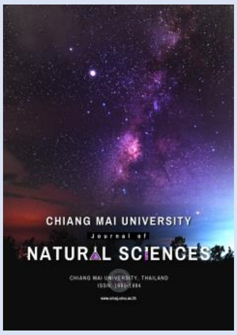

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Research article

Nutrient Yield of Brown Hemp and Its Utilization as Protein Source in Concentrate on Brahman×Thai-Native Cattle Performances

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Abstract Two experiments were conducted to evaluate the effects of cutting ages and height on the nutrient composition and yield of brown hemp (BH) in concentrate diets on Brahman×Thai-Native cattle performances. The first experiment was to determine the effects of cutting ages (30, 40 and 50 days) and height (30, 40 and 50 cm) on the nutrient composition and yield of BH. The experiment was a 3×3 factorial arrangement in a randomized complete block design. This study clearly showed that cutting ages at 50 days had a greater effect on the nutrient composition and yield than at 30 and 40 days, but the cutting heights did not reveal any significant differences in yield. However, the BH cutting for animal feed before plowing, besides improving the soil for green manure, also benefited feed resources. The second experiment was to study the effects of BH meal (BHM) in concentrate on Brahman×Thai-Native cattle performances. Twelve cattle, averaging 252 ± 18 kg body weight and at ages of 16-18 months were stratified randomly and assigned to one of the three feeding treatments. Cattle were fed BHM in different ratios: the treatments were 0, 10, and 20% of BHM, respectively. There were no significant differences in the dry matter intake among the treatments of 0, 10 and 20% of BHM in concentrate rations. For average daily gain, the minimum response observed was a significant difference at the highest level of 20% of BHM. Therefore, 10% of BHM can be used in the concentrate rations for beef cattle.

Keywords: Brahman×Thai-Native cattle, Brown hemp, Concentrate ration, Performances

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INTRODUCTION

Feed and feeding management are the main factors that are important for the growth of beef cattle which directly affect the production cost, especially the cost of concentrate feed. The costs of the main raw materials of cattle feed such as cassava and palm kernel tend to increase. Beef farmers, particularly in tropical regions, need to consider many requirements to find an approach to provide good quality, low-priced feedstuff to reduce feed production costs. Previous studies of Hove et al. (2001), Phillips et al. (2002), and Wanapat (2002) have demonstrated that locally grown foliages such as kenaf (*Hibiscus cannabinus*) and cassava (*Manihot esculenta*, Crantz) foliage have been successfully used as protein supplements for ruminants. Their results show that locally grown protein foliage can be substituted for expensive grain concentrate (e.g. soybean meal) as protein supplements for ruminant production. Therefore, it may be possible to utilize leguminous plants as a protein source in ruminants as an alternative which will have positive benefits. Yuangklang et al. (2011) reported that the curcumin-induced increase in nitrogen retention was greater for the ration with a low level of leucaena leaf meal for beef cattle. When *Leucaena Lecocephala* and *Moringa oleifera* leaves were used to overcome shortages of good quality feeds as a supplementation to goats during the dry season they had a positive effect on growth rate and reproductive performance (Mataveia et al., 2019). The brown hemp (BH) or sunnhemp (*Crotalaria juncea*), a type of local forage legume crop which also has high protein and other nutritive values (Sarkar et al., 2015) can be used as fodder feeding alternatives for ruminants. Furthermore, BH has been tested as a soil nourishing improver of plants which can be used as a green manure to improve soil fertility by nitrogen fixation (Tripathi et al., 2013). BH is considered as a potentially valuable crop, due to its high yield and fast growth, its relevant nutritional characteristics and its important role in crop rotation as well as for its use as livestock feed. Recently, BH has been of interest as its fiber is environmentally friendly (Heuzé et al., 2018) and, in addition, BH leaves have valuable traits for use as raw materials in dried form for animal feed since they contain 17.7 to 24.6% crude protein (CP) (Srisaikham and Lounglawan, 2018). A 14% CP concentrate supplemented with 25 or 50% sunnhemp (also known as BH) meal with urea-treated rice straw in a beef cattle diet was found not to have any effects on dry matter intake, live weight change, average daily gain, nutrient digestibility, rumen-pH, ammonia nitrogen concentrations or rumen volatile fatty acids concentrations (Srisaikham and Lounglawan, 2020).

Using high-protein BH contributes to more economic beef cattle feeding by reducing feed costs which represent 70% of the total operating costs. In addition, BH is a plant that has been promoted by the Thai government as a suitable plant for soil improvement, and there are sufficient amounts available for use as a protein source in concentrate available for beef cattle feed all the year round. Therefore, the objective of this experiment was to study the optimum level of BH as a protein source in the concentrate diet of Brahman×Thai-Native cattle and to study the effects on ruminal fermentation and nutrient digestibility of beef cattle feed.

MATERIALS AND METHODS

Plant materials and experimental site

Brown hemp (*Crotalaria juncea*) seeds used in this study were obtained from Nakhon Ratchasima Animal Nutrition Research and Development Center, Nakhon Ratchasima, in the north-east of Thailand. BH was planted on the experimental farm at Suranaree University of Technology (SUT) in the late rainy season to early winter season (July to September 2013) with very little rainfall in order to avoid plant diseases caused by pathogenic rust fungi. SUT’s Farm is located in a tropical area at Latitude 14° 52' 13.49" N and Longitude 102° 01' 15.19" E, at 189 m above sea level and it has a naturally high level plain with coarse-loamy, mixed, subactive, nonacid, isohyperthermic Fluvaquentic Endoaquepts (USDA taxonomy) (Land Development Department, 2019) with a slope of 0-2% for the field crops at SUT, Suranaree district, Nakhon Ratchasima, Thailand.

Experimental design

The first experiment was conducted in a 3 x 3 factorial in a randomized complete block design (RCBD) with 4 replications giving a total of 36 field plots each (3 x 3 m). There were 4 blocks with 9 treatments per block. The factors A and B were the cutting ages (30, 40 and 50 days) and the cutting heights (30, 40 and 50 cm), respectively, to investigate the influence of different cutting ages and cutting heights on the yield and nutrient composition of BH. The soil was prepared for planting by plowing twice in regular furrows followed by 1 more tillage subsequently. The plot used for planting was 1 m^2 and each plot was divided into 6 rows. Planting was 12.5 kg of seeds ha^{-1} whilst the distance between adjacent plants in a row was 50 x 50 cm. Prior to sowing, all plots were fertilized with 187.5 kg 15N-15P-15K per ha^{-1} and 97.5 kg 15N-15P-15K ha^{-1} which were applied one month after sowing. Herbicides and insecticides were also applied as required according to local practice.

The total amount of fresh weight of the whole plot of BH harvested at the cutting ages according to the experimental design, and the heights of the plants were tape measured at the stalk and cut at 30, 40 and 50 cm above ground level by knife to measure production. Also, 500 g of freshly harvested BH samples were randomly collected from each plot, chopped by machine, and then samples were taken and dried at 60°C for 48 hours to obtain a dry weight yield. Dried weight BH samples were ground to pass through a 1-mm screen in order to analyze the chemical composition for proximate and detergent analyses of the dry weight per plant following a trial plan at the experimental site on the SUT farm. Crude protein content was determined by the Kjeldahl method (procedure 928.08, AOAC, 1998). Ether extract was determined by using petroleum ether in a Soxtec System (procedure 948.15, AOAC, 1998) and the ash contents were quantified by AOAC (1990). Neutral detergent fiber and acid detergent fiber were determined using the method described by Georing and Van Soest et al. (1970) and adapted for a FOSS-Fiber Analyzer : Fibertec™ 8000. The chemical analysis was expressed on the basis of final DM. At the same time, the residual freshly harvested BH of the whole plot was also prepared for use as raw material in the formulation of concentrates for the experiment after being chopped and then sun-dried for 3 days. The results of the chemical composition and yield production of the BH harvest from the first experiment were evaluated before the BH was used as a supplement in concentrate for the beef cattle diet in Experiment II.

Note: The collection of all data from the first experiment was a duplicate of the backup results data reported from our previous study on the utilization of sunnhemp meal in beef cattle diet supplemented with urea-treated rice straw (Srisaikham and Lounglawan, 2020).

Experimental design, animals and feeding

Experiment II followed the recommendations of the Institute of Agricultural Technology, Suranaree University of Technology Animal Care and Use Ethics Committee and was approved by its committee No. 1/2011

Twelve Brahman×Thai-Native cattle growing males aged 16 to 19 months old and body weight (BW) (252 ± 18 kg (mean ± SD) at the beginning of the study) were assigned to one of three treatments in RCBD, blocked by initial live weight to eliminate other factors that were likely to affect these observations. The beef cattle were open housed (60 m x 40 m x 6 m, L x W x H) in individual pens (4 x 2 m galvanized steel pipes) with concreted floor at the SUT farm with free access to clean tap water and mineral salt block licks. All cattle were dewormed using Ivermectin injections and they were injected with vitamin AD_3E before the start of the trial. The cattle were individually offered two daily feeds at 1% body weight (BW) on DM basis of concentrate ration together with *ad libitum* rice straw daily at 07.00 and 16.00 hours. The treatments were 1) BHM 0 (concentrate with no BHM), 2) BHM 10 (concentrate with 10% BHM) and BHM 20 (concentrate with 20% BHM) (Table 1). Animals in all the groups were offered *ad libitum* rice straw. The chemical composition of feeds and rice straw used in this study is shown in Table 2. The experiment was conducted for a period of 60 days with the first 2 periods of 14 days, for treatment adaptation and for the measurement of feed intake, respectively.

Table 1. Formulation of concentrates used in the experiment.

Item	BHM[1] level (Percentage of ingredients)		
	BHM 0	**BHM 10**	**BHM 20**
Brown hemp meal	0	10	20
Cassava pulp	48	45	43
Cassava chip	9	7	7
Rice bran	17	15	10
Molasses	6	6	6
Soybean meal	6	3	0
Palm meal	10	10	10
Urea	2	2	2
Mineral mix[2]	1.6	1.6	1.6
Premix[3]	0.4	0.4	0.4
Total	**100**	**100**	**100**

Note: [1] BHM = Brown hemp meal, [2] Mineral mix contains per kg: 120 g Ca; 140 g Na; 32 g P; 20 g S; 15.4 g Mn; 7 g Zn; 2 g Mg; 1 g Fe; 1.25 g Cu; 0.33 g Co; 0.03 g Se; 0.1 g, [3] Vitamin-mineral premix contains per kg: 2,000,000 IU Vit. A; 640,000 IU Vit. D3; 64,000 IU Vit. E; 160 g Ca; 99 g S; 80 g P; 16 g Fe; 16 g Mn; 12 g Zn; 3 g Cu; 0.2 g I; 0.05 g Co; 0.05 g Se.

Table 2. Chemical composition of feeds (Mean±SE[1]) used in the experiment.

Item	BHM[2] level			Rice straw
	BHM 0	**BHM 10**	**BHM 20**	
Dry matter	89.97 ± 0.29	89.34 ± 0.33	88.92 ± 0.26	92.14 ± 0.30
Crude protein	14.30 ± 0.52	14.44 ± 0.79	14.61 ± 0.65	3.77 ± 0.10
Ether extract	3.49 ± 0.32	3.33 ± 0.08	3.43 ± 0.32	0.52 ± 0.46
Ash	5.62 ± 0.18	5.51 ± 0.43	5.01 ± 1.06	4.29 ± 0.14
Crude fiber	11.04 ± 1.28	12.29 ± 0.75	13.80 ± 2.39	38.81 ± 0.31
Neutral detergent fiber	29.30 ± 3.22	33.42 ± 0.81	36.04 ± 0.30	74.50 ± 0.14
Acid detergent fiber	18.69 ± 0.51	20.57 ± 0.48	22.04 ± 0.12	53.40 ± 0.18
Acid detergent lignin	5.41 ± 0.21	5.77 ± 0.53	5.85 ± 0.12	11.18 ± 0.94
Non-fiber carbohydrates	47.29 ± 1.06	47.83 ± 1.11	40.91 ± 0.58	16.92 ± 0.26

Note: [1] SE = Standard error, [2] BHM = Brown hemp meal

Measurements, sample collection, and chemical analysis

The feeds were recorded daily. Residual feeds were collected and weighed every 10 days from each of the cattle. Feed samples were taken and dried in a hot air oven at 60˚C for 48 hours and ground through a 1 mm^2 mesh screen. Fecal samples were collected and weighed for five consecutive days in the last week of the experiment from each of the cattle and kept at 4°C pending an analysis of their chemical composition and then the apparent digestibility (%) from 10% of fecal sampling was calculated following the procedures used by Schnieder and Flatt (1975). At the end of the experimental period, feed samples were pooled and subsamples were taken for further chemical analysis. Samples were subjected to a proximate analysis. Total N was determined using the Kjeldahl method and CP was calculated by N content x 6.25. Ether extract was determined by using petroleum ether in a Soxtec System (procedure 948.15, AOAC, 1998) and the ash contents were quantified by AOAC (1990). Neutral detergent fiber and acid detergent fiber were determined using the method described by Georing and Van Soest et al. (1970), adapted for FOSS-Fiber Analyzer: Fibertec™ 8000. The chemical analysis was expressed on the basis of final DM. The cattle were recorded with an initial live weight at the start and a final live weight at the end of the experiment after a fasting period of at least 16 h to calculate the LWC and ADG and the feed intake per BW.

The rumen fluid of each of the cattle was collected (60 ml) at 0 and 4 h post morning feed using a flexible oral stomach tube constructed from vinyl (3/4 inches in length) with modified attachment to a suction pump on the last day of the experiment for determining the pH using a digital pH meter (MP 220 pH Meter, Mettler-Toledo Gombh, CH-9603 Schwerzenbach, Switzerland) immediately and kept at -20˚C for an analysis of the ammonia-nitrogen (NH_3-N) concentration by distillation according to the Kjeldahl method (AOAC, 1998) and the VFA concentration which included acetic acid (C_2), propionic acid (C_3) and butyric acid (C_4). The supernatant of the rumen fluid was analyzed for concentrations of VFA which were determined by gas chromatography (GC) following the procedures described by Song and Kennelly (1990) (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 by 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

The measured data of the chemical composition and yields (kg ha^{-1}) of BH cut at different ages and heights were analyzed by ANOVA for a 3 x 3 Factorial in RCBD, whereas all the data obtained from the experiment related to the cattle were analyzed by ANOVA for RCBD using the Statistical Analysis System (SAS, 1998). Significant differences among treatments means were compared by Duncan's new multiple range test (DMRT). Differences were considered significant when *P* values were less than 0.05 ($P < 0.05$) (Steel and Torries, 1980).

RESULTS

Effects of cutting age (30, 40 and 50 days) and height (30, 40 and 50 cm above ground level) on the nutrient composition and yield of brown hemp

This study clearly demonstrated that the cutting age at 50 days had a greater effect on the nutrient composition and yield than the cutting ages at 30 and 40 days and also resulted in higher yield rates of CP, ash, EE, CF, NDF, ADF, and ADL but that the cutting heights did not reveal any significant differences in yield ($P < 0.05$). A significant interaction between the age and height of BH showed lower CP, EE and NDF values with increasing age and decreasing height of cut ($P < 0.05$) as shown in Table 3. With the increasing age of the plants, CF, ADF and ADL significantly increased, however NDF content decreased ($P < 0.05$). Cutting height did not affect these parameters ($P > 0.05$).

In terms of all parameters of chemical composition, the production (ha^{-1}) of BH harvests showed that DM, CP, EE, ash, CF, NFE, NDF, ADF, hemicellulose, cellulose, and ADL increased significantly ($P < 0.05$) with increasing cutting ages. However, the different cutting heights of BH harvests did not reveal any significant differences in DM yield (Table 4). CP yield ranged between 524 to 816 kg ha^{-1} and was significantly affected by all 3 different cutting ages at harvest time. The highest mean CP yield was found at the cutting age of 50 days (816 kg ha^{-1}), conversely, 30 days showed the lowest CP yield. No differences were observed in relation to the different cutting heights and the interactional effect between cutting at different ages and height (age x height) on CP yield. An earlier cutting regime resulted in lower CF, ADF and ADL compared to the later cutting at 50 days.

Table 3. Nutrient composition (%) of brown hemp cut at different cutting ages and heights.

Item	30 days				40 days				50 days				SEM[1]	*P* value		
	30 cm	40 cm	50 cm	Mean	30 cm	40 cm	50 cm	Mean	30 cm	40 cm	50 cm	Mean		Age	Height	Age × Height
Dry matter	21.11	20.34	19.63	20.36	22.22	22.45	21.54	22.07	23.15	23.32	23.01	23.16	0.61	0.05	0.29	0.48
Crude protein	21.32	21.87	23.07	22.09	20.33	20.41	21.43	20.72	18.79	19.83	19.94	19.52	0.28	0.02	0.01	0.01
Ether extract	3.33	3.54	3.61	3.49	3.15	3.27	3.35	3.26	2.87	2.84	2.91	2.87	0.08	0.05	0.01	0.01
Ash	6.98	6.47	7.01	6.82	6.55	6.41	6.78	6.58	6.54	6.44	6.32	6.43	0.17	0.11	0.07	0.05
Crude fiber	13.81	12.87	12.33	13.00	17.93	17.41	17.32	17.55	23.01	22.74	22.03	22.59	1.74	0.01	0.78	0.30
Neutral free extract	33.45	34.91	34.35	34.24	29.82	30.05	29.58	29.82	25.64	24.83	25.79	25.42	2.01	0.01	0.11	0.43
Neutral detergent fiber	40.01	38.77	36.54	38.44	42.87	40.75	38.97	40.86	44.22	43.35	42.29	43.29	1.89	0.04	0.08	0.02
Acid detergent fiber	25.11	24.92	22.36	24.13	27.54	26.13	25.41	26.36	29.98	29.1	28.47	29.18	0.88	0.03	0.03	0.65
Hemicellulose	14.90	13.85	14.18	14.31	15.33	14.62	13.56	14.50	14.24	14.25	13.82	14.10	0.27	0.05	0.03	0.65
Cellulose	20.63	20.94	19.05	20.21	21.68	20.62	21.10	21.13	22.97	22.52	22.23	22.57	0.41	0.04	0.03	0.65
Acid detergent lignin	4.48	3.98	3.31	3.92	5.86	5.51	4.31	5.23	7.01	6.58	6.24	6.61	0.29	0.02	0.07	0.82

Note: [1] SEM = standard error of mean.

Table 4. Yield (kg ha^{-1}) of brown hemp cut at different cutting ages and heights.

Item	30 days				40 days				50 days				SEM[1]	*P* value		
	30 cm	40 cm	50 cm	Mean	30 cm	40 cm	50 cm	Mean	30 cm	40 cm	50 cm	Mean		Age	Height	Age× Height
Dry matter	1,027	938	754	906	2,641	2,518	2,430	2,530	4,521	4,091	3,954	4,189	525	0.01	0.34	0.71
Crude protein	219	205	174	199	537	514	521	524	849	811	789	816	93	0.01	0.27	0.83
Ether extract	34	33	27	31	83	82	81	82	130	116	115	120	11	0.01	0.33	0.12
Ash	72	61	53	62	173	161	165	166	296	263	250	270	28	0.01	0.21	0.11
Crude fiber	142	121	93	119	474	438	421	444	1,040	930	871	947	54	0.01	0.04	0.05
Nitrogen free extract	343	327	259	310	788	757	719	755	1,159	1,016	1,020	1,065	90	0.01	0.11	0.36
Neutral detergent fiber	411	364	275	350	1,132	1,026	947	1,035	1,999	1,773	1,672	1,815	122	0.01	0.04	0.04
Acid detergent fiber	258	234	169	220	727	658	617	667	1,355	1,190	1,126	1,224	109	0.01	0.03	0.19
Hemicellulose	153	130	107	130	405	368	330	368	644	583	546	591	113	0.01	0.05	0.32
Cellulose	212	196	144	184	573	519	513	535	1038	921	879	946	132	0.01	0.05	0.15
Acid detergent lignin	46	37	25	36	155	139	105	133	317	269	247	278	27	0.01	0.05	0.22

Note: [1] SEM = standard error of mean.

Nutrient intake and body weight

Voluntary feed intake (VFI), which is the amount of feed or ration that an animal will voluntarily consume per day of the rice straw and not different among treatments. DMI % of BW was not affected by the treatments (*P* >0.05). Means of DMI, DMI % of BW, total DMI kg/d are given in Table 5. No significant differences were found in the final live weights and LWC when the proportions of BHM in the concentrate were increased (*P* >0.05). However, ADG found in BHM 20 was significantly lower than the control group (BHM 0) (*P* <0.05), but its ADG was not statistically different from that of BHM 10.

Table 5. Effect of brown hemp meal contained in the concentrate on the mean values for nutrient intake and the growth performance of Brahman×Thai-Native cattle.

Item	BHM[1] level			SEM[2]	*P* value
	BHM 0	BHM 10	BHM 20		
Concentrate					
Dry matter intake, kg/day	2.67	2.67	2.67	-	-
%BW[3]	0.92	0.97	0.94	0.03	0.56
g/kgBW$^{0.75}$	38.0	39.6	38.7	0.04	0.65
Rice straw					
Dry matter intake, kg/day	6.81	6.66	6.63	0.12	0.57
%BW	2.36	2.43	2.37	0.16	0.46
g/kgBW$^{0.75}$	97.2	98.9	96.1	1.52	0.27
Total					
Dry matter of total intake, kg/day	9.48	9.33	9.30	0.14	0.69
%BW	3.28	3.40	3.31	0.22	0.75
g/kgBW$^{0.75}$	135.2	138.5	134.8	2.17	0.59
Live weight change					
Initial live weight, kg	254.1	245.4	256.5	12.60	0.21
Final live weight, kg	289.2	274.3	283.7	21.80	0.33
Live weight change, kg	35.1	28.9	27.2	5.50	0.13
Average daily gain, kg/day	0.6[a]	0.5[ab]	0.5[b]	0.04	0.04

Note: [1] BHM = Brown hemp meal, [2] SEM = Standard error of mean, [3] BW = Body weight, [a, b] Means within a row with different superscripts are significant different (*P* <0.05).

Nutrient digestibility, rumen-pH, ammonia nitrogen (NH_3-N) and volatile fatty acid (VFA).

As for the digestibility of DM, no significant difference was found between the concentrate group without BHM and the concentrate group with BHM at 10 and 20 (*P* >0.05) (Table 6). No difference was observed in rumen pH values nor in the concentration of ammonia nitrogen and VFA among treatments (*P* >0.05). Mean values are presented in Table 7.

Table 6. Effect of brown hemp meal contained in the concentrate on the mean values for nutrient digestibility (%) of Brahman×Thai-Native cattle.

Item	BHM[1] level			SEM[2]	*P* value
	BHM 0	BHM 10	BHM 20		
Dry matter	61.06	59.56	57.87	1.47	0.22
Crude protein	68.92	66.12	64.96	2.36	0.44
Ether extract	76.89	74.91	75.73	1.27	0.43
Crude fiber	52.00	50.80	50.90	0.48	0.59
Neutral detergent fiber	42.19	40.79	39.55	0.95	0.29
Acid detergent fiber	25.14	26.74	23.80	0.67	0.44
TDN[3] (%)	68.56	66.56	66.00	0.66	0.47
DE[4] (MJ/kgDM)	12.65	12.22	12.08	0.32	0.35
ME[5] (MJ/kgDM)	10.37	10.02	9.91	0.26	0.18

Note: [1] BHM = Brown hemp meal, [2] SEM = Standard error of mean [3]TDN = Total digestible nutrients, TDN_{1X} (%) (total digestible nutrient at maintenance level) = tdNFC + tdCP + (tdFA x 2.25) + tdNDF -7 (NRC, 2001); where tdNFC (truly digestible non-fiber carbohydrates) = 0.98 (100 - [(NDF – NDICP) + CP+ EE + Ash]), tdCPf (truly digestible CP for forages) = CP × exp[-1.2 × (ADICP/CP)], tdCPc (truly digestible CP for concentrates) = [1 – (0.4 × (ADICP/CP))] × CP, tdFA (truly digestible fatty acid) = FA where FA = EE – 1.0, If EE<1.0 then FA = 0, and tdNDF (truly digestible neutral detergent fiber) = 0.75 (NDFn – Lignin) $[1 - (\text{Lignin/NDFn})^{0.667}]$, [4] DE = DEP (digestible energy at production level) (Mcal/kgDM) = DE_{1X} x Discount (NRC, 2001), [5] ME (Metabolizable energy) was 82% of DE (NRC, 2000).

Table 7. Effects of brown hemp meal contained in the concentrate on pH, ammonia nitrogen (mg/dl) and the individual amounts and the ratio of volatile fatty acid (mol/100 mol) at 0 h and after 4 h feeding of Brahman×Thai-Native cattle.

Item	BHM[1] level			SEM[2]	*P* value
	BHM 0	BHM 10	BHM 20		
pH					
Hour 0	7.01	6.45	6.98	0.19	0.78
Hour 4	6.11	6.09	6.32	0.32	0.50
NH_3-N		(mg/dl)[4]			
Hour 0	8.43	7.97	9.07	0.33	0.29
Hour 4	12.66	13.08	14.24	1.42	0.17
Acetate; C_2		(mol/100 mol)			
Hour 0	67.33	66.69	67.59	0.48	0.88
Hour 4	68.07	67.11	66.34	0.96	0.44
Propionate; C_3		(mol/100 mol)			
Hour 0	21.43	21.23	20.40	0.44	0.54
Hour 4	20.53	21.27	21.37	0.37	0.37
Butyrate; C_4		(mol/100 mol)			
Hour 0	11.23	11.90	11.00	0.29	0.36
Hour 4	11.43	11.40	11.96	0.33	0.29
C_2:C_3					
Hour 0	3.15	3.16	3.25	0.08	0.75
Hour 4	3.31	3.30	3.11	0.12	0.50

Note: [1] BHM = Brown hemp meal, [2] SEM = Standard error of mean, [3] NH_3-N = Ammonia nitrogen, [4] mg/dl = Milligrams per deciliter, C_2:C_3 = Acetate:Propionate.

DISCUSSION

The findings of this study demonstrate the potential for evaluating BH nutritive value and yield based on different cutting ages and height measurements as being the major factors in determining the qualitative traits and quantities of BH. There was a great effect on nutrient composition at 50 days' cutting age compared with 30 and 40 days, since CP, fiber concentration (CF, NDF, ADF and ADL) mostly appeared as negative correlated values, like higher CP at a young age, but low fibre content. The earlier cutting age of BH at 30 days resulted in high protein and low yield, while the later time of cutting of BH at 50 days achieved low protein with high yield which is in accordance with Testa et al. (2011) who studied DM and the qualitative characteristics of alfalfa legume as affected by harvest times and soil water content (irrigated and rainfed). Testa et al. (2011) found that the bud flowering had a low yield at early harvest with high protein content and digestibility, however, the full flowering led to a high yield with low protein content and digestibility at a late harvest. An increase in the period of cutting ages of another family (Gramineae - purple guinea grass) which was harvested from 30, 45 and 60 days, resulted in a reduced CP while the DM yield at the 45 d cutting interval was the highest, and statistically different from the intervals of 30 and 60 days (Sukkasame et al., 1999). Considering the protein levels of forage beans at different cutting ages, it was found that hamata, *Graham stylo (Stylosanthes guianensis),* Siratro *(Macroptilium atropurpureum)*, and Centro *(Centrosema pubescens)* had the highest CP at 8 weeks of age which was 18.8, 22.8, 20.8 and 22.9%, respectively, compared with cutting at 4, 6, 10 and 12 weeks, while the yield of all types of legumes increased with the greater ages of the crops (Kasarntikul, 1993). This study shows that the CF, ADF, and ADL yields showed a negative correlation with cutting height, while different parts of the plants were separated during BH growth and the leaf/stem ratio had the highest stem yield (De Santis et al., 1997). In fact, cutting the plants early resulted in a richness of leaves which is in accordance with the research of Sheaffer et al. (2000) who demonstrated that the leaf yield was highest in early harvest regime and the stem yield was highest in the late harvest regime. This study indicates that a BH harvest after 50 days is the best cutting age for harvest since it produces a greater DM and nutrient yield than after 30 and 40 days and, despite the low fiber, results in high protein. However, there are many factors that may affect the productivity of the crop, such as the planting periods, which result in planting of different densities, and production may also depend on soil type or fertility, BH species and the environmental conditions.

The values of the nutrient compositions of all the treatments in the second experiment, i.e., DM and CP, were similar. Other than the NDF and ADF contents, there was not a considerable difference in the profile of all the treatments; however, the quality of nutrients may vary from ingredient to ingredient. In contrast, NDF and ADF increased with increasing BHM levels in the concentrates. Energy values were reduced with increasing levels of BHM addition. This can be attributed to higher CP and less fiber content of rice bran and soybean meal rather than BHM. The present study replaced rice bran and soybean meal with BHM.

Table 5 shows the results of nutrient intake and the growth performance of Brahman×Thai-Native cattle with BHM contained in the concentrate. No significant difference was found for DMI: kg/d ($P > 0.05$) when the ratio of BHM in the concentrate increased. No differences in total feed intake were found in Ongole cross *(Bos indicus)* cows (318 ± 12 kg LW) fed rice straw *ad libitum* with supplemented four levels of legumes (*Gliricidia sepium* and *Leucaena leucocephala*) (0, 11, 21, and 42 g DM/kg$W^{0.75}$ day) for 20 weeks (Syahniar et al., 2012). Similarly, Antari et al. (2014) reported that there was no significant differences in total DM and ME intake or rice straw intake between mature Brahman (*Bos indicus*) cows fed on two different diets of fed rice straw and onggok plus urea or gliricidia in Indonesia. Onggok is a fibrous cassava by-products left after starch has been extracted from the tuber, whereas gliricidia is a leguminous tree belonging to the Fabaceae family. However, the intake of onggok, gliricidia and total DM and ME were higher in weeks 16 to 21 than in weeks 1 to 15 ($P < 0.001$) in Brahman cows. The supplemented legumes (gliricidia + leucaena) in a basal diet of rice straw for Ongole crossbred cows (Ongole filial bulls initial weight of 308.25 ± 38.36 kg) was influenced ($P < 0.01$) by the amounts of DM, organic matter and CP intake (Da Costa and Da Costa, 2017). Moreover, Suankul (2011) studied the effects of *Stylosanthes guianesis* CIAT 184 in concentrate rations on Thai-Native goat production performance during 120 days. The DMI of these Thai-Native goats was similar between the treatments which received the concentrate supplemented with proportions of *Stylosanthes guianesis* CIAT 184 at 80:20%, 60:40%, 40:60%, and 20:80%, respectively ($P > 0.05$). In our earlier study, the intake of alfalfa dehydrated pellets with 10% and 20% in a total mixed ratio (TMR) in meat goat diet had no effect on DMI, average daily gain or nutrient digestibility (Srisaikham and Quanjai, 2021). The reason for the results showing no differences in DMI might be due to that fact that these experimental diets were designed to be iso-nitrogenous and iso-caloric, which had similar content to CP (approximately 14% CP) in all the formula feeds in which cattle were fed BHM in different ratios of BHM 0, 10 and 20, respectively.

The weight change parameters have been used to interpret the growth performance status of beef cattle when they consume the feed. In the current study, all the treatments a similar initial weight with similar nutrient profiles, and no significant differences were observed for the assessment of the weight changes between the BHM 0 and BHM 10 in the concentrate ratio together with ad libitum rice straw, including the final weight and LWC, during either experimental period. In theory, an increase in the growth rate is related to increased DMI (De Brito et al., 2017) and, furthermore, the weight gain can be improved by supplemental feeding of pasture or roughage (e.g., dry pasture) in lambs (Atti and Mahouachi, 2009; Turner et al., 2014). Supplementation of the diet with the inclusion of cassava peels with gradual reductions of the amounts of cassava leaves and cowpea haulms (legume) increased the proportion of 100:400:475 g/kg DM in the improved growth of West African Dwarf goats, which was related to DMI with a significantly increased quadratic (Q) and a cubic (C) (P <0.05) (Abatan et al., 2015). However, the results of the present study show significantly different decreases in ADG across diets that contained BHM 20 (Table 5) compared to BHM 0. The total DMI ranged from 9.30 to 9.48 kg/day, but the differences were not significant (P >0.05) due to the inclusion of BHM in the diets. It would be logical to explain that the content of non-fiber carbohydrates (NFC) in BHM 10 and 20 was lower than BHM 0, and NFC, including starch, sugars and pectin, in which the starch density decreased as the inclusion of BHM in the diet increased; this finding was as expected and it is probably one of the key reasons that affects ADG; although the DMI showed no significant differences which is consistent with the research of Kongphitee et al. (2018). Replacing rice straw with an NFC source (cassava pulp) in fermented TMR beef cattle fed diets improved growth performance, energy intake and energy retention because of the increase in digestible feed intake and the digestibility of DM, OM, NDF, and NFC (Kongphitee et al., 2018). The fermented TMR energy density increased as the proportion of cassava pulp in the diet increased due to the fact that cassava pulp has a higher NFC content than rice straw. Our results are consistent with those of Zhu et al. (2013) and Liu et al. (2014) who reported that the corn stover diet supplemented with an NFC source provided readily fermentable carbohydrates in the rumen which resulted in microbial protein yield and metabolizable protein supply in comparison with alfalfa diet. Similar to the increased NFC diet or starch in dairy cows which can improve lactation performance (Cantalapiedra-Hijar et al., 2014) and feed efficiency (Wei et al., 2018). A few studies have been found in the literature which provided data for tropical legumes contained in the diets of beef cattle (Yuangklang et al., 2011) and swamp buffalo (Foiklang et al., 2011) in Thailand. Our results are in agreement with observations in the case of Bermuda grass pasture (BG; *Cynodon dactylon*), sunn hemp forage (SH; *Crotalaria juncea*) or a mixed forage BG + SH diets for ADG in Kiko-cross growing intact male goats (Min et al., 2019) in which ADG was higher (P <0.01) for a greater NFC content in legume diets than grasses. However, there was no direct evidence due to voluntary feed intake of cattle being raised on indoor feeding or stall-fed ruminants, which is controlled by metabolic and physical factors which affect grazing animal experiments differently depending on grazing behavior (searching to access feed or prehending).

In this study, the nutrient digestibility of DM, CP, EE, CF, NDF and ADF (Table 6) appeared to be similar in all groups, for example, rumen pH, NH_3-N and VFA concentrations at 0 h before and after post feeding (Table 7) (P >0.05), demonstrating that the BHM contained in the concentrate at 0, 10 and 20 had no effect on beef cattle. Normally, DMI of the roughage (DMIR) reduced by increases in the levels of fibers, so the fibers might reduce the animals' digestibility and slow the rate of passage of the feed, especially for high fiber mature forages (Stuart et al., 1990). These are the most important factors limiting animal production from forages. This factor leads to the situation where the feed intake of forage by ruminant animals is relatively low and productive performance is decreased. One explanation for our results is that all the treatment diets were designed to have similar CF content.

The levels of rumen pH for all treatments in the group were between 6.09 - 6.32, which is similar to the normal range of levels for animals, i.e., 5.5-7.0 (Dehority, 2003). Furthermore, the levels of NH_3-N concentration in the rumen is a key source for the growth of bacteria that exploits the fibers (Hungate, 1966) and these were between 12.66 -14.24 mg/dl, which was in the range of the optimal level (15-30 mg/dl) to improve rumen ecology, digestibility and feed intake as reported Wanapat et al. (2018) who studied lactating dairy cows. The results of this study suggest that the combination of an appropriate amount of BHM can be utilized as a protein source in concentrate that uses cassava pulp and cassava chip as a carbohydrate source in the formula and this may improve fermentation in the rumen by providing the proper pH for microbial activity, as described by Hungate (1966). The BHM 0, 10 and 20 contained in the concentrate led to an increase in the NH_{3}-N concentration in rumen during the first 4 h after post feeding. This could be a potential use of nitrogen for microbial protein synthesis which is often the foremost component of metabolizable protein supply in animal ruminants (Moorby et al., 2006). Moreover, the nutrient digestibility of CP was greater than that of Wanapat et al. (2018), which suggests that the more the feeding sources of protein are degraded, the higher the increase in NH_{3}-N concentration in the rumen.

There were no significant differences in the concentrations of TVFA, C_2, C_3, C_4, and the proportions of C_2:C_3 (P >0.05) in all the beef cattle which consumed BHM in the concentrate of the treatments group. The proper proportions of C_2, C_3 and the proportions of C_2:C_3 conformed to the suggestions of Wanapat (1990), who recommended that they should be between 65-70, 20-22, and 1-4, respectively. The decomposition of the structural carbohydrates in the rumen, i.e., 60% of cellulose and hemicellulose in the roughage produced C_2 and C_4, respectively (Murphy et al., 1982), and may be attributed to nutrient digestibility in the rumen as well.

CONCLUSION

This study clearly showed that a cutting age of 50 days had a greater positive effect on CP and yield than the cutting ages of 30 and 40 days and also resulted in a higher yield of CP, ash, EE, CF, NDF, ADF and ADL. When BHM produced from the harvest of an over 50 days' crop was included at the level of 10% in the concentrate diet of beef cattle as a replacement for other protein sources, it did not affect DMI, LWC, nutrient digestibility, rumen-pH, NH_{3}-N or rumen VFA concentrations.

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