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Pangola (*Digitaria eriantha)* Hay as a Roughage Source in Total Mixed Ration (TMR) on Growth Performance and Meat Quality of Thai Native Male Goats in a Tropical Area

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Abstract The productivity and chemical composition of Pangola grass during rainy and dry seasons. Results revealed to be used Pangola grass as a roughage source in the total mixed ration (TMR) for growth performance and meat quality of Thai native male goats in the tropics. Temperature was recorded as well as maximum and minimum relative humidity. The first experiment included recording the productivity and analysing the chemical composition of DM, CP, Ash, EE, CF and NFE of Pangola grass during the rainy and dry seasons of 2013-2015. The second experiment that involved classifying fertilized male goats weighing 15 ± 2 kg. into 3 groups. Each group contained 5 goats, and the classification was repeated 3 times for 45 goats in total. Group 1 had straw as a roughage source in the total mixed ration (TMR1). Group 2 used bean hulls as a roughage source in the total mixed ration (TMR2), and Group 3 used Pangola grass hay as a roughage source in the total mixed ration (TMR3). The ratio between roughage and concentrated feed was 15:85 with an average protein content of 14% CP to record the production efficiency and meat quality. The results showed that in the first experiment, the total dry matter yield of Pangola and chemical composition in winter were higher compared to summer due to the propensity of declining yield as the plants aged. For the second experiment, the ADG and CPI of Pangola grass hay (TMR3) were significantly higher than the values for straw (TMR1) and bean hulls (TMR2) ($P<0.05$), whereas for total gain, TDMI, feed conversion ratio, blood urea nitrogen, feed cost, carcass traits, qualities and consumer preference, tests of the goat meat did not show any significant differences ($P>0.05$)

Keywords: Pangola *(Digitaria eriantha)*, Total Mixed Ration (TMR), Thai Native Male Goat

Introduction

The temperature in South East Asia ranges from 27 °C – 31°C from April to October, while the maximum temperature can rise above 41°C for several weeks a year (Tantasupark *et al*., 2000) and those temperature shifts can be a

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substantial problem that leads to declining performance and meat quality. Animal feed resources and other materials that could be used as animal feed are important to small livestock both in terms of quantity and quality. They are a key resource for successfully increasing the efficiency of ruminant production, especially when providing enough feed with good quality (Wannapat, 2009; Wiyabot and Penwijitra, 2010). The lack of roughage during the dry season is a limitation when raising Thai cattle. Straw and bean hulls are widely available and are cheap derivatives, but they are low in nutrients (Danglao *et al.*, 2006). Forage crops are necessary for fibre or roughage in the digestive system of ruminants. Additionally, high-quality forage crops can enhance productivity and reduce costs by diminishing the amount of expensive concentrated feed required, thus increasing profit. However, many agriculturists do not make it a priority to feed their animals high-quality food, as we can see from the low ratio of farm area dedicated to forage crops compared to the number of animals (Dhammasang and Suriyapatra, 2012). The food source for goats is similar to cattle and milk cows. Grass is the main source of roughage for goats, but it is scarce and has low quality during the dry season in the tropics (Tudsri, 1997; Kaewwongsa, 2012). High-quality roughage can promote growth and reduce costs, especially when using Pangola grass (*Digitaria eriantha*), which agriculturists are encouraged to plant for their business (Pralomkarnjana, 1999). Pangola grass (*Digitaria eriantha*) grows with a dense tussock and soft leaves. Its small trunk is favoured by livestock and is suitable for drying. It contains 7-13 stolons that are 3-8 centimetres each and grow well in various soil types from sandy soil to clay or watered areas (Kullana *et al*., 2007). The average amount of protein in Pangola grass hay is 7.88%, TDN 61.9, ADF 35.7%, NDF 63.3%, Ca 0.44% and P 0.3% (Department of livestock development, 2003). The average productivity of the grass planted in lowland and upland areas for livestock was 800-1,200 kgs/rai a year. Some agriculturists have switched to growing Pangola on their farms because it can be harvested 7-9 times per year (Thong *et al*., 2006). However, for the best results, further research on factors influencing high productivity must be conducted each season (Wiyabot and Thongchue, 2013).The objectives of this study were to determine the effects of management variables on Pangola (*Digitaria eriantha*) quality during the fall grazing period and the effects that these variables had on subsequent production and applications for goats to determine the best Pangola management process.

Materials and methods

This research was conducted by planting Pangola grass in the Mutsee area at Nakhon Sawan Rajabhat University while managing a goat farm in the Thap Than district of the Uthai Thani province in Thailand. At 2 pm each day, data were collected, including ambient temperature, wet-dry bulb temperature and relative humidity (RH). The Temperature-Humidity Index (THI) was determined from the following equation:

$$THI = Tdb + 0.36 (Tdp) + 41.2$$

where Tdb was the dry bulb temperature (˚C) and Tdp was the dew point temperature (˚C) (Armstrong, 1994) using values from 2013-2015. The two experiments were conducted according to the following procedure.

The first experiment was conducted from 2013-2015. The herbage quality and quantity were measured based on the forage quality and production. In the rain and during winter, the same analysis was conducted to compare the differences between grazed fields in hay yields from the summer of yr 3 and the summer after the 3rd yr of grazing. Differences in herbage mass and the chemical composition of fields containing stockpiled Pangola (*Digitaria eriantha*) were also measured at the initiation of winter grazing. The plantation bed was sandy loam with pH = 7.9, 2 mg/kg phosphorus (very low), 2 mg/kg potassium (very low) and 3.9 mg/kg calcium (high) within a 3×4 metre area. Before planting, water was pooled in the bed to soak the Pangola stolons for 1 week (Department of livestock, 2006a) until the white roots were 3-5 cm long (using 200-250 kg/rai of Pangola stolon). After 1 month, the water was pooled again for 2 days, and 25 mg/rai 15-15-15 chemical fertilizer was added. Then, the bed was left for 10-15 days and watered for a second time with 10 kg/rai of urea fertilizer (46-0-0) (Department of livestock, 2006b). The Pangola was harvested 70 days after planting by cutting near the soil to make it grow steadily. The cycle was repeated seasonally throughout the 3 years of the experiment. Data collections were repeated over 5 d to obtain samples from all pastures grazed during the experiment. The standing crop was estimated by harvesting and bagging 20-30 randomly located Pangola (*Digitaria eriantha*) plants at ground level. The herbage was dried at 55 ˚C for 48 h and weighed to determine the kilograms of DM/rai (Short *et al*., 1996). The herbage samples were then ground to pass through a 1-mm screen in a Wiley mill and analysed for DM, ash, CP, EE, CF, NFE, NDF and ADL (Goering and Van Soest, 1970) and ADF (AOAC, 1990).

In the second experiment, the effects of using Pangola grass hay as the source of roughage for the total mixed ration (TMR) on growth performance and meat quality in Thai native male goats were examined. The experiment included 45 fertilized, 11-month-old, native male goats that weighed 15 ±2 kg. The research was conducted at Talook Doo in the Thap Than district of Uthai Thani province for 90 days. Before conducting the experiment, all goats received Ivermectin to eliminate parasites and Niclosamide to control cestoda.

Additionally, they were injected with a vaccine to prevent Haemorrhagic septicaemia as well as foot and mouth disease. The goats lived in stalls with clean water and mineral blocks provided at all times. The experiment was conducted with a Completely Randomized Design (CRD) including 3 groups with 3 replicates per 5 goats. Group 1 was fed straw as a source of roughage (TMR1), Group 2 was fed dried peanut hulls as a source of roughage (TMR2) while Group 3 was fed Pangola grass hay as a source of roughage (TMR3). A dietary balance was obtained by using the recommended values of INRA (1988) and AFRC (1993) for energy, protein, fibre, calcium, phosphorus, sodium and chloride. The level of crude protein (CP) on DM basis was 14% CP (Rattana *et al.*, 2010). In this study, the diet component was placed at a ratio of 85:15 concentrate : forage. The TMR used in this experiment was added to each treatment at 1.5% of body weight (BW), and the amount of TMR was gradually increased 15 days prior to the initiation of the trial. After starting the experiment, a TMR at 3.00% of BW was equally divided into two parts and was provided twice a day at 9.00 am and at 4 pm (Soon *et al.*, 2009). The animals were assigned to each group and placed in each group with 25 goats kept in each pen (2×2 m) with free access to fresh water. The eatable quantity was measured each day for 14 days before starting the trial, and then the goats were fed TMR1, TMR2 and TMR3 according to their group assignment. The researcher recorded data by measuring the weight of the food before and after feeding the animals. Goats were weighed on the first day and the 14th day before trial, whereas during the trial, the researcher weighed the goats every 15 days. Then, the average daily gain and the feed conversion rate were calculated (Rattana, *et al*., 2010.). Five millilitres of blood were collected from all goats through the jugular vein before breakfast (0 hours) and 4 hours after breakfast on the last day of the experiment to determine the blood urea nitrogen (BUN) with a urea two-step enzymatic colourimetric test using Urea Liguicolor. For the slaughter and cutting after 90 days, the researcher randomly picked 4 goats in a group according to the methods of Danglao *et al.,* (2006) and weighed the goats before they fasted. After 24 hours of fasting, the goats were weighed again to obtain the fasted live weight. Then, the animals were bled and the carcass was weighed. The pelting started from 4 shanks, the skin was removed from flesh, 4 shins were cut, and the head as well as internal organs were removed. The hot carcass weight was obtained after weighing the finished carcass and storing the carcass at 0.5-1 °C for 24 hours. The carcass percentage was found using the following formula;

$$\text{Carcass Percentage} = \frac{\text{Carcass Weight}}{\text{Live Weight}} \times 100$$

The carcasses were removed from refrigeration and weighed to obtain the chilled carcass weight. The carcasses were thawed for 1 hour and then cut into 2 pieces and weighed. The length from the anterior edge of the 1st rib to the anterior edge of the aitch bone was measured. The width from the edge at the spinous process up to the sternum was measured. The cross-sectional area of the *Longissimus dorsi* between the 12th rib and the 13th rib of the left carcass was measured as well. These values were used to calculate the carcass percentage.

The qualitative measurements of the *Longissimus dorsi* muscle were performed using the following methodologies for each characteristic. Meat colour: For muscle oxygenation, each sample was exposed to the air for 15 min. After this period, the meat was slightly dried with paper towels and the colour was measured using a portable colour meter (Minolta CR 410). The components L* (lightness), a* (red-green) and b* (yellow blue) were shown in the CIELAB colour system and assessed at three different points on the muscle surface using an illuminant D65 and an observational angle of 10˚ (Caldara, 2013).

Exudate loss (EL): Steak samples with a 2.5-cm width were prepared with the external fat removed and were weighed on a semi-analytic scale. The samples were maintained under simulated retail conditions on a shelf with a 45-degree angle of inclination in trays that were covered with plastic film at 4 ±1˚C for 48 h. After this period, the exudate was discharged, and the samples were weighed again. The EL was expressed as a percentage of the initial weight (Caldara, 2013).

Weight loss by cooking (WLC): Steak samples with a 2.5-cm width were prepared with the external fat removed and were weighed on a semi-analytic scale and roasted without the addition of condiments. The oven was pre-heated to a temperature of 170 ˚C. The internal temperature of the sample was monitored during cooking using sensors that were tied to a digital thermometer. When the internal temperature reached 80 ˚C, they were removed from the oven and cooled at room temperature. Then, the steaks were weighed. WLC was expressed as a percentage of water lost relative to the original sample weight (Caldara, 2013).

Shear force (SF): three cylindrical sub-samples were removed from each WLC sample parallel to the muscle fibre orientation. These sub-samples were placed with the fibre oriented perpendicular to the Warner Bratzler lamina as described by Soon *et al*. (2009). An average of three repetitions and the value of shear force for each sub-sample were used to assess the tenderness of the meat (Caldara, 2013).

As for the analysis method, in the first experiment, the botanical composition of the stockpiled fields was analysed using the GLM procedure in SAS (1982), while the second experiment was analysed using ANOVA in Proc

GLM (SAS, 1982) according to the Completely Randomized Design (CRD). Differences were compared using Duncan's multiple range test (Steel and Torrie, 1980).

Results

The temperature and relative humidity during this experiment averaged across rooms were 30.8±1.1˚C and 85.0±7.6%, respectively. The highest temperature was 41˚C, while the lowest temperature was 24 ˚C (data not shown). All experimental diets provided a similar amount of DM, OM, EE, Ash and GE to all treatments (Table 1). This study showed that the productivity of Pangola grass hay (*Digitaria eriantha*) from 2013-2015 in winter was higher compared to summer, whereas the productivity of the grass would decline with age (Figure 1).

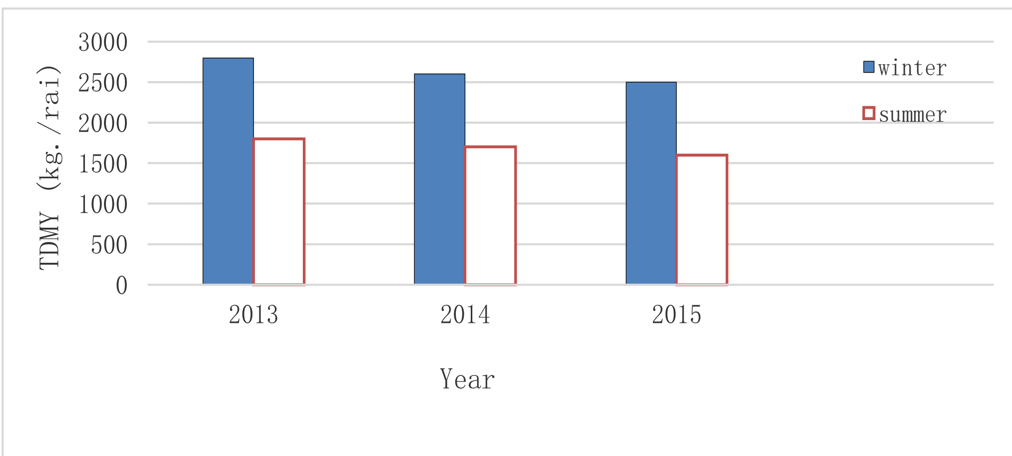

Figure 1. Total dry matter yield of Pangola (*Digitaria eriantha*) in the 3rd yr of grazing

As for the chemical composition of Pangola (*Digitaria eriantha*) from 2013-2015, the analytical results showed that in both winter and summer, the nutrient values of Pangola grass were similar but declined over time (Table 2). In the growth performance of Thai native goats using different sources of roughage in the total mixed ration (TMR), ADG and CPI for Pangola grass hay (TMR3) were significantly higher compared to straw (TMR1) and bean hulls (TMR2) ($p<0.05$), but total gain, TDMI and feed conversion ratio did not show any significant difference ($p>0.05$) (Table 3)

After using different roughage sources in the total mixed ration (TMR), blood urea nitrogen, and feed cost showed no significant differences among the three sources (p>0.05) who reported that a higher amount of fibre in the feed would cause a higher BUN value. The propensity of feed cost for Pangola grass hay would be the lowest among the three sources (Table 4)

The consumer preference test for goat meat after using different roughage sources in the total mixed ration (TMR) found that there was no significant difference among the three sources (p>0.05) (Table 5) The carcass traits and quality after using different roughage sources in the total mixed rations (TMR) demonstrated there were no significant differences among the three sources (p>0.05) (Table 6)

Table 1. Ingredients and chemical composition of the experimental diets

Item	Treatment diet (14% CP)			Pangola
	TMR 1	TMR 2	TMR 3	
Ingredients (% of dry matter)				
Pangola grass hay	-	-	15.0	-
Peanut Hulls	-	15	-	-
Rice Straw	15.0	-	-	-
Cassava chips	43.5	44.5	45.0	-
Palm Kernel cakes	21.5	21	20.5	-
Soybean meal	17.5	17	17.0	-
Dicalcium phosphate	1.0	1.0	1.0	-
Salt	1.0	1.0	1.0	-
Premix[1/]	0.5	0.5	0.5	-
Total Nutrient[2/]	100	100	100	-
Chemical composition (% DM)	86.87	85.70	87.90	87.03
DM	92.67	93.67	92.00	91.92
OM	14.22	14.12	14.42	4.46
CP	0.52	0.45	0.45	1.68
EE	14.46	13.99	13.85	31.80
CF	7.52	7.80	7.95	8.07
Ash	0.45	0.49	0.51	0.44
Ca	0.26	0.30	0.32	0.2
P	4.73	4.51	4.05	4.37
GE (Mcal/kgDM)				

[1/] Mineral and Vitamin premix per 100 kilograms feed contains: Vitamin A 12.50 million IU, Vitamin D_3 2.50 million IU, Vitamin E 40,000 IU, Co 0.40 g, Se 0.40 g, I 1.70 g, Cu 20 g, Mn 85.00 g, Zn 115.00 g, Fe 135.00 g, K155.00 g, Mg 175.00 g, feed additive 10.00 g, and other ingredients 5.00 kg.
[2/] Calculated based on chemical composition of feedstuff from NRC (1981).

Table 2. Effects of winter and summer on chemical composition of Pangola grass hay (*Digitaria eriantha*) in the 3rd yr of grazing

Item (%)	2013		2014		2015		SEM
	Winter	Summer	Winter	Summer	Winter	Summer	
DM	87.05	90.11	89.51	90.20	90.10	91.01	0.29
CP	10.64	11.3	9.71	11.4	8.72	11.70	0.17
EE	1.16	1.10	1.02	1.00	1.11	0.95	0.49
CF	32.84	33.12	32.75	34.18	32.91	35.75	0.51
NDF	73.25	70.11	72.11	69.88	73.19	72.10	0.87
ADF	38.45	28.71	36.39	26.19	35.12	25.03	0.7
ADL	5.35	2.25	4.70	3.10	6.52	2.80	0.55

DM = dry matter, CP = crude protein, EE = ether extracts, CF = crude fibres, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin.

Table 3. Effects of Total mixed ration (TMR) on Growth performance of Thai Native goats

Item	TMR_1	TMR_2	TMR_3	SEM
Initial body weight (kg)	15.60	15.48	15.58	0.41
Final body weight (kg)	29.50	30.41	29.45	0.16
Total gain (kg)	14.48	14.13	15.01	0.78
ADG (g/d)	94.19[b]	95.32[b]	98.10[a]	0.13
TDMI (g/d)	660.31	667.11	663.18	1.71
CPI (g/d)	116.00[b]	117.31[b]	128.71[a]	0.31
Feed Conversion Ratio	6.50	6.18	6.34	0.15

[a,b,c] Values with different superscripts within the same row are significant ($p<0.05$);
ADG = Average daily gain, TDMI = Total dry matter intake, CPI = Crude protein intake;
SEM = standard error of the mean.

Table 4. Effects of total mixed ration on blood urea nitrogen and feed cost for Thai Native goats

Item	TMR_1	TMR_2	TMR_3	SEM[1/]
BUN, mg/dI				
0 h-post feeding	7.91	7.08	7.84	1.10
4 h-post feeding	10.78	10.27	10.91	0.22
Mean	9.34	8.67	9.37	1.14
Feed cost; Baht/head				
Concentrate cost	235.25	226.50	225.15	-
Total cost	257.75	246.91	260.75	-
Feed cost/kg weight gain, Bath	66.42	77.25	50.51	-

[1/]SEM = Standard error of the mean.

Table 5. Effects of total mixed ration (TMR) on consumer preference tests with the goat meat

Item	TMR_1	TMR_2	TMR_3	SEM[1/]
Tenderness	3.32	3.35	3.33	0.41
On flavour intensity	3.55	3.59	3.56	0.32
Off flavour intensity	2.95	2.96	2.97	0.36
Overall acceptability	3.34	3.36	3.40	0.07

[1/]SEM = Standard error of the mean.

Table 6. Effects of total mixed ratio (TMR) on carcass traits and qualities

Item	TMR_1	TMR_2	TMR_3	SEM[1/]
Carcass				
Slaughter weight (kg)	27.25	27.15	27.14	0.39
Fasted BW, (kg)	25.85	25.71	25.71	0.87
Empty body weight (kg)	24.12	24.41	24.59	0.24
Hot carcass weight (kg)	12.80	12.62	12.29	0.60
Cold carcass weight (kg)	12.31	12.79	12.03	0.81
Dressing percentage (%)	45.29	45.92	45.60	0.14
Carcass length, (cm)	49.71	49.82	49.12	0.41
Carcass width, (cm)	23.82	24.10	24.05	0.52
Loin eye area, (cm^2)	6.82	6.27	6.45	0.45
Meat percentage (%)	58.05	58.61	58.15	1.03
Fat percentage (%)	4.72	4.06	4.05	1.01
Bone percentage (%)	18.81	18.61	18.28	1.28
pH 45 min	6.46	6.86	6.07	0.25
Temperature 45 min	39.62	39.20	39.80	0.21
L* (lightness)	53.12	52.71	52.81	1.01
a* (redness)	5.05	5.54	5.61	0.27
b* (yellowness)	2.40	2.51	2.43	0.31
Cooking loss (%)	25.80	25.71	25.11	0.32
Drip loss (%)	54.35	54.03	54.67	0.31
Shear force (kg/cm^3)	3.18	3.13	3.20	0.12
Chemical composition				
Moisture (%)	74.23	74.31	74.32	0.81
Crude protein (%)	22.11	22.31	22.36	0.19
Crude fat (%)	1.42	1.45	1.48	0.05
Crude ash (%)	1.05	1.03	1.00	0.17

[1/]SEM = Standard error of the mean.

Discussion

Pangola (*Digitaria eriantha*) hay used as a roughage source in the total mixed ration (TMR) on growth performance and meat quality in Thai Native male goats in a tropical area. The demand for forage crops in Thailand is high, especially during dry seasons when the pastures for animal feeding are only two million rai (Dhammasang and Suriyapater, 2012). This study showed that the productivity of Pangola grass hay (*Digitaria eriantha*) from 2013-2015 in winter was higher compared to summer, whereas the productivity of the grass would decline with age (Figure 1). Moore and Gareia (2001) reported that in a warm or hot climate, the lower amount of sunlight caused slower grass growth due to a reduced quantity of lignin. This result did not correlate with the results of Kullana *et al*. (2007), who reported that the weight of grass hay in the first and second year after the grass was planted as well as the average were not different. Tudsri (1997) suggested that agriculturists in Thailand should manage Pangola grass beds by putting fertilizer on them in the early and mid-season to make the soil fertile and increase productivity.

As for the chemical composition of Pangola (*Digitaria eriantha*) from 2013-2015, the analytical results showed that in both winter and summer, the nutrient values of Pangola grass were similar but declined over time (Table 2). The CP and IVOMD were related to the planting time and grass bed. (Aiken, 1997) This outcome agreed with the results of Hitz and Russell (1998), who said that the values of OM and IVOMD in the 1^{st} yr were different from the 2^{nd} yr and 3^{rd} yr; however, Short *et al*. (1996) reported that the grass bed quality changed over time, which caused the CP percentage to increase from 1989-1992 and indicated that management of Pangola grass beds should include fertilization with animal manure or fertilizer (Wiyabot and Penwijitra, 2010). In the growth performance of Thai native goats using different sources of roughage in the total mixed ration (TMR), ADG and CPI for Pangola grass hay (TMR3) were significantly higher compared to straw (TMR1) and bean hulls (TMR2) ($p<0.05$), but total gain, TDMI and feed conversion ratio did not show any significant difference ($p>0.05$) (Table 3), which did not correlate with the results of Danglao *et al*. (2006) but did agree with the results of Hitz and Russall (1998), who reported that using bean hulls and straw as the roughage source in the TMR did not influence the growth performance of goats (CP = 14%). Chaichaoom *et al*. (2007) reported that using Pangola grass hay as the roughage source did not have any influence on the weight of growth, eatable quantity and feed conversion ratio, whereas Thong *et al*., (2006) suggested that using the Pangola grass hay as the roughage source at a rate of 85% could increase the dry matter eatable quantity, which was similar to the results for Kaewwongsa (2012).

After using different roughage sources in the total mixed ration (TMR), blood urea nitrogen, and feed cost showed no significant differences among the three sources ($p>0.05$), which did not agree with the outcomes of Rattana *et al*. (2010) who reported that a higher amount of fibre in the feed would cause a higher BUN value. The propensity of feed cost for Pangola grass hay would be the lowest among the three sources (Table 4), which did not agree with the results of Loerch (1996), who reported that the feed cost was not different, or Chaichaoom *et al*. (2007) and Rattana *et al*. (2010), who reported that the higher rate of fibre did not affect the feed cost.

The consumer preference test for goat meat after using different roughage sources in the total mixed ration (TMR) found that there was no significant difference among the three sources (p>0.05) (Table 6), which correlated with the results of Chaichaoom *et al*. (2007) and Hitz and Russell (1987), who reported that after testing with participants, there was no difference in the softness, moisture, taste and overall preference.

The carcass traits and quality after using different roughage sources in the total mixed rations (TMR) demonstrated there were no significant differences among the three sources (p>0.05) (Table 5), which agreed with the results of a study of carcass and chemical composition of goats fed Total Mixed Rations at a protein level of 14% (Soon *et al*., 2009). Chaichaoom *et al*. (2007) suggested that using Pangola as the roughage source caused the lowest level of fat. Rattana *et al*. (2010) reported that a higher ratio of roughage led to a larger hot carcass.

Conclusion

This study investigated the effects of Pangola (*Digitaria eriantha*) hay used as a roughage source in the total mixed ration (TMR) on growth performance and meat quality in Thai Native male goats in a tropical area. The results showed that the total dry matter yield and chemical composition of Pangola in the winter were higher compared to summer over time, especially the amount of productivity per rai. As for the effect of nutrients in the roughage sources in total mixed rations (TMR) on growth performance of Thai native goats, the results showed that the ADG and CPI of the Pangola roughage source (TMR3) was significantly higher compared to straw (TMR1) and bean hulls (TMR2) (p<0.05).

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