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Effects of Feeding Silage of Napier Pakchong 1 Fermented with Mung Bean Concentrate on Production Performance, Nutrient Digestibility, Carcass Yield and Meat Quality of Male Dairy Goat

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Simple Summary: Nowadays, global dairy goat production is increasing continuously, resulting in higher proportions of male dairy goats, which is not the primary purpose of goat dairy farming. Using mung bean concentrate (rich in protein and co-product from the vermicelli industry) to improve the quality of silage made from Napier Pakchong 1 grass would be a solution that is beneficial and sustainable for dairy goat farming. After feeding weaned male Saanen dairy goats for 5 months with silage made from Napier Pakchong 1 fermented with 10% mung bean concentrate, the goats in this study had heavier weight, better nutrient utilization, more carcass yield, and improved meat quality. Thus, this study provides information for added value to the male Saanen dairy goat production chain.

Abstract: The current study aimed to investigate the effects of feeding silage of Napier Pakchong 1 fermented with mung bean concentrate on production performance, nutrient digestibility, carcass yield, and meat quality of male dairy goats. Silage made for experimental treatments was prepared as follows: Treatment 1 (T1) containing 100% Napier Pakchong 1 grass (without mung bean concentrate added) as a control, while Treatment 2 (T2) and Treatment 3 (T3) containing 90% and 80% Napier Pakchong 1 grass, respectively, mixed with 10% and 20% mung bean concentrate, respectively. Fifteen weaned male Saanen-growing goats were assigned to 3 experimental treatments in a completely randomized design; the study lasted for 150 days. The nutritive value of feed, production performance, nutrient digestibility, blood urea nitrogen, carcass yield and dressing, basic meat quality, and composition of meat were collected or analyzed. The results found that the goats fed with the silage made from Napier Pakchong 1 added 10% and 20% mung bean concentrate showed improvements in nutritive value, growth rate, key nutrient digestibility, blood urea nitrogen, carcass yield, the water-holding capacity of cooked meat, and fat content in meat. However, adding 10% mung bean concentrate had a trend of more beneficial value added into the production chain of male Saanen dairy goats for meat purposes. Thus, silage made from Napier Pakchong 1 fermented with 10% mung bean concentrate as a roughage source for male Saanen dairy goats intended for meat purposes is recommended.

Keywords: mung bean concentrate; production performance; nutrient digestibility; carcass yield; meat quality; male dairy goat

1. Introduction

The global dairy goat population has seen a continuous increase in numbers and goat milk production [1]. Rearing dairy goats can efficiently increase the farmer's income, improve the nutrition status of the people and, finally, help realise the strategic objectives of poverty alleviation, especially in developing countries [2]. Saanen goats continue to be popular around the world because of their high volume of milk; research to characterise and select goats for higher production continues [1]. In the meantime, similar to other agricultural sectors specialized in female-derived products (dairy, eggs), practical and ethical issues arise as there are only limited purposes for surplus male offspring [3]. This leads to limited scientific data that exists for male dairy goat production and is probably similar to those identified in male dairy calves [4]. In the Netherlands, virtually all surplus male goats are fattened for either pet food or human consumption [3].

In livestock production, economic issues of livestock farming are the main factors affecting livestock production performance. Producing animal products such as milk and meat put a strain on the environment for the production of surplus male dairy goats [3]. Feed conversion efficiency with high-quality feed staff for both concentrate and roughage is required to sustain and promote fast growth in meat-producing animals. Appling co-products or agricultural residues to livestock feeds is an important approach for sustaining the production of surplus male dairy goats. There is generally agreed that silage-making is a principal approach to ensure enough feed and nutrition throughout the year. Silage production in the tropics has been established as a sustainable means of supplementing feed for ruminants in dry scarcity periods [5]. Napier Pakchong 1 grass (*Pennisetum purpureum* × *Pennisetum americanum*) is a good quality roughage for ruminants as fast-growing and high yield in tropical and subtropical areas [6]. There were many reports [6–15] concerning the use of either Napier grass or Napier Pakchong 1 grass as a source for ensilage, especially in tropical areas. However, it is crucial to investigate appropriate additive substrates for silage fermentation. Mung bean meal or concentrate (for the more appropriate call) is a co-product of vermicelli industries, acquired from residues of vermicelli by separating the starch from mung bean seeds to further make vermicelli [6]. From the *in vitro* study of Boonkoed et al. [6], mung bean concentrate should be added at 10% and 20% for fermentation with Napier Pakchong 1 for making silage as improving the nutritional value of silage by increasing dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and gross energy (GE) contents and decreasing contents of ash, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL). Nutrient digestibility and blood urea nitrogen are possible useful parameters to get insight or explanation related to product performance and quality of carcass and meat.

From the consumer point of view, the goat has specific characteristics related to quality with presumed good acceptability of its products by consumers [16]. Guerrero et al. [16] suggested the importance of carcass and meat quality of small ruminants. Firstly, carcass quality is fundamental to compile some basic information about animals (age and weight), and to obtain information about tissular composition and the real value of commercial cuts. Secondly, meat quality can be defined by different attributes or variables for physical (pH and color), texture (shear force), and nutrient composition (proximate and fatty acid composition) aspects.

The authors hypothesized that high CP content (76.34%) [17] in mung bean concentrate would be a new feed ingredient supplied for higher CP content to make silage from the Napier Pakchong 1. This would lead to increased quality of silage as the earlier reports [18,19], especially CP enrich in a diet for muscle increment of male dairy goats. By this concept, it might be helpful for goat farmers to lower costs by using less proportion of concentrate in a diet, but a higher proportion of roughage containing useful and cheaper agricultural co-products. However, adverse effects Therefore, the current study aimed to investigate the influences of feeding silage of Napier Pakchong 1 fermented

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with mung bean concentrate on the production performance, nutrient digestibility, carcass yield, and meat quality of male dairy goats.

2. Materials and Methods

2.1. Silage

Napier Pakchong 1 grass was planted and acquired from experimental plots at the Department of Animal Production Technology and Fisheries, Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang. At 60 days of grass growth, the grass was cut and then chopped into 1-2 cm length sections using a grass chopper. The chopped grass was mixed with mung bean concentrate as 3 experimental diets of roughage source (pre-silage); Treatment 1 (T1) containing 100% Napier Pakchong 1 grass (without mung bean concentrate added) as a control, Treatment 2 (T2) containing 90% Napier Pakchong 1 grass mixed with 10% mung bean concentrate, and Treatment 3 (T3) containing 80% Napier Pakchong 1 grass mixed with 20% mung bean concentrate, as fresh weight basis. Subsequently, the pre-silage materials in all treatments were added with 1% molasses of the total fresh weight of pre-silage materials, then packed into plastic 50-liter buckets with thick walls by tightly pressing until full of each plastic bucket, according to the method of Bureenok et al. [20]. The thick plastic cover for each bucket was closed very tightly with a cover belt. Until 21 days of fermentation for ensiling, silage was obtained, and then samples of silage from all replications were analyzed for chemical composition (DM, OM, CP, EE, Ash, NDF, ADF, ADL, and energy content [21]. Samples of a concentrate diet and the pre-silage (Napier Pakchong 1, and mung bean concentrate) were also analysed for chemical composition and energy content, as mentioned earlier. The chemical composition and energy content of the concentrate diet, raw ingredients, and experimental diets are demonstrated in Table 1.

Table 1. Nutrient composition and energy content of concentrate, Napier Pakchong 1, mung bean concentrate, and silages for each dietary treatment.

Item	Concentrate*	NP1 grass	MBC	NP1 grass (100%) silage	NP1 grass (90%) + MBC (10%) silage	NP1 grass (80%) + MBC (20%) silage
DM (%)	94.76	34.88	92.62	22.43	35.48	39.87
OM (%)	90.28	90.62	96.71	90.09	93.17	94.99
CP (%)	19.15	5.99	85.52	7.9	25.11	38.63
EE (%)	5.85	3.31	3.31	1.61	2.31	2.54
NDF (%)	44.70	75.38	0.15	75.13	60.12	45.76
ADF (%)	27.02	55.01	0.11	53.53	46.78	30.52
ADL (%)	6.09	7.83	0.17	9.06	6.85	6.20
Ash (%)	9.72	9.38	3.29	10.57	5.81	5.20
GE (kcal/g DM)	4,286.21	4,348.07	5,727.07	4,119.91	4,636.11	5,039.64

* Corn, rice bran, cassava chip, soybean meal and palm meal are the main ingredients. NP1 grass = Napier Pakchong 1 grass, MBC = Mung Bean concentrate, DM = Dry matter, OM = Organic matter, = Crude protein, EE = Ether extract, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, ADL = Acid detergent lignin, GE = Gross energy.

2.2. Animals and Trials

Fifteen healthy uncastrated male Saanen growing goats were purchased from a commercial farm after weaning at 3.5-4.0 months of age. They had an average body weight of 18±1 kg and were assigned to 3 experimental treatments in a completely randomized design with 5 replications per treatment. The animals were individually placed into a pen of 2×2 m^2 size and were fed 1% body weight with concentrate (19.15% crude protein), and *ad libitum* with roughage. Thus, the goats in the T1, T2, and T3 were offered a curtained amount of concentrate proportionally to their body weight, and *ad libitum* for the silage made from Napier Pakchong 1 grass (100%), Napier Pakchong 1 grass (90%) added with mung bean concentrate (10%), and Napier Pakchong 1 grass (80%) added with mung bean concentrate (20%), respectively. After 2 weeks of the adaptation period, the finishing period started and continued for 150 days.

After the end of the feeding trial, all experimental animals were used for a digestibility trial for 7 days. The Acid-insoluble ash (AIA) marker method was applied for the digestibility trial. The samples of the concentrate, silage, and feces were collected and then dried at 65 °C for 72 hrs and stored at -20 °C pending further chemical analysis. The digestibility of nutrients and energy was calculated as follows:

Coefficient of digestibility (%)

= 100 – {100 × [(%AIA in diet × %Nutrient in feces) / (%AIA in feces × %Nutrient in diet]}

After the end of the digestibility trial, blood samples were collected into a tube containing EDTA (ethylenediaminetetraacetic acid) at 0, 3, and 6 h after feeding for blood urea nitrogen (BUN) analysis.

2.3. Carcass and Meat Quality

At the end of the experiment, all studied goats were fasting for 12 h with free access to drinking water and then weighed (pre-slaughter live weight) at a goat standard slaughterhouse. All goats were slaughtered. After the removal of non-carcass components, the hot carcass weight was recorded. The whole hot carcasses were chilled at 10-15 °C for 6 h, and then at 2-4 °C until 24 h [22]. The commercial dressing percentage was calculated based on half of the empty body weight. To estimate carcass composition, carcasses were split into two halves from the median line. Each half carcass was dissected following the Thai Agricultural Commodity and Food Standards (TACFS 6005-2006) with a minor modification. Briefly, the left and right side of each carcass was separated into seven primal from the left and right side was weighed and then calculated as % of the whole primal cut.

For meat quality measurement, the *longissimus dorsi* (LD) muscle was removed from the right side of the carcasses at 24 h after chilling. Muscle pH was measured with a pH meter equipped with a spear-tip glass electrode (SevenGo, Mettler-Toledo International Inc., Greifensee, Switzerland). The 1.5 cm thick chop removed from the right LD muscle was used to measure drip loss. Each meat sample was individually weighed, hung in a tightly sealed plastic bag, and stored at approximately 1 °C for 48 h. Meat samples were then cleaned for an excess of superficial juice and reweighed. Drip loss was calculated as a percentage of weight loss before and after suspension.

The CIE L^* (lightness), a^* (redness), and b^* (yellowness) color values were determined in triplicate at different locations on the surface of each 3-cm-thick slice after 45 min of exposure to oxygen at 25°C using a portable spectrophotometer (MiniScan EZ, Illuminance D65, 10° observer, Hunter Associates Laboratory Inc., Reston, USA) with a 2.54-cm-diameter aperture. Each 3-cm-thick slice was weighed before being placed in a high-density polyethylene bag, heat-sealed, and cooked in a water bath (80°C) until the internal temperature reached 70°C. The cooked samples were removed from the bag and allowed to cool to room temperature before being weighed again. The difference in weight between cooking was used to quantify the cooking loss and expressed as a percentage of the weight before cooking. For measurements of shear force, each cooked sample was cut transversely and along the muscle fiber orientation into eight pieces of 1.3 × 1.3 × 3-cm^3 cubes. Each cube was sheared perpendicular to the muscle fibers using the texture analyzer (EZ-SX, Shimadzu, Kyoto, Japan) equipped with a 50-kg load cell and a crosshead speed of 50 mm/min. The shear force value of each LD muscle was calculated by averaging the values of eight cubes.

2.4. Nutrient and Fatty Acid Composition of Meat

The chemical composition (DM, CP, EE, and Ash) and energy content of LD muscle were analyzed. The lipid extraction with chloroform was performed as described by Folch et al. [23]. Methyl nonadecanoate was used as an internal standard during extraction. Fatty acid methyl esters (FAMEs) were analyzed by gas chromatography (7890B, Agilent, Santa Clara, CA, USA), using a fused silica capillary column (100 m × 0.25 mm × 0.2 µm film thickness, SPTM-2560, Supelco, Bellefonte, PA, USA). The peaks of FAMEs were detected and quantified by comparing the retention times with the standard of FAME C4-C24 components. The percentage of each fatty acid was calculated relative to the total fatty acid content.

2.5. Statistical Analysis

Data were analyzed using One-way ANOVA followed by the Duncan Multiple Range Test (DMRT) using SPSS 28.0 statistic software with a significance level of $p<0.05$.

3. Results

3.1. Nutrient Composition in Diets

From Table 1, the values for the proportion of DM, CP, EE, and GE increased, whereas the proportion of NDF, ADF, and ADL decreased following higher levels of mung bean added for making Napier Pakchong 1 silage. Although statistical analysis could not be applied to nutrient composition in this study, the changes in nutrients and energy content were similar to the changes in nutrient and energy composition reported by Boonkoed et al. [6].

3.2. Production Performance

The production performance of the male dairy goats in this experiment is shown in Table 2. There were higher ($p<0.010$) total gains and average daily gains for the goats fed with Napier Pakchong 1 fermented mung bean concentrate at 10% (T2) and 20% (T3) when compared with the goats fed with fermented Napier Pakchong 1 silage (T1). Lower concentrate intake of % intake per body weight ($p<0.050$) was found in goats fed with silage of Napier Pakchong 1 added mung bean at 10% (T2) and 20% (T3) when compared with those fed with Napier Pakchong 1 silage (T1), while no difference was found among treatments in the other intakes of concentrate, roughage, and total feed. The CP intake of the goats from roughage and total feed was highest ($p<0.010$) for the goats fed with silage of Napier Pakchong 1 added mung bean at 20% (T3) and second high ($p<0.010$) for those fed with silage of Napier Pakchong 1 added mung bean at 10% (T2), while there was no difference ($p>0.050$) among experimental treatments for CP intake from concentrate. For GE intake of the studied goats, there was no difference ($p>0.050$) among experimental treatments.

Table 2. Production performance of the male dairy goats fed different treatments for 150 days.

Item	T1	T2	T3	SEM	P-Value
Initial body weight (kg)	19.56	19.06	18.84	1.70	0.984
Final body weight (kg)	22.31	29.62	28.63	1.54	0.151
Total gain (kg)	3.67^{B}	12.34^{A}	11.85^{A}	0.64	<0.010
Average daily gain (g/d)	24.44^{B}	82.27^{A}	79.00^{A}	4.27	<0.010
Feed intake (g/d)					
Concentrate	162.41	186.61	172.25	11.72	0.705
Roughage	309.82	430.49	442.97	26.91	0.125
Total	472.22	617.11	615.23	32.98	0.163
Feed intake (% of BW)					
Concentrate	0.722^{A}	0.628^{B}	0.604^{B}	0.02	<0.050
Roughage	1.450	1.470	1.528	0.09	0.934
Total	2.166	2.098	2.130	0.08	0.939
Feed intake (g/kg $BW^{0.75}$)					
Concentrate	15.620	14.622	13.890	0.47	0.347
Roughage	31.004	34.066	35.402	1.89	0.635
Total	46.626	48.690	49.292	1.67	0.795
CP intake (g/d)					
Concentrate	29.47	33.86	31.26	2.24	0.705

Roughage	5.49^{C}	38.35^{B}	68.23^{A}	4.43	<0.010
Total	34.96^{C}	72.22^{B}	99.48^{A}	5.21	<0.010
GE intake (Mcal/d)					
Concentrate	0.70	0.81	0.99	0.15	0.705
Roughage	1.33	1.87	2.54	0.52	0.342
Total	2.02	2.68	3.52	0.65	0.339

^{ABC} Means having different superscripts within the same row are significantly different (*p*<0.050 or *p*<0.010).

3.3. Nutrient Digestibility and Blood Urea Nitrogen

There was increased digestibility for DM (*p*<0.010), CP (*p*<0.010), and EE (*p*<0.050) among the goats that received Napier Pakchong 1 fermented with mung bean at 10% (T2) and 20% (T3) when compared with the goats that received Napier Pakchong 1 silage (T1) (Table 3). However, there was no influence (*p*>0.050) of mung bean level added for silage making. The digestibility of NDF and ADF was the highest (*p*<0.010) for the goats that obtained silage of Napier Pakchong 1 supplemented with 20% mung bean concentrate. The goats that obtained Pakchong 1 supplemented with 10% mung bean concentrate (T2) showed no difference (*p*>0.05) for ADF digestibility, but lower (*p*<0.010) ADF digestibility when compared with the goats given the Napier Pakchong 1 silage (T1). For ash digestibility, the goats had no difference (*p*>0.05) for the digestibility among experimental treatments. The goats obtained from Napier Pakchong 1 supplemented with 10% mung bean concentrate (T2) had higher (*p*<0.050) GE digestibility when compared with the goats obtained from the Napier Pakchong 1 silage (T1). However, the goats that obtained Napier Pakchong 1 supplemented with 20% mung bean concentrate (T3) showed no difference in GE digestibility when compared with those that obtained the silage of Napier Pakchong 1 (T1) and Napier Pakchong 1 added 10% mung bean concentrate (T2).

Table 3. Nutrient and gross energy digestibility of the experimental male dairy goats fed different treatments.

Item	T1	T2	T3	SEM	P-Value
DM digestibility (%)	53.64^{B}	66.53^{A}	66.71^{A}	0.92	<0.010
CP digestibility (%)	56.54^{B}	83.30^{A}	87.93^{A}	0.70	<0.010
EE digestibility (%)	74.94^{B}	80.65^{A}	81.49^{A}	0.63	<0.050
NDF digestibility (%)	53.25^{A}	48.84^{A}	32.29^{B}	0.57	<0.010
ADF digestibility (%)	52.80^{A}	45.24^{B}	42.81^{C}	0.17	<0.010
Ash digestibility (%)	42.99	47.56	40.32	1.36	0.317
GE digestibility (%)	56.15^{B}	65.82^{A}	62.57^{AB}	0.87	<0.050

^{ABC} Means having different superscripts within the same row are significantly different (*p*<0.050 or *p*<0.010). DM = Dry matter, OM = Organic matter, = Crude protein, EE = Ether extract, NDF = Neutral detergent fiber, ADF = Acid detergent fiber, GE = Gross energy.

For blood urea nitrogen (Table 4), at the beginning of feeding (0 h), the goats received the silage of Napier Pakchong 1 added mung bean concentrate had a proportional increase of BUN (*p*<0.010) according to a higher level of mung bean concentrate supplemented. At 3 h after feeding, the goats that received the silage of Napier Pakchong 1 added 10% mung bean concentrate (T2) had higher BUN (*p*<0.010) than those received Napier Pakchong 1 silage (T1) but becoming no difference (*p*>0.05) of BUN from the goats received the silage of Napier Pakchong 1 supplemented with 20% mung bean concentrate (T3). At 6 h after feeding, the BUN of the goats that obtained the silage of Napier Pakchong 1 (T1) and Napier Pakchong 1 supplemented with 10% mung bean concentrate (T2) had higher values, resulting in no difference (*p*>0.05) for the BUN levels among experimental treatments.

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Table 4. Blood urea nitrogen (mg/dl) of the male dairy goat fed different treatments.

Time after feeding	T1	T2	T3	SEM	P-Value
0	14.10^{C}	27.90^{B}	36.00^{A}	1.15	<0.010
3	16.60^{B}	30.70^{A}	35.62^{A}	0.99	<0.010
6	35.80	32.60	35.90	6.71	0.974

^{ABC} Means having different superscripts within the same row are significantly different (*p*<0.010).

3.4. Carcass and Meat Quality

From Table 5, there was no difference (*p*<0.050) in pre-slaughter weight among the goats in experimental treatments. However, both the %hot and %cold carcass of the goats obtained the silage of Napier Pakchong 1 added 10% (T2) and 20% (T2) were higher than (*p*<0.001) those obtained the Napier Pakchong 1 silage (T1).

Table 5. Carcass characteristics of male dairy goats fed different treatments.

Item	T1	T2	T3	SEM	P-Value
Pre-slaughter weight (kg)	21.89	28.21	27.37	1.56	0.2322
Hot carcass (%)	37.85^{B}	45.65^{A}	45.60^{A}	0.43	<0.001
Cold carcass (%)	36.09^{B}	43.99^{A}	44.81^{A}	0.35	<0.001
Dressing percentage					
Rack (%)	8.85^{B}	10.94^{AB}	11.94^{A}	0.47	<0.050
Neck and shoulder (%)	16.69	16.74	17.62	0.72	0.351
Breast (%)	8.34^{B}	9.95^{AB}	10.03^{A}	0.43	<0.050
Loins (%)	8.90^{B}	11.87^{A}	9.95^{AB}	0.52	<0.050
Chump (%)	9.78	8.21	7.24	0.40	0.392
Foreleg (%)	21.89	20.02	18.98	0.57	0.245
Hind leg (%)	25.56	22.33	24.30	0.452	0.878

^{AB} Means having different superscripts within the same row are significantly different (*p*<0.050 or *p*<0.001).

There was no difference (*p*<0.050) for the dressing percentage of the neck and shoulder, chump, foreleg, and hind leg (Table 5). The goats fed with the silage of Napier Pakchong 1 added 20% mung bean concentrate (T3) had the highest value for dressing percentage of rack and breast. However, there was no difference (*p*>0.050) in rank and breast for the goats fed with those fed with the silage of Napier Pakchong 1 at different levels and between those fed with the silage of Napier Pakchong 1 (T1) and Napier Pakchong 1 added 10% mung bean concentrate (T2), while higher dressing proportion (*p*<0.050) of neck and breast for the goats fed with the silage of Napier Pakchong 1 added 20% mung bean concentrate (T3), compared with those fed with the Napier Pakchong 1 silage (T1). Similar results for the dressing percentage of loin were found as mentioned earlier, except for the highest value found in the goats fed with the silage of Napier Pakchong 1 added 10% mung bean concentrate (T2) and higher loin dressing percentage for the goats fed with the silage of Napier Pakchong 1 added 10% mung bean concentrate (T2), compared with those fed with the Napier Pakchong 1 silage (T1).

From Table 6, there were no differences (*p*>0.050) among experiment treatments for $pH_{ultimate}$, $color_{ultimate}$ (L^* and a^*), %drip loss, and shear force. The highest values of b^* for $color_{ultimate}$, and % cooking loss found in the goats obtained in the Napier Pakchong 1 silage (T1) were higher than the lowest values of those found in the goats obtained in the silage of Napier Pakchong 1 added 20% mung bean concentrate (T3). The goats that obtained the silage of Napier Pakchong 1 added mung bean concentrate at 10% (T2) had lower b^* for $color_{ultimate}$ than those obtained the silage of Napier Pakchong 1 added mung bean concentrate at 20% (T3), but no difference (*p*>0.050) from those obtained the Napier Pakchong 1 silage (T1). In the meantime, the goats that obtained the silage of Napier Pakchong 1 added mung bean concentrate at 10% (T2) had lower b^* for $color_{ultimate}$ than those

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that obtained the Napier Pakchong 1 silage (T1), but no difference (p>0.050) from those that obtained the silage of Napier Pakchong 1 added mung bean concentrate at 20% (T3).

Table 6. Physical and texture meat quality for *longissimus dorsi* muscle of male dairy goats fed different treatments.

Item	T1	T2	T3	SEM	P-Value
$pH_{ultimate}$	5.89	5.87	5.87	0.14	0.997
$Color_{ultimate}$					
CIE L^* (lightness)	37.05	37.54	35.13	0.64	0.304
CIE a^* (redness)	8.37	9.59	7.87	0.43	0.276
CIE b^* (yellowness)	13.24^{A}	11.67^{A}	9.88^{B}	0.33	<0.010
Drip loss (%)	10.06	8.65	8.28	0.32	0.094
Cooking loss (%)	33.71^{A}	24.35^{B}	22.30^{B}	0.89	<0.001
Shear force (N)	49.31	47.07	40.98	2.06	0.296

^{AB} Means having different superscripts within the same row are significantly different (p<0.010 or p<0.001).

3.5. Fatty Acid Composition of Meat

For proximate analysis of the LD muscle, there was increased EE content (p<0.050), but decreased ash content (p<0.050) for the goats that were given the silage of Napier Pakchong 1 added to 10% (T2) and 20% (T3) mung bean concentrate when compared with those that were given the Napier Pakchong 1 silage (Table 7). However, different levels of mung bean concentrate added to Napier Pakchong 1 ensiling had no effect (p>0.050) on the content of EE and ash in the LD muscle.

Table 7. Chemical composition and fatty acid composition for *longissimus dorsi* muscle (fresh meat) of the male dairy goats fed different treatments.

Item	T1	T2	T3	SME	P-Value
Chemical composition					
DM (%)	24.61	25.01	25.25	0.17	0.327
CP (%)	24.02	23.93	23.49	0.17	0.400
EE (%)	0.77^{B}	1.44^{A}	1.23^{A}	0.08	<0.050
Ash (%)	1.31^{A}	1.26^{B}	1.27^{B}	0.01	<0.050
GE (kcal/g DM)	1,355.63	1,371.33	1,388.80	21.51	0.822
Fatty acid profile (g/100 g)					
C14:0	3.36^{A}	2.42^{B}	2.60^{AB}	0.19	<0.050
C15:0	0.81	0.60	0.54	0.07	0.218
C16:0	25.41	26.10	26.92	0.48	0.474
C16:1	2.52	2.47	2.28	0.08	0.444
C17:0	1.30	1.26	1.31	0.06	0.930
C17:1	1.01	0.98	0.98	0.05	0.982
C18:0	22.79	21.83	22.00	0.47	0.707
C18:1n9c	20.76	23.42	23.07	0.74	0.302
C18:1n9t	2.26	1.84	1.81	0.15	0.408
C18:2n6c	7.31	8.34	7.47	0.50	0.702
C18:2n6t	1.13	0.93	0.83	0.08	0.318
C18:3n3	0.29^{A}	0.19^{B}	0.22^{AB}	0.02	<0.050
C18:3n6	0.15	0.17	0.14	0.02	0.350
C20:0	0.44	0.61	0.58	0.04	0.102
C20:3n6	6.65	6.17	4.96	0.74	0.271
C21:0	1.47	1.24	1.04	0.11	0.668
SFA	55.58	54.06	54.99	0.71	0.708

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UFA	42.08	44.50	41.76	0.82	0.354
MUFA	26.55	28.70	28.15	0.78	0.541
PUFA	15.53	15.80	13.61	1.18	0.741
PUFA/SFA	0.29	0.29	0.25	0.02	0.763
PUFA/MUFA	0.61	0.56	0.50	0.06	0.778
n-6	8.59	9.44	8.43	0.48	0.689
n-3	0.29^{A}	0.19^{B}	0.22^{AB}	0.02	<0.050
n-6/n-3	32.09^{B}	50.48^{A}	39.33^{AB}	3.11	<0.050

^{AB} Means having different superscripts within the same row are significantly different (p<0.050); SFA : Saturated fatty acid = C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C21:0, UFA : Unsaturated fatty acid = C16:1 + C17:1 + C18:1n9c + C18:1n9t + C18:2n6c + C18:2n6t + C18:3n3 + C18:3n6 + C20:3n6, MUFA : Monounsaturated fatty acid = C16:1 + C17:1 + C18:1n9c + C18:1n9t, PUFA : Polyunsaturated fatty acid = C18:2n6c + C18:2n6t + C18:3n3 + C18:3n6 + C20:3n6, n-6 = C18:2n6c + C18:2n6t + C18:3n6 + C20:3n6, n-3 = C18:3n3.

The goats fed the silage of Napier Pakchong 1 added 10% mung bean concentrate (T2) had lower (p<0.050) contents of C14:0, C18:3n3, n-3, and n-6/n-3 profile when compared with those fed with the Napier Pakchong 1 silage. However, other individuals and types of fatty acid profiles had no difference (p>0.050) among experimental treatments.

4. Discussion

When comparing the nutrient and energy contents of roughage as silage prepared by fermenting Napier Pakchong 1 added mung bean concentrate at 10% and 20% with those prepared by fermenting Napier Pakchong 1, the changes of nutrients and energy content were similar to the change of nutrient and energy composition reported by Boonkoed et al. [6]. The differences in values for nutrient and energy contents would be the results from different times of silage making and many factors [24] involved during fermentation for ensilage. Adding mung bean concentrate for fermentation of Napier Pakchong 1 to make silage might improve the nutritive value of the silage due to the increase of DM, OM, CP, EE, and GE contents, but decrease the contents of NDF, ADF, ADL, and ash. This improvement might be attributed to the nutrient composition contained in the mung bean concentrate as rich in CP and low NDF, ADF, and ADL. However, nutrient profile of the silage made from 20% mung bean concentrate inclusion in the Napier Pakchong 1 silage (T3) is low NDF and ADF, and high CP, which resulted from mung bean concentrate adding. Based on nutrient composition, the goats in the T3 presumably fed with silage containing nutrient profile likelihood to concentrate, except for high content of CP and moister. The study of Sonklin et al. [17] reported the content of 76.34% CP, 1.05% EE, 3.16% ash, 0.96% fiber, and 18.49% carbohydrate in mung bean meal by-product at a mung bean noodle factory. These nutritive values are closed nutritive values in the present study. Small differences in nutritive value might be factors of different processes of producing noodles or vermicelli. From the study of Boonkoed et al. [6], making Napier Pakchong 1 silage without the inclusion of mung bean concentrate and with 10% mung bean concentrate resulted in good quality of silage in terms of pH value (3.8-4.2) and proportion of lactic acid (3-13%) and butyric acid (<2%) bacteria. This leads to the use of these levels on mung bean concentrate in the current study. For the higher levels (³ 20%) of mung bean concentrate inclusion, adding 20% mung bean concentrate to the Napier Pakchong 1 silage seems to be a risk of adverse effects after feeding goats, but the lowest risk when compared to the other higher level on inclusion. Thus, before the start of this study, the authors have done a preliminary study by making Napier Pakchong 1 silage by adding 0%, 10%, and 20% mung bean concentrate according to the methods mentioned in the earlier section in this study and then they were offered to goats in our university animal farm lasting for 30 days. The preliminary study results showed normal feed intake and no clinical adverse effects on the studied goats. Thus, the 3 levels of mung bean concentrate inclusion were applied for the present study.

The results of the nutrient composition of silages (Table 1) indicated a remarkable increment of CP content in the Napier Pakchong 1 silages made from adding mung bean concentrate at 10% and 20%. The goats fed with the 10% and 20% mung bean concentrate included in Napier Pakchong 1 silage had higher CP intake. Therefore, supplementing mung bean concentrate to the Napier Pakchong 1 grass for making silage is a method of ensiling to supply of more protein [5]. Fiber content in silage is more easily digestible. The protein associated with the fiber will be released into the rumen and then, be used by the rumen microbiota. Although there was no statistical difference for the GE intake of the experimental goats, the GE intake values were proportionally increased with higher levels of mung bean concentrate inclusion. The calculation of CP and GE intake in this study would illustrate the condition of a non-isonitrogenous and non-isocaloric diet.

The goats fed with roughage of the silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate had higher growth performance (82.27 g/d and 79.00 g/d, respectively) than those fed with the Napier Pakchong 1 silage (24.44 g/d) (Table 2), likely due to the result of the higher digestibility of DM, CP, EE, and GE and lower digestibility of NDF and ADF for the goats fed with the silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate (Table 3).

Higher digestible nutrients and energy would lead to better utilization for body metabolism processes and protein storage in the goat body, resulting in growth performance improvement. The higher body weight gain and better growth rate of the goats fed with the silages added 10% and 20% mung bean concentrate, whereas no difference for the final weight among 3 experiment treatments would be caused by high variation of the final body weight. In addition, a lower intake of concentrate for the goats fed with silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate might help farmers to reduce feed costs, especially from concentrate sources. In the meantime, using 20% mung bean concentrate as an additive for Napier Pakchong 1 silage should be too high level because body weight gain and growth rate did not differ from those offered 10% mung bean concentrate added to Napier Pakchong 1 silage.

The normal range of blood urea nitrogen for goats reported by Latimer is 10-20 mg/dl. [25]. However, Mohammed et al. [26] reported a normal range of 25-60 mg/dl for goats as the influence of the goat breed. From the report of Al-Bulushi et al. [27], the average BUN level from 5 goat breeds is in the range of 14.62-48.45 mg/dl. This information leads to the possibility of using the normal range of 10-60 mg/dl as a reference. In the report of Al-Bulushi et al. [27], Saanen goas had a BUN of 33.16±13.45 mg/dl, suggesting high variation and probably other factors affecting the value of BUN. Before feeding the experimental goats in this study, there was the lowest BUN (14.10 mg/dl) for the goats that received the Napier Pakchong 1 silage, while the next higher (27.90 mg/dl) and highest (36.00 mg/dl) was found in the goats that received the silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate, respectively. After that, the goats who received the silage of Napier Pakchong 1 added 10% mung bean concentrate had higher BUN values of 30.70 and 35.62 mg/dl BUN at 3 h and 6 h after feeding, respectively. The goats who received the Napier Pakchong 1 silage had 16.60 and 35.80 mg/dl BUN at 3 h and 6 h after feeding. In the meantime, the goats who received the silage of Napier Pakchong 1 added 20% mung bean concentrate had a level of BUN more than 35.0 mg/dl before feeding, and at 3 h and 6 h after feeding. These indicated the effects of higher proportion levels of nitrogen contained in the roughage and metabolite of nitrogen in the body of the goats. Furthermore, Harmeyer and Martens [28] reported that the saliva of goats and sheep contains 10 to 30 mg N/100 ml, and of the total salivary N of mixed saliva 60 to 70% was urea N, while the salivary urea concentration corresponded to 60% of the urea concentration in plasma. This information likely concludes that ensilaging by adding 10% and 20% mung bean concentrate in the present study supports the concept of microbial protein synthesis, reduces protein degradation in the rumen and increase amino acid absorption in the intestinal tract, as mentioned earlier. All goats in the present study were healthy throughout the study. Diet enrich CP would lead to higher gas production in the rumen. Bloat results as a failure in the eructation of gases produced by microbial fermentation in the rumen. The sheep and goats have rapid changes in the frequency and type of ruminal contraction patterns responsible for eructation, promoting evacuation of intraluminal gas

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[29]. This implied that gas production possibly produced might be reduced by the eructation of goats. Rumen acidosis commonly follows excessive consumption of offending feedstuffs, abrupt changes in the diet without adaptation of the rumen microflora, inconsistent delivery of ration, and mixing errors [29]. The adaption period to the experimental diets for 14 days in this study and low non-fibrous carbohydrates in the studied silages (not show data) might be caused by less fermentation in the rumen, resulting in no occurrence of rumen acidosis.

In the current study, the experimental goats had an age of approximately 9 months, including 5 months for feeding the experimental diets. With this age and 19.15% CP content in concentrate, the experimental goats fed with the Napier Pakchong 1 silage with adding 10% and 20% mung bean concentrate could reach 29.62 and 28.63 live body weight, respectively, while the goats received the Napier Pakchong 1 silage (without mung bean adding) could reach only 24.44 kg live body weight. In the study of Suwit et al. [30] conducted in Thailand, a study group comprised two-way cross (50% Anglo-Nubian ×50% Southern Thai native) goats fed with 16% CP in concentrate, reaching 30.08 live kg body weight at the age of 329 days (approximately 11 months). These results implied that increasing protein levels in roughage via silage made in this study would lead to the male dairy goats having comparable growth performance to the two-way crossbreed (50% Anglo-Nubian ×50% Southern Thai native) of goats, a representative of meat goats. For carcass quality, there was an increased %hot and cold carcasses for the goats fed with the silage of Napier Pakchong 1 added with 10% and 20% mung bean concentrations. These results could be explained by the higher values for the proportions of CP, EE, and GE contents in roughage sources as silage, and the enhanced digestibility of these nutrients. From Table 7, there was no difference in %CP in *longissimus dorsi* muscle among experimental treatments. This might be explained by muscle containing a certain proportion of CP composition, but the size and number of muscular fibers might be increased. Higher energy from EE and GE obtained would lead to more energy available to be used for metabolized nutrients and higher CP available and uptake into the body, allowing more deposition of protein in the goat body, especially striated muscle. In the meantime, the lower content of NDF and ADF in silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate would help the fermentation processes in the rumen of the experimental goats by increasing chewing activity, as reported by Schulze et al. [31] in heifer dairy cows. The total intake of DM, CP, and GE of the goats fed with 10% and 20% mung bean concentrate added to the Napier Pakchong 1 silage was comparable to that of male British Saanen kid goats slaughtered at 28 kg body weight [32]. Thus, it is clear that the goats in the current study had received nutrients from the concentrate at almost similar levels with a low proportion of total intake, but they obtained nutrients mainly from the silages that contributed high nutrients.

From the scientific point of view mentioned earlier, feeding the male Saanen dairy goats with the silage made from Napier Pakchong 1 fermented with mung bean concentrate at 10% and 20% would improve production performance and carcass weight to be comparable to crossbred Anglo-Nubian and Southern Thai natives. These showed that the genetic potentials of male Saanen dairy goats can be augmented by improving the quality of their diet.

Fasting the goats before slaughtering for 12 h might lead to loss of final live body weight. The dressing percentage of the experimental goats obtained from the silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate increased the values of weight proportion for the rack, breast, and loin. However, the difference is not as apparent as found in %hot and %cold carcasses. When comparing the results of dressing percentage in this study to that in the study of Suwit et al. [30], all dressing percentages were close to each other, even the sum of neck and shoulder primal cut, implying comparable carcass yield for male Saanen goats to a meat goat genotype. From the study of Dhanda [33], crossbred Boer x Saanen kids performed better in terms of the production of Capretto and Chevon carcasses than the kids from other genotypes (Boer x Angora, Boer x Feral, Boer x Saanen, Feral x Feral, Saanen x Angora, and Saanen x Feral) used. This report would partly support that the male Saanen breed has some genetic potential for producing meat.

For physical meat quality, the $pH_{ultimate}$ of goat meat in the current study fell in a range of 5.87-5.89, which was in the normal range of pH 5.8-6.2 for goat meat [34]. The onset of rigor mortis (pH~

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6) occurred at elevated temperatures between 13.1 °C and 17.1 °C [22]. Goat meats with pH values above 6 are generally considered unsuitable for storage because of the favorable development of proteolytic microorganisms [35]. These implied that the goat meats of the current study passed the onset of rigor mortis and had a lower risk of microorganism contamination. The $pH_{ultimate}$ values of < 6.0 for the goat meats in the current study might be the result of delayed chilling management. Lower muscle glycogen storage caused the $pH_{ultimatte}$ to remain high [36,37], which was influenced by several factors from production, pre-slaughter, slaughter, and post-slaughter [22,35].

Supplementation of 10% and 20% mung bean concentrate for ensiling with Napier Pakchong 1 had no effect on the lightness (*L**), redness (a*), %drip loss, or shear force of meat from goats receiving these silages. For the yellowness of the experimental goat meat, there was lower yellowness of meat from goats fed with the silage made from Napier Pakchong 1 fermented with 20% mung bean concentrate. This was likely the result of higher content of fat in muscle for the goats offered the 20% mung bean concentrate inclusion in the Napier Pakchong 1 silage. This fat content might have less yellowness because xanthophyll contained in mung bean might be reduced by heating processes [38] for vermicelli production.

The measurements of drip and cooking loss could be presumable indirect methods to measure water-holding capacity [39]. Cooking losses from goat meat tend to be high (35%), and this detracts from the sensation of juiciness [34]. The lower the cooking loss related to the better the juiciness of the meat [35]. There was higher content of fat in meat from the goats fed with the silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate. Muscles with a higher content of intramuscular fat tend to have a higher water-holding capacity, because intramuscular fat loosens up the microstructure of meat, causing more water to be incorporate [40]. The tenderness of the meat was shown by the shear force value. For the current study, a range of 40.98 – 49.31 N in LD muscle was obtained and comparable to the results from the earlier reports for Saanen goats [41–43].

From the physical and chemical aspects of meat quality, it could be explained the relationship between these parameters as the followings. The final meat pH of below 6 indicated a proper glycolysis process during delayed chilling and cold chilling. The meat's final pH of about 5.8-5.9 is associated with the capacity to hold water meat. The final meat pH is negatively correlated to water-holding capacity and tenderness.

From the aspect of meat composition, the higher fat and lower ash contents found in the goats that received the silage made from Napier Pakchong 1 fermented with 10% and 20% mung bean concentrate might correspond to each nutrient found in the silage, but with non-linear correlation. For fatty acid composition, the lowest content of C14:0 for the goats fed with the silage made from Napier Pakchong 1 fermented with 10% mung bean concentrate. This implied a beneficial effect on consumer health, which C14:0 has four times the hypercholesterolemic effect of the other fatty acids [35]. The three main fatty acids found in the LD muscle were C16:0, C:18:0, and C18:1n9c. In the meantime, the majority of fatty acids contained in the mung bean seed were C16:0, C18:0, C18:1, C18:2, and C18:3 [44]. Biohydrogenation in ruminants leads to extensive loss of unsaturated fatty acids and the accumulation of partial hydrogenation products [45–48]. Monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) left over from the biohydrogenation would be further absorbed from the gut and then be metabolised for energy generation and deposited in the goat body. The lower contents of C18:3n3, n-3, and n-6/n-3 profile for the meat of the goats fed with the silage of Napier Pakchong 1 added 10% mung bean concentrate when compared with those fed with the Napier Pakchong 1 silage. This might be partly explained by different biohydrogenation in rumen and/or PUFAs are preferentially oxidised for body metabolism when compared to SFA [49]. From the earlier report, fats having high PUFA/SFA and low n-6/n-3 ratio are considered favorable as they decrease the risk of cholesterolaemia [50]. The goats fed with the silage made from Napier Pakchong 1 added 10% mung bean concentrate had PUFA/SFA of 0.29 and the n-6/n-3 ratio of 50.48. When compared with those fed with the Napier Pakchong 1 silage, which is identical mean for PUFA/SFA (0.29), it was dramatically higher for the ratio of n-6/n-3 (32.09) when compared with those fed with the Napier Pakchong 1 silage. In the meantime, the n-6/n-3 ratio of 39.33 was found in the goats fed with silage made from Napier Pakchong 1 added 20% mung bean concentrate. This leads to the

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possible background of fatty acid dynamic and deposition required to be studied aiming to increase n-3 fatty acid in goat meat.

The results from the studied parts of carcass dressing, meat quality, and composition of nutrients and fatty acids in meat provide crucial background information for improving the carcass and meat quality of male dairy goats, which is a value-added into the goat meat production chain. From an overall point of view, the current study has shown success in improving the production performance, carcass yield, and meat quality of male dairy goats via the use of co-product from the mung bean industry for vermicelli production. The appropriate level for supplementation of mung bean concentration for Napier Pakchong 1 ensiling would be 10%, which is sufficient to improve the nutritive value of silage, growth rate, key nutrient digestibility, blood urea nitrogen, carcass yield, water-holding capacity of cooked meat, and higher fat content in meat. However, the supplementation of mung bean concentrate had no effect on fatty acid content in meat. Further investigations should focus on the effective level of mung bean concentrate, its economic impact, broad carcass, and meat quality.

5. Conclusion

This work revealed that feeding 4-month-old male Saanen dairy goats by silage made from Napier Pakchong 1 fermented with 10% mung bean concentrate as a roughage source for 5 months would improve growth rate, increase key nutrient digestibility, augment carcass yield, depress cooking loss, and provide higher fat content in the goat meat. Before implementing the results of the current study to the dairy goat farms, more studies should be performed to find appropriate levels of mung bean concentrate added to the Napier Pakchong 1 silage. This study provides a prospective approach to improving the production potential of male Saanen dairy goats as well as provides basic information for further elucidation.

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