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Quality, Texture Profiles, Collagen Contents and Chemical Compositions of Meat from Thai Native Goats Fed with Different Protein Levels in Total Mixed Rations

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ABSTRACT

Background: The main cost of animal production is the protein content in the feed. Hence, it is necessary to determine a suitable protein content for productive performance and meat quality of the Thai native goats.

Methods: This study was carried out to investigate effects of protein levels in total mixed rations (TMR) on meat quality, texture, collagen contents and chemical compositions of *Longissimus dorsi* (LD) muscles of Thai native goats that were subjected to 4 alternative levels of protein in TMR (9, 12, 15 and 18%) for 4 months.

Result: The results revealed that the pH1h and *a** values were higher in goat meat from 18% dietary protein group (P<0.05). Regarding water holding capacity, it was found that the 12% dietary protein group had a higher thawing loss than the others (P<0.05). In texture profile analysis, the group that received the protein at 18% level had the higher in shear force than in the 9 and 12% dietary protein groups (P<0.05). For the chemical compositions, it was found that the 12% dietary protein group had highest insoluble collagen and total collagen contents. The protein levels of 15 and 18% gave the lowest fat content (P<0.05), followed by the dietary protein levels 12 and 9% in rank order. It can be concluded that increasing protein levels in TMR resulted in a redder meat but reduced tenderness and fat content of goat meat.

Key words: Crude protein, Goat, Meat quality, Meat tenderness, Total mixed rations.

INTRODUCTION

Goat meat is among the main sources of protein for humans and conforms with the current consumer demand of lean and nutritious meat (Kannan *et al.*, 2014). Due to its low contents of saturated fatty acids and cholesterol, goat meat seems to be healthier in the human diet than other types of red meat, with a reduced risk of stroke and coronary disease (Ivanović *et al.*, 2016). Nowadays, goats are raised throughout the world except in extremely cold areas. Thai native goats are commonly raised in free-range systems and the feeding is based on native grasses or forage with low nutritive values and these animals are given little or no energy and protein supplements (Kochapakdee *et al.*, 1994).

Tenderness is a key factor affecting the choice of meat by consumers (Geay *et al.*, 2001) and the amount of connective tissue that accumulates in the muscles directly influences tenderness of the meat (Riley *et al.*, 2005), while collagen is an essential component of connective tissue. Collagen molecules form a connected network by crosslinking, to support the structure of the skeletal muscles (McCormick., 1994; Andreas *et al.*, 1995). Factors such as species, age, sex and nutrition or diet can affect the growth and building of muscle. Hence, there are numerous studies examining the influences of diet on meat quality and collagen content in meat (Aberle *et al.*, 1981; French *et al.*, 2001).

It is well known that the main cost in animal production is the feed and this depends on the protein content. Therefore, it is necessary to determine a protein content that suitable for productive performance, including meat quality, of Thai native goats. There are some studies investigating the effects of protein level in diet on growth performance of goats (Kochapakdee *et al.*, 1994; Chobtang *et al.*, 2009; Prasomsuk *et al.*, 2020; Fatmawati *et al.*, 2024) including the effects of feed energy levels on meat quality and collagen (Aberle *et al.*, 1981; French *et al.*, 2001; Kannan *et al.*, 2014; Wang *et al.,* 2015). However, the effects of protein level on meat quality remain still largely unknown. Therefore, an objective of the present study was to investigate the effects of feeding diets that contain different levels of crude protein (CP) on meat quality, texture profile,

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collagen content and chemical composition of meat from Thai native goats, for determining a suitable feed protein level for desirable meat quality.

MATERIALS AND METHODS

The experiment was carried out at the Scientific Laboratory and Equipment Center, Prince of Songkla University, Surat Thani campus, Thailand, during October 2018 to September 2020.

Meat samples

The 16 of *Longissimus dorsi* (LD) muscles were received from previous study (Prasomsuk *et al*., 2020), in which 16 Thai native goats that were approximately 4 months old with an average body weight of 11.43±0.13 kg, were given a 14-day adaptation period and randomly allocated and subjected to 4 feeding regimens having different levels of protein in total mixed ration (TMR), namely 9, 12, 15 and 18%, for 4 months. The experiment was established according to completely randomized design (CRD) with 4 replicates in each experimental group. The ingredients of experimental diets are shown in Table 1. TMR was provided ad libitum twice a day and water was freely available to the goats. After the end of the feeding trial, the animals were slaughtered in a local abattoir and the LD muscles were sampled.

Meat quality analysis

The pH was measured at 1 h and 24 h post mortem using a penetrating electrode attached to a portable pH-meter (Mettler Toledo).

The color measurement was performed at 24 h post mortem and for this the meat was cut and exposed to air for approximately 40 minutes and the CIE-Lab coordinates *L**, *a** and *b** were determined with a Hunterlab Miniscan color meter (D65 light source, 10° standard observer, 45°/0° geometry, 1-inch light surface, white standard). Three readings were taken for each sample and the averages of *L**, *a** and *b** were recorded.

The water holding capacity of goat meat was determined in terms of drip loss, thawing loss and cooking loss, according to Uytterhaegen *et al*. (1994) at 24 h post mortem.

Table 1: Ingredients and chemical compositions of experimental diets.

Ingredients	Level of protein in TMR (%)			
	9	12	15	18
Oil palm leaflets	55.00	55.00	55.00	55.00
Palm kernel cake	4.00	4.00	7.00	5.40
Soybean meal	6.00	13.40	15.00	25.00
Cassava chip	21.00	17.00	14.00	5.00
Corn	-	-	5.00	5.00
Molasses	13.40	10.00	6.00	4.00
Salt	0.20	0.20	0.20	0.20
Premix	0.40	0.40	0.40	0.40
Chemical composition (% of dry matter)				
Dry matter	86.76	87.58	88.19	88.84
Crude protein	9.00	12.00	15.00	18.00
Crude fat	2.42	2.92	3.05	2.99
Metabolizable energy (ME; Mcal/kg)	2.45	2.42	2.40	2.39
Crude fiber	13.63	14.19	14.40	14.62
Ca	0.75	0.74	0.72	0.71
P	0.14	0.16	0.17	0.18

Analysis of Warner-Bratzler shear force (WBS)

For determination of Warner-Bratzler shear force, the LD muscles were cooked in a thermostatic water bath at 90°C for 15 minutes and cut into 1×2×1 cm size for shear analysis using Warner Bratzler shear blade connected to NRI TSS500-2 shear testing machine (1 kN). The shear force was measured perpendicular to the axis of muscle fibers with 3 replicates for each type of sample. The peak in the shear force profile was regarded as that shear force which represents tenderness of the meat.

Texture profile analysis (TPA)

The texture profiles of goat meat were analyzed by using Texture analyzer, Brookfield, model CT3 (10,000 g). The LD samples were cooked at 90°C for 15 minutes, cut into 1×1×1 cm pieces for measurement with 3 replicates for each type of sample. The texture profile of the meat is reported in terms of hardness, cohesiveness, adhesiveness, springiness and chewiness.

Analysis of collagen contents and chemical compositions of meat

The soluble and insoluble collagens were quantified through their hydroxyproline content based on the methodology proposed by Hill (1966). The absorbance was measured at 558 nm using a spectrophotometer and collagen content is expressed in mg/g of meat.

The chemical composition of meat was determined according to the official methods of analysis of AOAC (Latimer, 2016). Crude protein (CP) was quantified according to the Kjeldahl method and crude fat (CF) or ether extract (EE) was obtained with Soxhlet extraction. The moisture was removed in a dry oven at 60°C for 48 hours.

Statistical analysis

The data were analyzed using the general linear model procedure in SPSS Statistics program. Means were compared using Duncan's multiple range test and differences were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Meat quality

Meat quality attributes for goat LD muscle as influenced by protein level are presented in Table 2. The results revealed that pH1h was higher in 18% protein group than in 15, 9 and 12% groups, respectively ($P<0.05$). However, the ultimate pH (pH24h) in LD did not significantly differ among the treatments ($P>0.05$). In addition, it was observed that

Table 2: Effects of protein level in total mixed rations (TMR) on meat quality of Thai native goats.

	Level of protein in TMR (%)				SEM	P-value
	9	12	15	18		
pH_{1h}	6.15^{c}	5.95^{d}	6.34^{b}	6.57^{a}	0.06	0.00
pH_{24h}	5.69	5.60	5.68	5.67	0.02	0.52
*L**	25.30	26.41	24.56	25.49	0.36	0.35
*a**	7.14^{ab}	6.76^{b}	8.01^{a}	7.78^{a}	0.18	0.03
*b**	13.91	14.18	14.54	15.77	0.32	0.16
%Drip loss	2.83	2.54	2.65	2.96	0.10	0.46
%Thawing loss	3.23^{b}	3.90^{a}	3.32^{b}	3.39^{b}	0.09	0.02
%Cooking loss	24.36	24.58	26.05	26.45	0.37	0.09

$^{a-d}$ Values with different superscripts within the same row are significantly different (p<0.05).

Table 3: Effects of protein level in total mixed rations (TMR) on meat texture profile and Warner-Bratzler shear force (WBSF) of Thai native goats.

	Level of protein in TMR (%)				SEM	P-Value
	9	12	15	18		
WBSF (Kg)	2.93^{b}	3.18^{b}	3.43^{ab}	4.11^{a}	0.16	0.04
Hardness (g)	1802.42	1827.72	2006.36	2455.83	106.84	0.08
Cohesiveness	0.02	0.01	0.02	0.02	0.00	0.19
Adhesiveness (mJ)	7.41	5.06	3.16	2.79	0.85	0.19
Springiness (mm)	19.17	25.78	30.19	26.57	1.87	0.22
Chewiness (mJ)	6.69	7.13	9.60	7.07	0.92	0.73

$^{a-b}$ Values with different superscripts within the same row are significantly different (p<0.05).

the redness (*a**) of muscle from the 15 and 18% protein groups was higher than for the 12% dietary protein group (P<0.05). However, the lightness (*L**) and yellowness (*b**) of meat did not significantly differ (P>0.05). The dietary protein level at 12% gave a higher thawing loss than the other treatments (P<0.05). However, meat water loss during chilling (drip loss) and cooking loss was not significantly different (P>0.05).

Warner-Bratzler shear force (WBSF) and texture profile analysis (TPA)

Effects of protein level in TMR on WBSF and TPA of native goat meat are shown in Table 3. The WBSF results showed that the high protein group (18%) had the greatest shear force, larger than in the 9 and 12% dietary protein groups (P<0.05), but not significantly different from the 15% dietary protein group. In TPA hardness, cohesiveness, adhesiveness, springiness and chewiness of meat did not significantly differ by treatment (P>0.05). However, a high protein level in the feed tended to increase the hardness of meat (P<0.1), which was consistent with the WBSF.

Collagen contents and chemical compositions of meat

Collagen contents and chemical compositions of LD of Thai native goats are shown in Table 4. The results indicated that the insoluble collagen and the total collagen content in goat meat had statistically significant differences (P<0.05). The 12% protein diet gave the highest insoluble collagen content and total collagen content. However, the soluble collagen did not significantly differ by treatment (P> 0.05). In chemical compositions, the fat content of goat meat was highest in the 9% group, followed by the 12, 15 and 18% dietary protein groups (P <0.05). However, the moisture and the protein contents had no significant differences (P>0.05).

Generally, the meat pH is a measurement of the post mortem glycolysis and it depends on many important factors, for example on pre-slaughter stress, fasting, carcass temperature, as well as on factors intrinsic to the animal itself, such as species, age, *etc.* (McGeehin *et al.*, 2001). The pH of meat decreases slowly from the initial about 7.0 and reaches 5.6-5.7 in 6-8 hours post mortem, then drops to the final pH between 5.3-5.7 within 24 hours post mortem. Pratiwi *et al.* (2007) indicated that muscle pH in general declined during the immediate post mortem period and the acceptable range for pH at 24 h for goat meat is within 5.6-5.8. In this study, the muscle pH at 24 h was within the acceptable range for goat meat in all cases. Rate and extent of pH decline are known to affect the development of meat quality attributes, such as color and tenderness (Simela *et al.*, 2004). In this study, muscle pH corresponded to reported values for muscles of various goat breeds (Dhanda *et al.*, 2003; Kadim *et al.*, 2003). Simela *et al.* (2004) reported a tendency towards the dark firm and dry (DFD) condition for chevon with an ultimate pH higher than 6. In bovine, muscles with a pH higher than 5.8 are usually classified as DFD (Tarrant and Sherington, 1980). Moreover, the pH is an important measure of meat quality and Warriss (2010)

Table 4: Effects of protein level in total mixed rations (TMR) on meat collagen contents and chemical compositions of Thai native goats.

	Level of protein in TMR (%)				SEM	P-Value
	9	12	15	18		
Collagen content (mg/g meat)						
Soluble collagen	1.15	1.16	1.14	1.15	0.00	0.22
Insoluble collagen	3.12[b]	3.53[a]	3.19[b]	3.31[b]	0.05	0.00
Total collagen	4.26[b]	4.68[a]	4.33[b]	4.46[b]	0.05	0.00
Chemical composition (%)						
Moisture	73.56	73.41	73.35	73.71	0.08	0.11
Protein	21.70	21.76	21.86	22.10	0.09	0.47
Fat	5.00[a]	3.01[b]	2.14[c]	1.95[c]	0.23	0.00

[a-c] Values with different superscripts within the same row are significantly different ($p<0.05$).

explains that the ultimate pH (pH24h) is related to the drip loss of meat. In the present study, the pH24h showed no differences between treatments, so that the %drip loss of meat might not differ as well. Besides water holding capacity of meat, pH is also strongly related to the color of the meat. In other words, a higher pH tends to match a darker meat color (Fletcher, 1995).

In this study, the WBSF results are consistent with Tang *et al.* (2010), which reported that animal diet with a low protein level reduced WBSF in pork. However, the mechanism for increasing the tenderness of meat in the low-protein diet is unknown, but it may be by the accumulation of intramuscular fat in animal muscles during a low-protein diet. Wang *et al.* (2015) investigated the effects of two dietary protein levels (15% and 17%) and three dietary energy levels (11.72, 12.55 and 13.39 MJ/Kg DM) on meat quality of the Hainan black goat and found that the tenderness of the *Longissimus dorsi* and *Semimembranosus* decreased when the protein level of the feed was higher, while tenderness tended to increase when the energy level of feed was higher.

Collagen is a component of the muscle connective tissue and increases meat toughness. In other words, collagen is considered to be "background toughness" of meat and especially soluble collagen is associated with toughness of the meat (Moon, 2006). However, the collagen content of meat may differ by muscle type. In this experiment, it was observed that the dietary protein level did not affect soluble collagen that plays an important role in the toughness of the meat, which is inconsistent with Moon (2006) who found that the tender muscle had a lower total collagen content and lower shear force in beef. Therefore, the softness of meat in this study is likely due to differences in fat contents of the muscles. On considering the protein level in the diet, the group fed with low protein had a high fat content in meat and this made the meat more tender. Aside from the collagen content, intramuscular fat can play an important role in the meat tenderness (Nishimura *et al.*, 1999).

CONCLUSION

In conclusion, protein is an essential nutrient for animal growth. Animal feed with insufficient protein leads to poor growth performance, while increased protein level in animal feed raises the production costs. Aside from growth performance and production costs, also meat quality should be taken into account. In this study, a high protein level in TMR resulted in redder meat, reduced the fat content and reduced meat tenderness. However, increased protein level in the diet had no effect on collagen content of goat LD muscle.

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Conflict of interest

The authors declare that they have no conflict of interest.

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