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Carcass and Meat Quality of Three Genotype Populations in Goat Breeding for Meat Purposes in Thailand

By

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Summary：The objective of this study was to assess the carcass characteristics of three genotypes of meat goats in Thailand, kept in a semi-intensive system with concentrated feed at 1% of body weight. Eighteen healthy male yearlings, including Southern Thai native, two-way crosses (50% Anglo-Nubian × 50% native) and three-way crosses (50% Boer ×25% Anglo-Nubian ×25% native) goats were randomly selected and slaughtered after being starved for 24 h. Three-way crosses had greater ($P<0.01$) fasted live weight, carcass weight and carcass length than two-way crosses and native goats in the same environment. The dressing percentage (based on empty body weight) ranged from 50.20% to 54.28%, with highly significant differences between genotypes. Three-way crosses had greater ($P<0.01$) loin eye area than two-way crosses and native goats (16.97, 11.19, and 8.13 cm^2, respectively).

Physical properties, chemical composition of meat, and muscle microstructure of the three genotypes were determined. There were no differences in physical properties between genotypes, except for bone percentage. Native goats had lower ($P<0.01$) bone content than two-way and three-way crosses. The muscle-bone ratio was higher ($P<0.01$) in native goats than in other goats, even using the criterion of edible meat (muscle+fat-bone ratio, $P<0.05$). The protein percentage of muscles was significantly higher in three-way crosses (22.4%) than in two-way crosses and native goats ($P<0.05$). The fat percentage of three-way crosses was higher ($P<0.01$) than that of two-way crosses and native goats. Genotype had a significant ($P<0.05$) influence on meat quality in regard to shear force and lightness. The *longissimus dorsi* had a lower shear force value than the *biceps femoris* and *triceps brachii* ($P<0.05$). The International Commission on Illumination system values for the *biceps femoris* and *triceps brachii* were lower ($P<0.05$) than those for the *longissimus dorsi*.

Key words：goat, carcass characteristics, meat quality, physical properties, chemical composition

Introduction

The goat population in Thailand is relatively small (383,796). With 95,000 head slaughtered annually, the annual total production of goat meat is 14,250 tons[1]. Goats are predominantly raised by smallholders, particularly of the Muslim community in the southern part of the country. The three breeds of goat commonly raised for meat in Thailand are the Anglo-Nubian, the Boer, and the native. The Anglo-Nubian and Boer were first introduced in Thailand in 1983 and 1996, respectively, by the Department of Livestock Development (DLD) to improve growth rate, carcass quality, and production potential. In contrast to these two exotic breeds, native goats inherit good resistance to tropical parasites and diseases as well as tolerance of the tropical climate ; however, native goats have a lower meat yield compared with exotic breeds. Adult native goats have a dressing percentage of 45–50 at

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slaughter ; hence, the native goat is a preferred source for breeding. Boer goats have high muscle and low bone content, with a muscle-bone ratio (MBR) of 4.7, and their dressing percentage exceeds 50. Individual variation in meat tenderness indicates the possibility of improving the trait through selection[2-4].

The project "Research and Development of Thai Meat Goat in the South," aimed at establishing a new breed of Thai meat goat well adapted to the environment in the south of the country and with high growth performance and excellent meat quality, was supported from 1995 by the Agricultural Research Development Agency. These goats have been developed by crossbreeding Anglo-Nubian and native goats to produce two-way crosses, with selection focused mainly on achieving high growth rates. Two-way cross does were then crossed with Boer bucks to produce three-way crosses, which showed higher productivity[5]. It is believed that crossbreds derived from the mating of exotic breeds and native goats will be both more productive and suitable for local conditions. There have been considerable effects on body size, growth rate, and meat production as well as adaptation to the local environment when exotic breeds were crossed with native goats[6].

Goat meat evaluation has received little attention, and knowledge of its yield and quality is consequently limited when compared with that of pig and cattle meat. However, this situation is changing because of increasing demand for goat meat in Thailand. The Muslim market—the largest in Thailand—demands male yearling goats with two permanent teeth and no visible physical changes (i.e., not castrated or deformed). Slaughtering must meet Halal standards. To satisfy market requirements and increase profitability, further evaluation of carcass characteristics and their improvement is required. The objective of this study was to assess the genetic potential of our native, two-way, and three-way cross goats in regard to their carcass characteristics in order to determine the effects of genotype on these characteristics, and hence meat quality, at a predetermined age.

Materials and Methods

(1) Animals and their management

Southern Thai native, two-way cross (50% Anglo-Nubian ×50% native), and three-way cross (50% Boer × 25% Anglo-Nubian ×25% native) goats were used for the carcass comparison study. Eighteen healthy male yearlings were randomly selected from the flock at the DLD Livestock Testing and Research Station in the southern part of Thailand. The climate there is humid and tropical, with a rainfall of 2400 mm per annum. The animals were raised on pasture and given a concentrated feed (containing 16% crude protein) at levels increasing gradually to 1% of body weight per head per day. Green grass, hay, and tree leaves were also provided.

(2) Slaughter procedure and carcass evaluation

The goats were slaughtered at the Prince Songkla University slaughterhouse, following overnight withholding of feed. The animals were slaughtered according to the Muslim practice by severing both jugular veins with a sharp knife without prior stunning. After complete bleeding, the head was removed at the atlanto-occipital joint and weighed. Blood was collected and weighed after the animal stopped bleeding. The skin was cut along the limbs and down the abdomen, and then removed manually and weighed. The fore and hind limbs were removed using a knife, and each was weighed with the skin. The tail was separated at the first intercoccygeal articulation and weighed. After dressing and evisceration, the offal was individually weighed. The alimentary tract was weighed and then cleaned of its contents (fill) and reweighed. The weight of fill was subtracted from the slaughter weight to determine the empty body weight (EBW). The kidneys and their surrounding fat were left attached to the carcass. The carcass was stored in a chilling room at 4℃ for 24 h, following which the cold carcass weight was recorded. Dressing percentage of the carcass was calculated based on fasting body weight and EBW. Carcass length was measured from the point of the hock to the point of the neck.

The left side of each carcass was separated into eight prime cuts : loin, hind leg, chump, rack, shoulder, foreleg, breast, and neck, as described by the Thai Agricultural Commodity and Food Standard[7]. The prime cuts were chilled at 4℃ for 24 h and, after weighing, each cut was separated into muscle, bone, and subcutaneous fat. Loin eye area was measured between the 12^{th} and 13^{th} ribs.

Moisture content was determined by the oven method[8], while protein content was determined by the Kjeldahl method[8]. Fat content was determined by the soxhlet apparatus method, and ash was determined following treatment in a furnace at 600℃[8].

(3) Physical properties analysis

Meat samples were dissected from the chump after chilling. The skin was removed, and obvious fat and connective tissue were trimmed off. The samples were cut into sections 3.0×4.0×1.5 cm before analysis of physical properties.

Meat color was determined using a colorimeter (Color Flex ; Hunter Lab, Reston, VA, USA), and values derived from the complete International Commission on Illumination (CIE) color profile system were reported as lightness

(L*), redness (a*), and yellowness (b*).

Cooking loss was expressed in terms of weight loss as a percentage of initial weight. The samples were placed in a tightly sealed plastic bag and cooked in a water bath at 80℃ for 10 min. After cooking, the samples were cooled in cold water at 10℃. They were then removed from the container, blotted with filter paper, and weighed to determine cooking loss.

The samples were cut into sections 1.0×2.0×0.5 cm for shear force analysis, which was measured using a texture analyzer equipped with a Warner-Bratzler shear apparatus. Shear force was measured perpendicular to the axis of the muscle fibers. The peak of the shear force profile was regarded as the shear force value[9].

(4) Statistical analysis

Data were analyzed using the General Linear Model procedures of SAS[10]. Significant differences were further analyzed using Duncan's new multiple range test[11] and the least significant difference test for sensory evaluation data.

Results and Discussions

(1) Carcass characteristics

Table 1 shows the effect of genotype on slaughter and carcass weights and percentages of certain dress-off items. Three-way crosses had heavier slaughter and carcass weights ($P<0.01$) and greater length ($P<0.01$) than two-way crosses and native goats. The significantly longer carcass of three-way crosses may be related to the larger size and enhanced capacity of Boer goats compared with native goats. However, hot or chilled dressing percentages based on EBW were less for three-way crosses than for the other groups ($P<0.01$), but hot dressing percentage based on slaughter weight did not differ significantly. Van Niekerk and Casey[2] reported that significant

Table 1 Least square means and standard errors for carcass yield characteristics stratified by genotypes

Characteristics	Native	Two-way crosses	Three-way crosses	SE	SL
Age at slaughter (days)	347	329	327	9.87	NS
Live weight (kg)	19.25^{c}	30.08^{b}	39.71^{a}	1.12	**
Daily gain (DG, kg)	0.05^{c}	0.09^{b}	0.11^{a}	0.002	**
Fasted live weight (kg)	18.35^{c}	29.02^{b}	37.50^{a}	1.02	**
Empty body weight, EBW (kg)	16.72^{c}	27.51^{b}	35.93^{a}	1.03	**
Hot carcass weight (kg)	8.75^{c}	14.77^{b}	19.08^{a}	0.70	**
Cold carcass weight (kg)	8.13^{c}	14.15^{b}	17.03^{a}	0.67	**
Hot dressing % (fasted live weight basis)	47.49	50.85	48.10	0.93	NS
Hot dressing % (EBW basis)	52.19^{a}	54.28^{a}	50.20^{b}	0.68	**
Chilled dressing % (fasted live weight basis)	44.12^{b}	48.75^{a}	45.29^{b}	1.02	**
Chilled dressing % (EBW basis)	48.47^{b}	51.41^{a}	47.28^{b}	0.84	**
Chiller shrinkage %	7.13^{a}	5.86^{a}	4.11^{b}	0.62	**
Carcass length (cm)	48.42^{c}	57.25^{b}	66.58^{a}	0.84	**
Carcass width (cm)	22.67^{b}	26.16^{a}	27.75^{a}	0.58	**
Body components (% of EBW)					
Head and horn	10.70^{a}	8.78^{b}	7.15^{c}	0.34	**
Hide	12.08^{a}	10.30^{b}	10.51^{b}	0.45	*
Blood	3.93^{a}	3.43^{ab}	3.05^{b}	0.17	**
Feet	3.18^{a}	2.90^{b}	2.76^{b}	0.08	**
Tail	0.14^{b}	0.20^{a}	0.19^{a}	0.01	*
Lungs and trachea	1.29	1.31	0.138	0.09	NS
Spleen	0.15	0.18	0.16	0.01	NS
Heart	0.43	0.41	0.38	0.02	NS
Liver	1.71^{a}	1.58^{b}	1.48^{b}	0.05	*
Kidneys	0.34^{a}	0.26^{b}	0.24^{b}	0.01	**
Diaphragm	0.25	0.26	0.27	0.03	NS
Testes and penis	1.17	0.86	0.93	0.10	NS
Gastrointestinal tract	5.66	5.03	5.69	0.28	NS
Total internal fat	6.06^{a}	6.05^{a}	3.49^{b}	0.61	*

a, b, c Means with different superscripts within rows differ significantly.
NS = Not significant; *, ** = Significantly different at 5, 1% respectively.
SE = Standard error of the mean; SL = Significance level.

differences between various goat genotypes for dressing percentage based on live weight were mainly attributed to variations in the weight of stomach and intestinal contents at slaughter. The dressing percentage (based on slaughter weight) was reported to be about 46%–48% in different goat breeds[12). BROWNING *et al.*[13) reported that the dressing percentages of Boer goats at 8–10 and 24 months of age were 48% and 50%, respectively. Breed affected the dressing percentage, which ranged from 42.5% to 44.6% based on slaughter weight and from 54.3% to 55.8% based on EBW[14).

The percentage contributions of various visceral organs, lungs and trachea, spleen, heart, diaphragm, testis and penis, and gastrointestinal tract (based on EBW) did not differ significantly. Native goats had a significantly greater ($P<0.01$) percentage of head, blood, feet, and kidney compared with other genotypes. GIBB *et al.*[15) found a significant effect of breed type on the weights of visceral organs, as a proportion of live weight.

(2) Carcass composition

There were differences between goat genotypes for carcass tissue mass (kg) (Table 2). When the weights of carcass muscle, fat, and connective tissue were expressed as a percentage of carcass weight, the effect of genotype was not significant ($P>0.05$), except for bone percentage. Native goats had less ($P<0.01$) bone content than both two-way and three-way crosses. Similar results were also reported by PRALOMKARN *et al.*[16), while SANTOS *et al.*[17) reported that carcass bone content (20.4%–21.4%) did not differ significantly between genotypes. Native goats recorded higher MBR ($P<0.01$) and edible meat/bone (muscle + fat-bone ratio) ($P<0.05$) than the other groups. HOGG *et al.*[12) explained that the differences in fat content, and consequently of bone and meat of different joints, are a reflection of the pattern of fat deposition and stage of maturity of the animal.

(3) Loin eye area

Loin eye area was measured between the 12th and 13th ribs and analyzed using Photoshop CS3 Extended (Adobe Systems Inc., San Jose, CA, USA). Carcasses from three-way crosses showed a significantly larger ($P<0.01$) loin eye area (16.97 cm^2) than those from the other two groups, greater also than the TACFS[7) (Table 3). JOHNSON *et al.*[18) reported significant differences between different goat genotypes in the loin eye area, which is in agreement with the findings of the present study. Rib eye area, fat thickness, and total tissue depth differed by genotype. Rib eye area of genotypes fed grainless diets ranged from 6.4 to 8.3 cm^2 [14).

(4) Proportion of primal cuts

Carcasses were separated into loin, hind leg, chump, rack, shoulder, foreleg, breast, and neck prime cuts. The effect of genotype on the percentage of carcass components for hot carcass weight is reported in Table 4. Carcasses from native and two-way crosses had higher ($P<0.01$) loin percentage than those from three-way crosses. Carcasses from three-way crosses had higher ($P<0.01$) breast percentage and higher ($P<0.05$) chump percentage. No differences ($P>0.05$) were found among groups for leg, rack,

Table 2 Least square means and standard errors for dissected carcass composition stratified by genotypes

Variable	Native	Two-way crosses	Three-way crosses	SE	SL
Total tissues in half carcass, kg					
Muscle	3.03^b	5.22^a	5.26^a	0.24	**
Bone	0.71^b	1.42^a	1.58^a	0.06	**
Fat	0.35^b	0.56^{ab}	0.63^a	0.07	*
Connective tissue	0.26^b	0.55^a	0.56^a	0.05	**
Tissues as % half carcass					
Muscle	69.81	67.30	66.02	1.05	NS
Bone	16.26^b	18.28^a	19.49^a	0.66	*
Fat	8.08	7.32	7.63	0.92	NS
Connective tissue	5.85	7.10	6.86	0.62	NS
Tissue ratios					
Muscle : Bone	4.34^a	3.69^b	3.42^b	0.17	**
Muscle+Fat : Bone	5.21^a	4.49^b	4.17^b	0.23	*

$^{a, b}$ Means with different superscripts within row differ significantly.
NS = Not significant; *, ** = Significantly different at 5, 1% respectively.

Table 3 Least square means and standard errors for loin eye area stratified by genotypes

	Native	Two-way crosses	Three-way crosses	SE	Significant level
Loin eye area (cm^2)	8.133^c	11.187^b	16.970^a	0.727	**
Perimeter (cm)	12.903^c	14.689^b	17.304^a	0.361	**
Height (cm)	4.539^b	5.186^a	3.687^c	0.153	**
Width (cm)	2.885^b	3.283^b	6.116^a	0.157	**

a, b, c Means with different superscripts within row differ significantly.

** = Significantly different at 1% respectively.

Table 4 Least square means and standard errors for carcass yield components (primal cuts) stratified by genotypes

	Native	Two-way crosses	Three-way crosses	SE	Significant level
Component in half carcass (kg)					
1. Loins	0.573^b	0.909^a	0.897^a	0.060	**
2. Hind leg	0.895^c	1.587^b	1.803^a	0.047	**
3. Chump	0.379^c	0.550^b	0.823^a	0.051	**
4. Rack	0.456^b	0.816^a	0.855^a	0.049	**
5. Shoulder	0.231^b	0.417^a	0.458^a	0.018	**
6. Fore leg	0.942^c	1.506^b	1.828^a	0.070	**
7. Breast	0.416^c	0.629^b	0.960^a	0.059	**
8. Neck	0.401^b	0.760^a	0.798^a	0.038	**
Total (Half carcass)	4.293^c	7.175^b	8.422^a	0.288	**
Component as % half carcass					
1. Loins	13.31^a	12.66^a	10.57^b	0.47	**
2. Hind leg	21.07	22.15	21.49	0.61	NS
3. Chump	8.86^{ab}	7.66^b	9.73^a	0.52	*
4. Rack	10.61	11.29	10.20	0.45	NS
5. Shoulder	5.40	5.83	5.48	0.26	NS
6. Fore leg	21.93	21.00	21.71	0.43	NS
7. Breast	9.76^b	8.74^b	11.31^a	0.50	**
8. Neck	9.07	10.66	9.52	0.60	NS

a, b, c Means with different superscripts within row differ significantly;
NS = Not significant; *, ** = Significantly different at 5, 1% respectively.

shoulder, and neck percentages. Differences in joint percentages of carcasses from several breeds were reported by Tshabalala *et al.*[19] and Santos *et al.*[17].

(5) Chemical composition and physical properties of muscles

The chemical composition of muscles from native goats, two-way crosses, and three-way crosses is shown in Table 5. The protein percentage in three-way crosses (22.40%) was significantly higher than that in two-way crosses (20.54%) and native goats (20.96%) ($P<0.05$). Sukniam *et al.*[20] reported that muscles from 50% Anglo-Nubian × native goats had a significantly lower fat content than those from native goats ($P<0.05$).

The physical properties of muscles of native goats, two-way crosses, and three-way crosses are shown in Table 6. Percentage cooking loss from the *longissimus dorsi* and *biceps femoris* was in the range 24.07%–25.61% and showed no difference between genotypes, which was within the normal range for goat muscle[21,22].

Schonfeldt *et al.*[23] found a cooking loss of 18%–22%, but Babiker *et al.*[24] and Johnson *et al.*[18] reported a loss of 30%–35% in cooked goat meat. The average cooking losses in some Ethiopian indigenous goats (29%) were lower than in Australian Capretto goats (35%) of similar slaughter weight. Higher cooking loss (62.2%) was reported for Nanjiang yellow goats. The variation in cooking loss reported by various workers can be attributed to differences in time and temperature of cooking, ultimate pH, and the muscle cut used. In general, the lower the cooking loss, the higher the juiciness of the meat.

Tenderness values for goat meat (2.8 kg/cm^2) are often within the acceptable range, but lower than those for lamb (4.8 kg/cm^2)[23]. Shear force values tend to follow similar trends to tenderness ratings. In the above studies, the *longissimus dorsi* had a lower shear force than the

Table 5 Least square means and standard errors for chemical composition of muscles stratified by genotypes

Chemical composition	Native	Two-way crosses	Three-way crosses	SE	Significant level
Moisture (%)	78.07[a]	77.48[a]	74.14[b]	0.55	**
Protein (%)	20.96[b]	20.54[b]	22.40[a]	0.49	*
Fat (%)	0.79[b]	0.76[b]	2.55[a]	0.13	**
Ash (%)	1.21	1.15	1.27	0.04	NS

a, b Means with different superscripts within row differ significantly;
NS = Not significant; *, ** = Significantly different at 5, 1% respectively.

Table 6 Least square means and standard errors for physical properties of muscles stratified by genotypes

	Native	Two-way crosses	Three-way crosses	SE	Significant level
Cooking loss (%)	25.61	24.45	24.07	0.88	NS
Shear force (kg/cm^2)	3.38[a]	3.42[a]	2.07[b]	0.37	*
L*	42.39[a]	44.29[a]	37.88[b]	1.67	*
a*	9.02	7.81	10.27	1.18	NS
b*	10.08	8.99	10.63	1.09	NS

a, b Means with different superscripts within row differ significantly.
NS = Not significant; * = Significantly different at 5 %.
L* depicts relative lightness, a* indicates relative redness and b* represents relative yellowness.

biceps femoris ($P<0.05$). Cooked meat from three-way crosses had a lower ($P<0.05$) shear force value (2.07 kg/cm^2) compared with native goats (3.38 kg/cm^2) and two-way crosses (3.42 kg/cm^2). Similar results (3.7–4.6 kg/cm^2) have also been reported by DHANDA *et al.*[21], while BABIKER *et al.*[24] reported shear force values ranging between 4.6 and 6.7 kg/cm^2. The difference in shear force values between breeds may be due to variation in connective tissue content. The variation in shear force values reported by various workers may also be attributed to differences in nutrition, age, time and temperature of cooking, and the muscle tested. JOHNSON *et al.*[25] reported that there were no significant differences in shear force values between breeds.

The CIE color profile system calculated the values of lightness, redness, and yellowness of the meat, which were found to be lower for the *biceps femoris* ($P<0.05$) than for the *longissimus dorsi*. There were no effects of genotype on lean color or surface discoloration (redness and yellowness values), although genotype did influence ($P<0.05$) lightness value. Three-way crosses showed lower ($P<0.05$) muscle color lightness value compared with the other groups. Meat color is an important parameter of meat quality, being determined largely by the content of myoglobin and its derivatives. It is normal for meat to change color depending on the presence or absence of air. For instance, exposed meat changes color due to reactions between myoglobin and oxygen. Hence, butchers prefer carcasses to have at least some fat cover (subcutaneous fat) evenly distributed over the carcass because this helps to maintain quality and an attractive appearance by preventing the meat from drying.

Conclusions and Recommendations

The three goat genotypes studied significantly affected carcass characteristics. Native goats generally had the lowest values for muscle characteristics and lightest weights. Crossing native goats with Anglo-Nubian and Boer goats (three-way crosses) appeared to improve carcass characteristics and bettered the composition of the former. The advantage of three-way crosses is primarily their higher slaughter carcass weight, carcass length, loin eye area, and acceptable quality at a predetermined age compared with two-way crosses and native goats. However, native goats had a higher MBR and edible meat proportion. Genotype also had an influence on shear force and lightness values of meat.

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タイ国における肉用ヤギ３集団の屠体成績と肉質

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要約：濃厚飼料給与量を体重の１パーセントとした給餌条件下で飼育したタイ産肉用ヤギ３集団の屠体成績を得ることを本研究の目的とした。南部タイ在来種，２元交雑（50% アングロヌビアン種×50% 在来種），３元交雑（50% ボアー種×25% アングロヌビアン種×25% 在来種）から健康な１歳雄 18 頭を無作為に選び，24 時間絶食後，屠殺した。３元交雑は２元交雑および在来種に比べ，屠殺前生体重，枝肉重量，枝肉長の値が有意（$P<0.01$）に大きかった。枝肉歩留は 50.20～54.28％で，３元交雑が有意（$P<0.01$）に低かった。３元交雑のロース心面積は，２元交雑や在来種に比して有意（$P<0.01$）に大きかった（それぞれ 16.97，11.19，8.13 cm^2）。屠体の物理学的特性，肉の化学組成と微細構造は，骨と肉の比率を除いて３集団に差はなかった。在来種の骨量は他集団に比べ有意（$P<0.01$）に低く，筋肉—骨比はほかの２集団に比べて有意（$P<0.01$）に高かった。また可食肉（筋肉＋脂肪）—骨比も有意（$P<0.05$）に高かった。肉のタンパク含量は３元交雑（22.4%）が有意（$P<0.05$）に高く，脂肪も同様（$P<0.01$）であった。肉の剪断力価と肉色は集団により有意（$P<0.05$）に異なった。胸最長筋の剪断力価は大腿二頭筋や上腕三頭筋より低く（$P<0.05$），国際標準照度値による肉色測定では大腿二頭筋と上腕三頭筋の肉色は胸最長筋よりも暗かった（$P<0.05$）。

キーワード：ヤギ，屠体成績，肉質，肉の物理学的性状，肉の化学組成

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