions, etc. Therefore, soil type and particularly rainfall were the main factors which could not be controlled and these influenced the output of the sunnhemp in this experiment. Similar results were also reported in the research of Chantiratikul et al, (2006) which studied the yield and nutrient content of kenaf (*Hibiscus cannabinus*) at different growth stages of maturity. In a study in Tanzania (Mkiwa et al., 1990), which investigated the nutritive value and yield of *Crotalaria ochroleuca*, which is the same species as *Crotalaria juncea*, was harvested at different stages of growth, and it was found that the yield of the older cuttings had a greater effect on the amount of DM and organic matter (OM) which corresponds to Srisaikham et al. (2019) who reported that the average height, yiled (total weight per area), the fresh weight per plant and the DM per plant at 60 ^{o}C in a hot air oven in whole plants of legumes forage including alfalfa (*Medicago sativa*), Verano stylo (Hamata) (*Stylosanthes hamat*a cv. Verano) and Tha pra stylo (*Stylosanthes guianensis* cv. Tha pra stylo) which belongs to the Fabaceae family similar to sunnhemp, and the 4 cutting ages were 30, 45, 60 and 75 days increased with increasing cutting ages.

Moreover, there was an interactional effect between the cutting intervals and the nutrient content of sunnhemp. Suksombat and Buakeeree, (2006) found that the leaf: stem ratio has an affect on the nutrients of plant. Levels of CP, EE, and ash decreased as the cutting interval increased, however, it tended to increase in the leaf as the cutting height increased but tended to decrease in the stem, while the NDF content increased with advancing plant maturity, especially in the stem fraction. Levels of CP, EE, and ash were noticeably higher than the stem. The proportion of plant leaf was consistently higher than stem and all nutrients measured showed markedly higher contents in the leaf than in the stem. The various cutting intervals of *Crotalaria ochroleuca* affected the chemical composition including DM, CP, CF, EE, ash and NFE. A higher percentage of CF showed a significant response to increases in the cutting intervals whereas CP, ash and EE decreased with increasing cutting intervals in *Crotalaria ochroleuca* for the whole plant, leaves and stems. Srisaikham and Rupitak (2019) reported that they found a significant interaction between type of legume forage (Alfalfa), Verano stylo (Hamata) and Tha pra stylo and cutting ages (30, 45, 60 and 75 days) in all aspects of the chemical composition ($P <$ 0.01) during the dry season on October 2018 to July 2019 in Sa Kaeo province. Each type of legume forage has an unequal response to increasing cutting ages. The chemical composition that decreased with increasing cutting ages were DM, CP, ash and tannin, whereas other chemical compositions (NDF, ADF and ADL) increased with increasing cutting ages. The average CP of 3 kinds of legumes decreased from 18.09% after the alfalfa was cut at 30 days from the first to fifth cutting intervals to 16.75% after cutting at 75 days, from 17.39% on the 30th days of harvest to 14.77% on the 75th days of harvest in Hamata and Tha pra stylo decreased from 18.02% to 12.97% on cutting at 30 days to 75 days respectively. This is in accordance with Srisaikham and Lounglawan (2018) who similarly demonstrated that CP of *Crotalaria juncea* decreased as the cutting interval increased from 35 to 55 days. The decrease in % ADF with increasing cutting height can possibly be attributed to the fact that the upper parts of the sunnhemp harvested at 50 cm height usually contained fewer branches and stems but more leaves than in the lower parts harvested at 30 cm. Therefore, the cutting at a height of 50 cm leads to higher nutrient quality as reflected in the higher % CP which is also in general agreement with the results of Srisaikham and Lounglawan (2018).

Although % CP at greater cutting intervals decreased, the CP yield per cut of the sunnhemp significantly increased with increasing cutting intervals could consequent with the result that the dry weight of the crop increased rapidly especially during the intervals of 40 to 50 days. However, this study found a lower percentage of CP (19. 8-25. 7%) in sunnhemp when compared with a previous report of Chaudhury et al. (1995) who studied the chemical elements in various parts of *Crotalaria juncea* and reported that they found greater approximately 25-30% CP in leaves which may have been the result of soil fertility, species or other unexpected environmental factors. Srisaikham and Lounglawan (2018) reported a similar reduction in CP of *Crotalaria juncea* when harvested at longer intervals, while the accumulation of cell walls and lignocellulose content markedly increased over greater intervals of time. Normally, the high lignified fiber obtained from the stem when the plants grow older produces a much higher total DM yield, but quality, which measured the CP portion of the leaves, decreased, which is consistent with some previous reports of nutritive values containing variable quantities of CP in sunnhemp at different cutting intervals and heights (Muir, 2002). With regard to the CP and CF yield and the current production results, the optimum cutting intervals and cutting height of sunnhemp for use as ruminant feed suggests that harvesting at intervals of 50 days is the most appropriate method. Nevertheless, cutting intervals at 30 days can have a marked effect on low fiber and high protein, a much lower yield than for intervals of 50 days, while the different cutting heights from 30 to 50 cm from ground level did not affect productivity. These results correspond to Srisaikham and Lounglawan (2018) who reported on sunnhemp and Suksombat and Buakeeree (2006) who reported on hedge lucerne (*Desmanthus virgatus*). However, the nutrient management depends on the type of fertilizer which influences the NPK levels and the spacing of seeds is also an important factor that influences the fiber yield of sunnhemp (Kavin et al., 2018). The nutritional content of CP is a common value measurement of protein, so it is often used to compare forages or to determine which quality of crop should be purchased. Protein levels are important for livestock because they are necessary for such ruminant animal products as meat and milk.

CP was a major nutrient in SM, accounting for 19.6%, and similar results were observed in other research studies (Srisaikham and Lounglawan, 2018) , and these are also corroborated by Sherasia et al. (2015) who studied sunnhemp hay (*Crotalaria juncea*). Min et al. (2019) reported that sunnhemp forage samples of a period of 45 d were approximately 90% DM, 17. 8% CP, 52% ADF, 53.1% NDF, 18% nonfibrous carbohydrate (NFC), 58. 9% total digestibility nutritent (TDN), whereas some mineral concentrations were 0.85% calcium, 0.26% phosphate, 0.45% magnesium, 1.24% potassium and 0.16% sulphur. The values of UTRS in our study are within the normal range described for rice straw fermented with 5% urea Badurdeen et al. (1994) who reported values of 7.7%, but these are higher than Wora-anu (2000) who reported 6.9% in experiment. In contrast, the mean CP of UTRS was lower than that of Wanapat et al. (2000) who reported a value of 8.5%. The chemical composition of these constituents may vary somewhat depending on rice varieties and various sources. Shen et al. (1998) conducted physical and chemical measurements of rice straw and they reported that weather, season, fertilizer usage and harvesting time were the main factors affecting the yield and components of rice straw. Shen et al. (1998) found that the season also affects the different chemical composition of rice straw, such as nitrogen, hemicellulose, cellulose and phosphorus content. In addition, the consistency of liquid urea used in the fermentation of the rice straw has a random effect on the chemical composition. Rice straw which has been treated with fermented with urea increased nitrogen levels from 35 to 171% (Shen et al., 1998).

The total DMI (kg/d) was affected by SM supplemented with UTRS at 75% (P < 0.05) which resulted in less roughage of DMI at 0 and 25% in beef cattle feed diets. This might be due to a high percentage of DM in the supplemented SM diet that resulted from low moisture content when compared to UTRS and may also reduce palatability. The DM content should unaffected by the DMI of cows fed on diets which ranged from between 30 and 70% DM (Holter and Urban, 1992). Moisture content has been reported to be negatively related to DMI, but this could be due to fermentation products rather than excess moisture (Allen, 2000) . NRC (2001) concludes that reports on the relationships between dietary DM content and DMI are conflicting and that, therefore, there is no optimum DM content of the diet for maximum DMI. In addition, this result might also be due to the fact that none of the experimental diets have been designed to be iso-nitrogenous or iso-caloric and the availability of feed in roughage *ad libitum*. However, the beef cattle fed diets based on a concentrated diet consumed less than the total DM of SM supplemented with UTRS at 0 and 25% compared to 50 and 75% (P < 0.05) had less CF, NDF, ADF and ADL compared to SM supplemented with UTRS at 50 and 75% , respectively. A linear decline in DMI was consequent upon an increased diet of NDF (Tafaj et al., 2007). Forage NDF diet is also a major factor affecting feed intake and rumen fill in high-producing animal ruminants (Noosen et al., 2020) which is consistent with the finding of Mertens (1994) who reported that the rumen fill was limited to DMI at high NDF concentrations in diets.

The final weight of beef cattle in this experiment was unaffected by the treatments due in part to the availability of roughage feed *ad libitum* during 60 days, but ADG is related to feed intake efficiency per day which is affected by the presence of the ratio of SM and UTRS supplements. LWC and ADG showed significantly different increases across diets which supplemented SM with UTRS at 0, 25 and 50%. An increment in ADG after supplementing SM with UTRS could possibly affect the intake of DM if it was similarly increased across the treatments. The increase in the growth rate is related to increased DMI (De Brito et al. , 2017) , but not always in case of lamb fed on radish (Campbell et al., 2011), and thus a comparison with other studies should take into account the different numbers of animals for each treatment, the nutritive value of the forages, and should apply dissimilar experimental designs for feeding regimes. Higher live weight gains were also observed when mixtures of pastures (chicory, plantain, red and white clover) were included in the diet of lambs (Hutton et al., 2011) , which is similar to Howes et al. (2015) who observed that an increase in both the efficiency of dietary protein and growth in lambs fed legumes which was compared to a more rapid rate of digestion than lambs fed on grass. In general, weight gain can be improved by supplementary feeding of lambs fed pasture or roughage (e. g. , dry pasture) Atti and Mahouachi (2009) and Turner et al. (2014). Nevertheless, the LWC and ADG decreased throughout from 75% SM supplementation with UTRS *ad libitum*, which is consistent with a report on the intake of cattle fed on *Brachiaria* which increased linearly with decreasing legume content (Macedo et al., 2010). Few *in vivo* studies for tropical legumes in beef cattle research in Thailand have been found in the literature. Increasing of legumes proportion in the diet above 75% of DM appeared to have little effect on the intake of forage and an analysis did not indicate a significant deviation from a linear relationship (Macedo et al., 2010).

The treatments had no effect on the apparent nutrient digestibility of DM, CP, EE, CF, NDF and ADF in the total digestive tract (Table 5) nor on rumen pH, NH_3-N and VFAs concentration at 0 h before and after post feeding (Table 6) ($P > 0.05$). The rumen pH level in all experimental groups was between 6.83 and 6.91, which is in the range of the normal rumen pH level of the ruminants between 5.5 - 7.0 (Dehority, 2003). To better understand the changes in rumen pH, NH_3-N and VFA concentrations after animals were fed on diets, an analysis was conducted of the breakdown and digestion of the ruminal microbes: the initial step showed the rumen pH was mostly low during the first 3 to 4 h after post feeding (Zimmer and Cordesse, 1996), and then gradually increased after fermentation by the microbes. Ruminal NH_3-N concentration increased after 3 h with the increased fermentation process after feeding, when the products of fermentation, mainly VFAs and microbial protein, then became available to the host ruminants. NH_3-N is an important source of nitrogen for use in microbial protein synthesis (Prihartini and Khotimah, 2011). Ruminal NH_3-N concentration showed a tendency to decrease when SM was supplemented with UTRS up to 75%. In this case, the reduction of DMI possibly resulted in cattle receiving lower CP content than those fed at 0 and 25%. Moreover, the mean NH_3-N concentration was in the range of 9.64 - 12.88 mg% which was close to the results of Wora-anu (2000) who reported that the highest ruminal NH_3-N concentration in cattle and buffaloes was found in those animals fed a ratio of 40: 60 of urea-treated rice straw with extracted rice bran. In addition, those groups of cattle that were fed at low SM supplemented with UTRS received a higher proportion of UTRS and the ruminal NH_3-N at 4 h after post feeding tended to be higher than those fed at 50 and 75%. However, no differences in nutrient digestibility were detected. Thus SM supplemented with UTRS had no influence on ruminal concentrations of pH, NH_3-N and VFAs, due to the fact that the nutrient digestibility of all four treatments did not show any significant differences between the groups.

CONCLUSION

This study clearly showed that cutting intervals of 50 days for sunnhemp with a cutting height of between 30 and 50 cm above ground level should be recommended to Thai farmers so that they can choose a useful alternative protein source for feeding beef cattle. Based of less than 75% of SM supplemented with UTRS is reccommened for beef cattle diet which has no effects on DMI, LWC, ADG, nutrient digestibility, rumen-pH, NH_3-N nor rumen VFA concentration.

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