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Meat Characteristics and Quality Changes during Storage of Boer Crossbred Goat Dressed via Conventional-Skinning and Singeing Methods

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Abstract

The effect of carcass dressing via conventional-skinning and singeing on samples from legs and shoulders of the Boer crossbred goat was examined. After deboning and resizing from its primary cuts, proximate composition, total collagen, and some physicochemical characteristics of the samples were determined. Storage study was then conducted to evaluate the physicochemical stability of samples over 5 days of refrigerated storage. Meat samples prepared by the singeing method generated significant lower moisture, ash, myoglobin, and redness (a*) as compared to those prepared by the skinning method ($P < 0.05$), while significant higher pH, cook loss, lightness (L*), and yellowness (b*) were noted ($P < 0.05$). Samples from the leg cut revealed lower protein and ash content, tender texture, and higher cook loss compared to samples from the shoulder cut ($P < 0.05$). During storage, samples that were subjected to singeing exhibited higher cook loss, discoloration, lipid oxidation (PV and TBARS), and metmyoglobin percentage compared to samples that were exposed to skinning ($P < 0.05$). Nevertheless, the lower oxymyoglobin percentage was obtained ($P < 0.05$) in those prepared from by than by skinning. Samples from the leg cut had higher cook loss, tender texture, and oxymoglobin percentage, while lower TBARS formation and metmyoglobin percentage were noted ($P < 0.05$). Drip loss, cook loss, lightness, and metmyoglobin percentage of samples increased with longer number of storage days, while redness, shear force, and oxymyoglobin decreased ($P < 0.05$). Discoloration and oxidation products from singeing are 2 substantial characteristics should be concerned when supplying meat for the retail market.

Keywords: Carcass dressing, goat meat, physicochemical characteristics, skinning, singeing

Introduction

In normal abattoir practice, skinning-off and evisceration are the main sequence procedures conducted after the animal is slaughtered [1]. In ruminants, skinning is a typical method used for skin-off in many world regions. The singeing method is another choice that occurs in some parts of the world, and might be related to ethnic consumers. In this method, hair is removed by fire while the animal skin is still intact with the carcass. A previous paper stated that carcass dressing by singeing is a practice formerly found in the goat abattoir practice of African and some Asian countries [2]. As regards to Thailand, the singeing method on goat carcass dressing has been applied by the traditional small ruminant meat industry for a long period, and tends to be more popular than skinning in the southern Thailand region. The singeing method is mostly applied for carcass dressing when skin-on meat is required. However,

there is a lack of information about the effect of singeing method on Thai goat meat quality. Therefore, goat meat quality from 2 dressing methods (singeing and skinning) used on 2 parts of each carcass (shoulder and leg cuts) was compared. In addition, the effect of storage time on the quality change of meat obtained from different parts and using different dressing methods were also studied. Information gained from this study could be useful in considering the appropriate methods of carcass dressing to further improve goat meat quality and utilization.

Materials and methods

Sample preparation

A total of 4 Boer crossbred (75 % Boer × 12.5 % Anglo-Nubian × 12.5 % Thai native) goats, aged 12±1 months old and of slaughtering weight 37.5±1.5 kg, were collected from the Thepa Research and Breeding Development Station, Department of Livestock Development, Thepa district, Songkhla province. During the growing period, the goats were given similar feed (*ad libitum* Signal grass with 2.0 % concentrate diet) and environmental conditions. After 24 h of resting period, goats were sacrificed according to Islamic procedure, as mentioned in Thai Agricultural Standard 8400 - 2007 [3] and the guidelines of Thai Agricultural Standard 9040 - 2013 on GMP for goat and sheep abattoirs [4]. The slaughtering process of the goat samples was handled in the Meat Laboratory, Department of Animal Science, Faculty of Natural Resources, Prince of Songkla University, Hat Yai district, Songkhla province.

After death, the goats were hung before carcass dressing. Two goats were dressed using the skinning method, while the other two were dressed according to the singeing method. The skinning was performed based on the guidelines of Thai Agricultural Standard 9040 - 2013 on GMP for goat and sheep abattoirs. The singeing procedure was started by flaming the skin surface to remove the hair. Then, the residual burned hair was removed using a scraper. The flaming was conducted again to burn the remaining hair completely. Finally, tap water and a brush were used to remove the burned hair. Carcasses from both dressing methods were eviscerated, washed, and then hung in a chill room at 4 °C for about 20 h. After chilling, the carcasses were transferred to a cutting room and were divided into primary cuts. Then, 4.0×2.0×1.0 cm meat pieces were obtained from the leg and shoulder cuts. The meat pieces were put in polyethylene (PE) plastic bags, and cooled in an ice box before being transported to the Department of Food Technology, Faculty of Agro-Industry, for meat quality analysis. At the same time, the samples for storage study were placed into absorber-equipped trays, and then wrapped in plastic to provide similar conditions to retail refrigerated butchery. Subsequently, samples were kept in a refrigerator (4 °C). The laboratory analyses were conducted at 1, 3, and 5 days of storage.

Sample analyses

Proximate composition

Proximate compositions, such as moisture, protein, fat, and ash content, were determined following the AOAC procedure [5].

Total collagen

The total collagen content of the samples was determined after acid hydrolysis [6]. Finely minced goat meat was hydrolyzed with 6N HCl at 110 °C for 24 h. Afterwards, the samples were clarified with activated charcoal, filtered and neutralized, and diluted with distilled water before determination of hydroxyproline content [7]. A UV-spectrophotometer (UV-1700 PharmaSpec, Shimadzu Corporation, Japan) was used to obtain an absorbance score at 558 nm, and the result was then converted to collagen content in the meat (mg/g) using the factor 7.25.

Myoglobin

The myoglobin content of the goat meat samples was determined according to an adapted method using a UV-spectrophotometer (Libra S22 Biochrom, England) [8]. A UV-spectrophotometer (Libra S22 Biochrom, England) was used to get the absorbance score of the samples at 572, 565, 545, and 525 nm. The concentration of myoglobin was calculated according to the equation as follows;

$$\text{Total myoglobin} = (-0.1666R1 + 0.086R2 + 0.088R3 + 0.099) \times A_{525} \quad (1)$$

where A572/A525, A565/A525, and A545/A525 are represented as R1, R2, and R3, respectively.

The myoglobin content was expressed as mg/g of meat sample by multiplying the obtained score by the molecular weight of goat myoglobin (16824 Da) [9,10].

pH

A homogenizer (WiggenHauser®, Germany) was used to mix the meat samples with deionized water at a ratio of 1:5 (wt/vol) for 1 min. Then, the homogenate was subjected to pH measurement using a digital pH meter (SevenGo S62-FK2 Mettler Toledo, Switzerland) [11].

Drip loss

The meat samples were cut into small equal pieces of dimensions of 2.0×1.0×0.5 cm using a stainless steel surgical blade (Feather Safety Razor Co Ltd., Japan). Each piece was weighed and packed into a sealed plastic bag before storage at a chilled temperature (4 °C). After 24 h, the sample was removed from the sealed plastic bag, blotted, and weighed in the same manner explained in the earlier sample preparation. Percentage of post weight to fresh weight of samples was calculated for drip loss [11].

Cook loss

The meat samples were prepared in the same manner as that of drip loss determination. Then, the samples were put in a plastic-sealed bag and heated in a water bath at 80 °C for 10 min. After cooking, the sample was cooled in tap water until reaching normal temperature. After that, the samples were removed from sealed plastic bag, blotted with filter paper, and weighed to determine the cook loss as a percentage of initial weight [11].

Texture

Sample sizes of 2.0×1.0×0.5 cm were prepared using a similar meat cutter as mentioned in the drip loss and cook loss analysis. A Texture Analyzer (TA-XT plus Stable Micro System Texture Analyser, UK) was used to determine the shear force value of the meat using a Warner-Bratzler blade [12]. The operating parameters consisted of a cross-head speed of 2 mm/s and a 50 kg load cell.

Color

Color was determined using a Hunterlab colorimeter (Hunterlab ColorFlex, Virginia). An aperture size of 0.50 inch was used during color determination. The colorimeter was calibrated using a black glass and white standard tile before sample analysis. The result was reported in the complete International Commission on Illumination (CIE) system color profile of lightness (L*), redness (a*), and yellowness (b*).

Oxymyoglobin and metmyoglobin

Extracted myoglobin solution from myoglobin analysis was used for myoglobin fraction determination. The absorbance was determined using a UV-spectrophotometer (Libra S22 Biochrom, England) at 582, 557, 525, and 505. Percentage of oxymyoglobin and metmyoglobin was calculated as follows;

$$[\text{OxyMb}] = C_{\text{OxyMb}} / C_{\text{Mb}} = 0.722\ R_1 - 1.432R_2 - 1.659R_3 + 2.599 \quad (2)$$

$$[\text{MetMb}] = C_{\text{MetMb}} / C_{\text{Mb}} = -0.159R_1 - 0.085R_2 + 1.262R_3 - 0.520 \quad (3)$$

where R1, R2, and R3 are A_{582} / A_{525}, A_{557} / A_{525}, and A_{503} / A_{525}, respectively [13].

***Peroxide value* (*PV*)**

A total of 11 mL mixture of 2:1 chloroform/methanol was added to one gram of sample in a centrifuge tube and homogenized (WiggenHauser®, Germany) for 1 min. Whatman paper number 1 was used to filter the homogenate. After that, a total of 2 mL of 0.5 % NaCl was added to the filtrate, vortexed for 30 s at a moderate speed, and then centrifuged at 3600 × g in a thermo electron centrifuge (SorvalBiofuge Primo R Centrifuge, Germany) for 3 min to create 2 clear phases of solution. Three mL of lower phase was taken carefully and transferred to a glass tube containing 2 mL of ice cold mixture of 2:1 chloroform/methanol. Soon after that, ammonium thiochianate and iron (II) chloride were added into the sample solution. Cumenehydroperoxide was used to prepare a standard curve of hydroperoxide. The supernatant was read using a UV-spectrophotometer (Libra S22 Biochrom, England). The absorbance was calculated to determining the result in mg hydroperoxide/kg meat sample [14].

***Thiobarbituric acid reactive substances* (*TBARS*)**

A 2 gram sample was homogenized (WiggenHauser®, Germany) with 2 ml TB-TBA-HCl reagent prepared from 15 % of TCA, 0.375 % TBA, and 0.25 N HCl in a centrifuge tube. The homogenate was transferred to a tube and heated in a boiling water bath for 15 min. Soon after, the tube was cooled with running tap water and centrifuged at 3600 × g/20 min/25 °C. The supernatant was filtered using Whatman filter paper number 1 and read using a UV-spectrophotometer (Libra S22 Biochrom, England) at 535 nm. A standard curve was prepared from 1,1,3,3-tetramethoxypropane at concentration 0 - 2 ppm. The absorbance was calculated to determine the result in mg malonaldehyde/kg meat sample [15].

Statistical analysis

The data were analyzed as a completely randomized design, using a model in which the effects of dressing method (singeing and skinning), carcass part (shoulder and leg), and their interaction were included. In addition, the changes of meat quality during storage at 1, 3 and 5 days of meat samples were also analyzed. The experiments of the study were done in duplicate (2 carcasses for each treatment). Each treatment sample was determined by 4 replications for chemical analyses and 8 - 12 replications for physical analyses. All data were subjected to analysis of variance with the general linear model using the IBM SPSS Statistics 17.0 computer program. Significant differences between treatment means were analyzed by Duncan's multiple range test ($P < 0.05$).

Results and discussion

Proximate composition and total collagen

The physicochemical characteristics of the Boer crossbred goat meat from different cuts using different dressing methods are presented in **Table 1**. Dressing method significantly affected moisture, protein, and ash content of the samples ($P < 0.05$); while the meat cut was significantly associated with variation of protein and ash content ($P < 0.05$). Samples prepared by the singeing process were significantly lower ($P < 0.05$) in moisture and ash content than those of samples prepared by skinning, but significantly higher ($P < 0.05$) in protein content. In the meat cut comparison, samples from the leg had lower protein content than those of shoulder ($P < 0.05$). Fat content and total collagen among fabrication samples were comparable. Moreover, moisture properties exhibited a significant interaction between dressing method and meat cut. In comparison between factors of treatment, the dressing method had more influence on the chemical compositions of meat than those of meat position and treatment combination.

The thermal process leads to the denaturation of meat protein and the alteration of protein structure; this fact causes the gradual loss of the meat's water-holding ability [16]. The greater the decrease in water-holding capacity on samples subjected to singeing, the more moisture released during carcass chilling and after cutting in terms of drip loss. Moreover, the singeing method showed more influence in lowering moisture content of shoulder meat than that of leg meat. This might be due to leg meat tending to have more fat content (even though non-significant results were identified), and ash, which could retard the effect of heat. Thus, singeing also caused a decrease in some portion of ash through loss of mineral compounds, particularly iron, via myoglobin-rich drip loss.

Table 1 Comparison effect of dressing method, meat cut, and combination treatments on quality characteristics of Boer crossbred goat meat.

Physicochemical	Dressing method			Meat cut			Dressing method × meat cut
	Skinning	Singeing	*p*-value	Leg	Shoulder	*p*-value	
Chemical							
Moisture	77.76±0.45	76.12±0.63	0.000	77.01±0.62	76.87±1.70	0.077	*
Protein	18.89±0.57	19.85±0.52	0.007	18.98±0.70	19.75±0.66	0.027	NS
Fat	2.93±0.58	3.43±0.15	0.151	3.44±0.14	2.92±0.56	0.137	NS
Ash	1.12±0.05	1.07±0.04	0.002	1.12±0.04	1.07±0.03	0.002	NS
Collagen	3.65±0.30	3.42±0.09	0.317	3.61±0.36	3.46±0.03	0.509	NS
Myoglobin	9.48±0.27	8.20±0.22	0.002	8.86±1.15	8.82±0.66	0.895	NS
Physical							
pH	5.60±0.02	5.96±0.06	0.000	5.75±0.23	5.81±0.27	0.357	NS
Drip loss	0.92±0.38	0.93±0.03	0.950	1.04±0.20	0.80±0.21	0.107	NS
Cook loss	33.81±1.98	36.07±0.27	0.000	35.55±0.47	34.34±2.72	0.009	*
Shear force	4.10±0.35	4.04±0.22	0.669	3.87±0.02	4.27±0.10	0.005	NS
L*	40.73±1.16	46.59±0.35	0.000	43.95±3.39	43.38±4.90	0.109	*
a*	15.56±0.90	14.30±0.08	0.001	14.59±0.48	15.27±1.30	0.061	NS
b*	8.45±0.42	9.77±0.39	0.001	9.40±0.91	8.82±0.95	0.103	NS

Means (±SD) within carcass dressing and within meat cut with $P < 0.05$ differ significantly
* = significant ($P < 0.05$)
NS = non-significant ($P \geq 0.05$)

Table 2 Comparison effect of dressing method, meat cut, storage time, and their combination on quality of Boer crossbred goat meat.

Physicochemical characteristics	Dressing method	Meat cut	Storage day	Dressing method × meat cut	Dressing method × storage day	Meat cut × storage day
Drip loss	NS	NS	*	NS	NS	NS
Cook loss	*	*	*	NS	NS	NS
L*	*	NS	*	NS	*	NS
a*	*	NS	*	*	*	*
b*	*	NS	NS	*	*	*
Shear force	NS	*	*	NS	NS	NS
PV	*	NS	NS	NS	NS	NS
TBARS	*	*	NS	*	NS	NS
OxyMb	*	*	*	NS	NS	NS
MetMb	*	*	*	NS	NS	NS

*significant ($P < 0.05$)
NS = non-significant ($P \geq 0.05$)

Myoglobin

Dressing method showed highly significant effects on the myoglobin content of the samples ($P < 0.05$), while meat cut had a non-significant effect ($P \geq 0.05$). This could be seen from the lower myoglobin content obtained in singed samples compared to skinned samples ($P < 0.05$), as shown in **Table 1**. In visual evaluation, a pale color was detected on such meat cuts. Myoglobin, with its heme pigment, might be lost its natural structure due to heat. The result from previous study implied that the higher the temperature used to heat the meat, the higher the denaturation occurring for 3 myoglobin fractions [17].

Consistent with the present study, another report explained that the loss of heme iron as the effect of thermal heating could be a secondary point to argue the lower myoglobin content phenomenon on singeing meat. The top side of beef had been reported as having a higher heme iron loss, with a total of 24 %; while sirloin, fillet, and roasted beef had losses of 11, 6, and 3 % among beef cuts, respectively [18].

pH

Dressing method caused significant effects on the pH of the meat samples ($P < 0.05$). In **Table 1**, it could be seen that the pH of singed samples was higher than that of skinned leg and shoulder samples ($P < 0.05$). At the same time, no substantial effects on meat cut was obtained. Formation of lactate as the product of glycolysis starts gradually once muscle is converted to meat [19]. Once glycolytic enzymes denaturation occurs as the effect of heat, the breakdown of glycogen to lactic acid might be retarded. Partial denaturation as a consequence of the singeing method might be enough to inactivate endogenous enzymes and finally lead to the higher ultimate pH of the singeing samples. As regards to the result of the skinning samples, there is no interfering effect on the glycolytic pathway. So, the breakdown of glycogen during post-mortem was not stopped; thus, the ultimate pH of such samples was lower than that of the singeing samples.

Drip loss

The process of drip loss formation in the meat was indicated by 2 actions, shrinkage of myofibrillar and solubilization of sarcoplasmic protein [20]. Dressing method and meat cut did not generate substantial effect on the drip loss of the samples ($P \geq 0.05$). Theoretically, heat as applied by the singeing method might interfere with the ability of meat to retain water and, thus, generate higher drip loss. Heat directly minimizes the water-holding capacity of meat and, thus, causes the discharge of juice from meat [21]. However, a non-significant result of drip loss between the samples obtained from the singeing and skinning methods was obtained. This might be due to the higher drip loss during chilled-hanging before the carcass being cut into primary cut and meat pieces before sample analysis. Thus, during 24 h storage in refrigerated conditions (as per the guidelines for drip loss analysis), less final drip obtained from the samples treated by the singeing method resulted in not much different consequences compared to samples prepared by the skinning method.

Cook loss

Dressing method, meat cut, and the combination of these 2 factors significantly affected the cook loss of samples ($P < 0.05$). Cook loss of the skinning samples was lower than that of the singeing samples ($P < 0.05$). Myofibrillar and collagen are 2 protein components in meat, responsible for water holding capacity [22]. Then, damage of the myofibrillar protein and collagen from the beginning of the carcass dressing by singeing caused more water release during cooking. Samples from the leg cut had higher cook loss than that of the shoulder cut. This might be associated with protein content between samples. It is well-known that protein content is responsible in determining water-holding capacity. A higher protein content in shoulder samples than that of leg might contribute to more water holding ability. Significant interaction between dressing method and meat cut revealed that variation obtained from dressing method and meat cut contribute severe effects on meat samples.

Shear force

Statistical results showed that meat cut meaningfully determined the texture of the samples ($P < 0.05$) when compared to dressing method ($P \geq 0.05$). It could be seen that samples from the leg cut had lower shear force than that of the shoulder cut. This might be due to the effect of lower moisture and higher protein content in the shoulder cut than that of the leg cut (**Table 1**). It is well-known that when less water is diluted in food material, a harder texture is commonly obtained. Besides, variation in microstructure (such as muscle fiber and sarcomere length) between samples might also lead to such phenomenon. Moreover, a reference also noted that variation of calcium and potassium in meat is also responsible for generating differences of meat tenderness. This is associated with the role of those elements in activation of meat protease (calpains and calpastatins) which is responsible for generating a softening effect on meat during the postmortem period [23]. This hypothesis was elucidated by the difference in ash content between meat from the leg and shoulder. The lower shear value of meat from the leg cut was concomitant with the significantly higher ash content.

Color (L*, a*, b*)

Dressing method had more influence on lightness (L*), redness (a*) and yellowness (b*) of the samples ($P < 0.05$). At the same time, lightness had a significant result from a combination effect of dressing method and meat cut ($P < 0.05$). The effect of singeing resulted in a significantly higher lightness and yellowness in the singeing samples compared to the skinning samples ($P < 0.05$). Redness of the skinning samples was higher than that of the singeing samples ($P < 0.05$). This result was consistent with the lower myoglobin content in the singeing samples. Heat caused alteration of the natural color of meat from red into pale in visual judgment, as significantly found in the singeing samples. At the beginning of heating (50 °C), denaturation and coagulation of myofibrillar protein occurred, and it was altered to be a dull-white clump. Once temperature increases to 60 °C, the denaturation and oxidation of red pigment myoglobin takes place. At this stage, a brown-gray color is produced [24].

Quality change during storage

The significance in the effect of dressing method and meat cut during storage on goat meat quality is presented in **Table 2**. Dressing method had more influence on quality changes than others factors, especially in the color of and the oxidation in meat. Storage time caused significant change in water holding capacity, shear value, and oxidation in pigment color of goat meat. The difference in meat cut contributed to significance in quality chance on shear value and oxidation of fat and myoglobin in meat. The treatment combination was found to be of most influence in the color of goat meat. The quality changes of goat meat obtained from different dressing and meat cuts during storage are described further in **Figures 1 - 5**.

Drip loss and cook loss

Drip loss and cook loss of Boer crossbred goat meat by different carcass dressing during storage is shown in **Figure 1**. During storage, an increasing trend in drip loss of the samples was noted ($P < 0.05$), while a non-significant effect from dressing method and meat cut was obtained ($P \geq 0.05$). At the same time, the cook loss of samples increased with storage time ($P < 0.05$) and was shown to be slightly higher in meat from the singeing method and leg cut ($P < 0.05$).

A gradual increase of drip loss in all samples during storage was related to the breakdown of myofibrillar protein by the longer number of storage days. A review explained that the decrease of water holding capacity in meat occurred during the storage period where rigor takes place. Myofibril, intracellular, and extra-cellular spaces of muscle release moisture progressively and come out to the meat surface as a drip. Loss of drip from the meat is started definitely from extracellular space, while the further drip from the smaller inner part of the muscle bundles come out over longer rigor time [25].

Singeing samples exhibited higher cook loss than that of skinning samples. This is associated with the initial denature of myofibrillar protein once heat is transferred to the goat carcass during dressing. Greater breakdown in the myofibrillar protein of the singeing samples in the present study led to higher

moisture loss when the meat was boiled during the cook loss analysis. A reference explained that denaturation of myofibrillar protein due to thermal effect initiated losses of water from its natural structure. Most structural alteration of meat protein occurs when actin is fully denatured; thus, this accelerates weight loss in meat [26] once cooking is applied.

Leg samples revealed a higher cook loss compared to samples obtained from shoulder cut ($P < 0.05$). Protein content, particularly myofibrillar protein, is a substantial factor in determining the ability of meat to retain water. The higher protein content obtained in meat from shoulder cut compared to that from leg cut, as shown in **Table 1**, might be reliable in determining more ability to retain water resulting in lower cook loss.

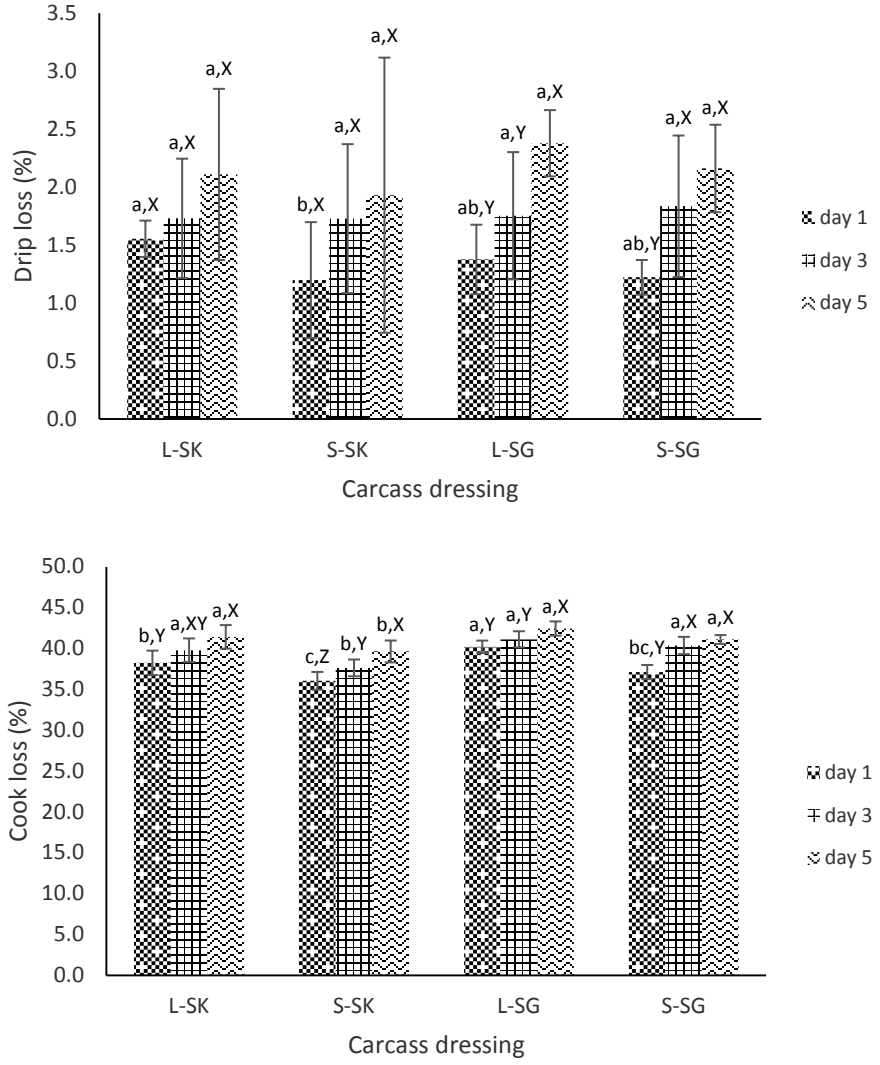

Figure 1 Water holding capacity (drip loss and cook loss) of Boer crossbred goat meat from different dressing methods and meat cuts during chilled storage.

[ab]Means(±SD) within carcass dressing with different small letter differ significantly ($P < 0.05$)
[XY]Means (±SD) within storage period with different capital letter differ significantly ($P < 0.05$)
L-SK = leg skinning; S-SK = shoulder skinning; L-SG = leg singeing; S-SG = shoulder singeing.

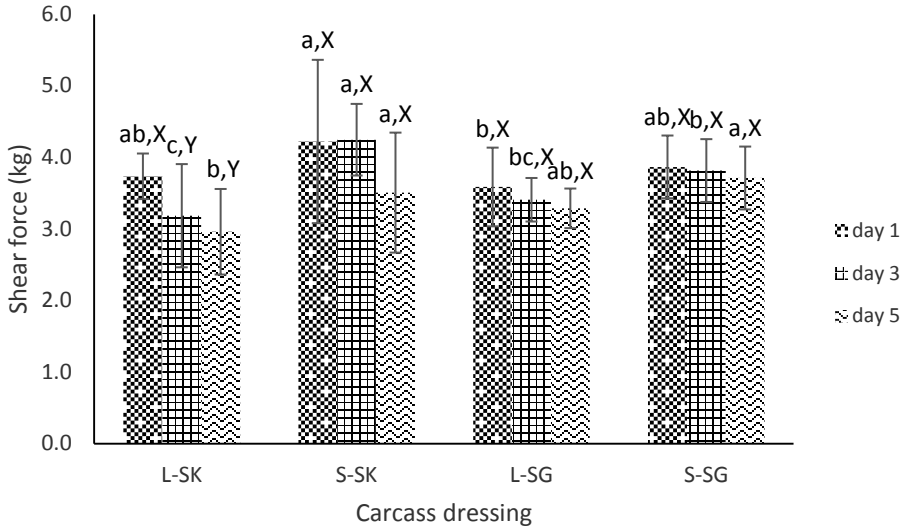

Figure 2 Shear force of Boer crossbred goat meat from different dressing methods and meat cuts during chilled storage.

[abc]Means (±SD) within carcass dressing with different small letter differ significantly ($P < 0.05$)
[XY]Means (±SD) within storage period with different capital differ significantly ($P < 0.05$)
L-SK = leg skinning; S-SK = shoulder skinning; L-SG = leg singeing; S-SG = shoulder singeing.

Shear force value

Change in shear force value of Boer crossbred goat meat from different carcass dressing and meat cut is presented in **Figure 2**. The result shows significant difference in texture between meat cut samples ($P < 0.05$). A significant decrease in shear value of samples during storage was noted ($P < 0.05$); while dressing method revealed a non-significant effect ($P \geq 0.05$) on shear value of treated samples.

Shear force of meat from the leg cut was significantly lower than that of the shoulder cut ($P < 0.05$). This might be associated with the assumption that higher moisture in the leg cut was still obtained during storage, as previously discussed. Tender texture in samples by longer number of storage days was shown ($P < 0.05$). Proteases from indigenous enzymes during storage were responsible for weakening of meat structure [27]. The loss of moisture might also have happened; however, the action of calpains probably had more significant effect on the resulting tender texture.

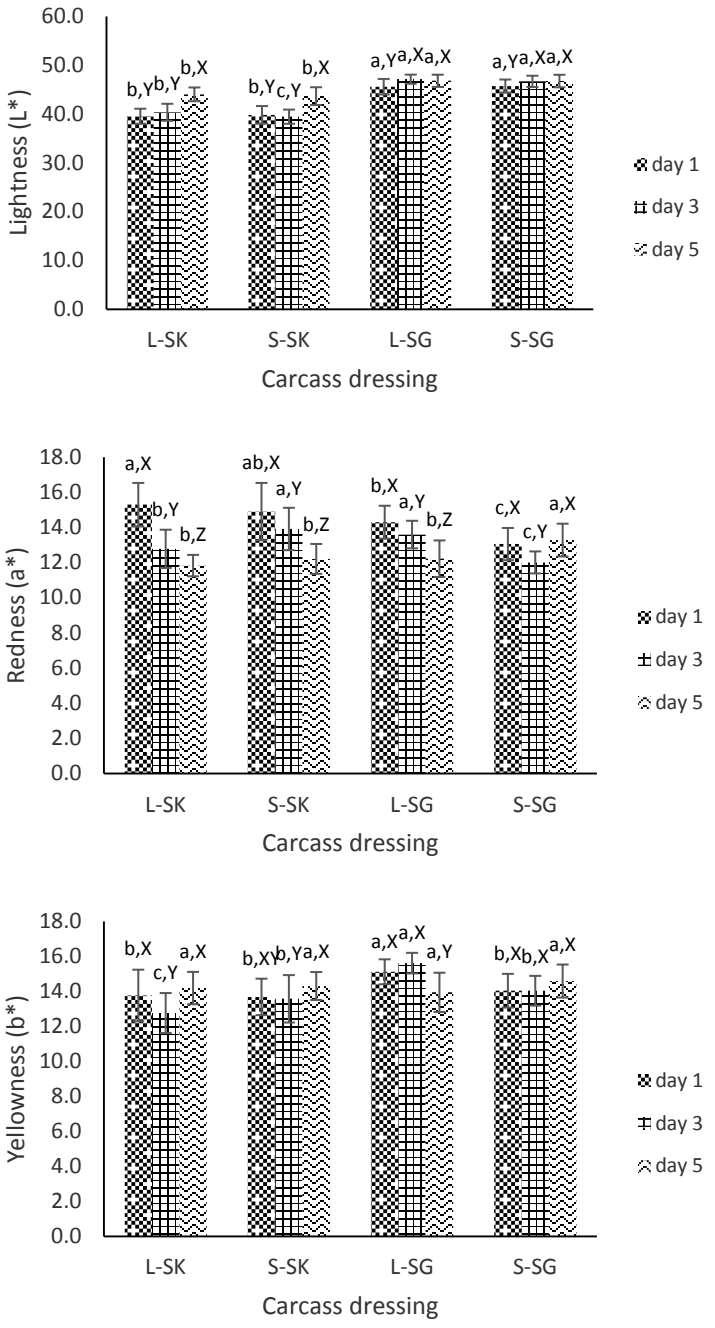

Figure 3 Color (L*, a*, b*) of Boer crossbred goat meat from different dressing methods and meat cuts during chilled storage.

[abcd]Means (±SD) within carcass dressing with different small letter differ significantly ($P < 0.05$)
[XYZ]Means (±SD) within storage period with different capital letter differ significantly ($P < 0.05$)
L-SK = leg skinning; S-SK = shoulder skinning; L-SG = leg singeing; S-SG = shoulder singeing.

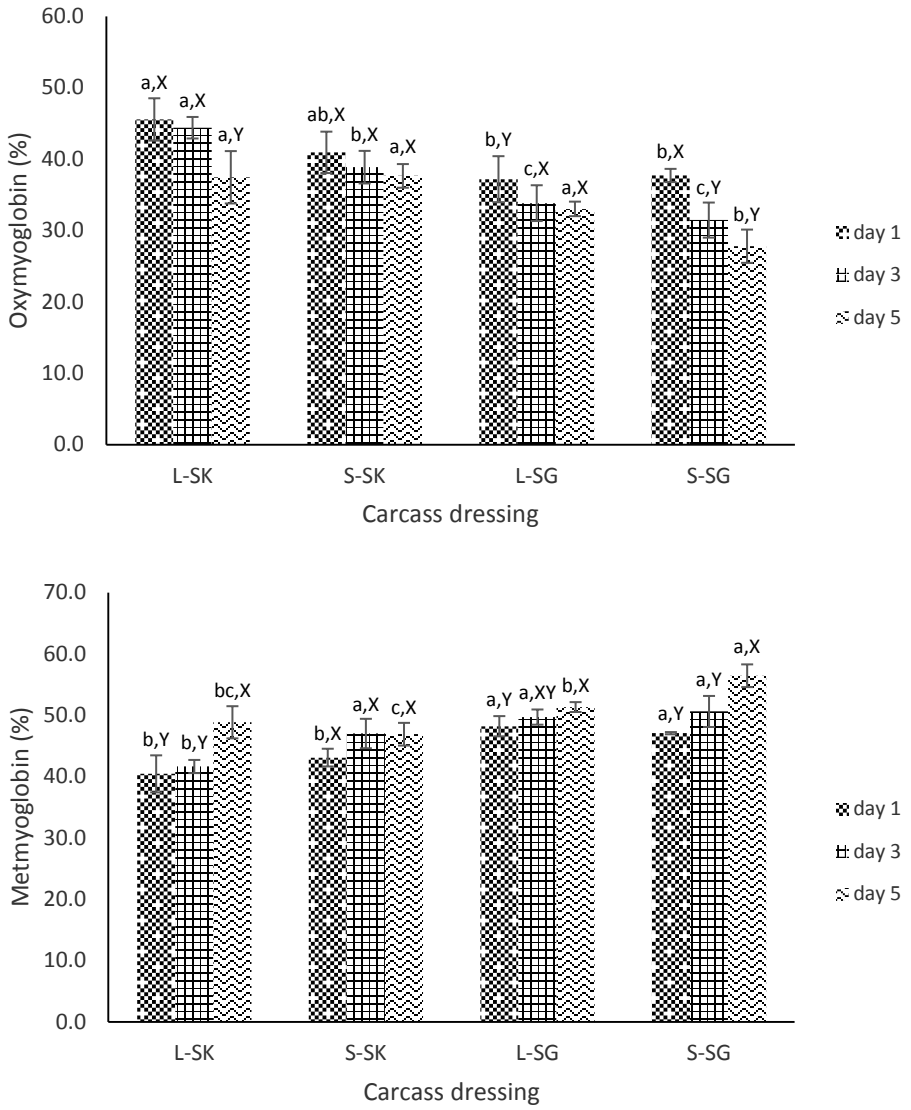

Figure 4 Oxymyoglobin and metmyoglobin of Boer crossbred goat meat from different dressing methods and meat cuts during chilled storage.

[abc]Means (±SD) within carcass dressing with different small letter differ significantly ($P < 0.05$)
[XYZ]Means (±SD) within storage period with different capital letter differ significantly ($P < 0.05$)
L-SK = leg skinning; S-SK = shoulder skinning; L-SG = leg singeing; S-SG = shoulder singeing.

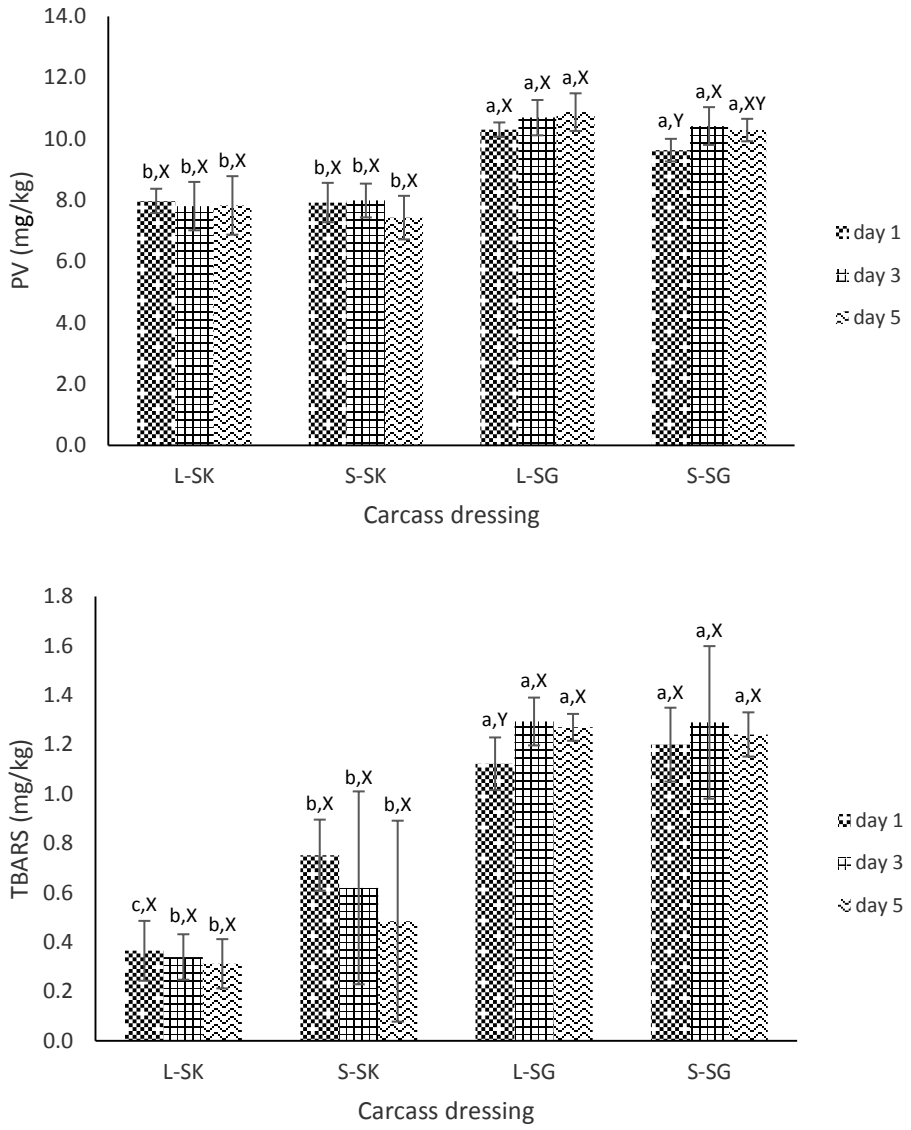

Figure 5 PV and TBARS of Boer crossbred goat meat from different dressing methods and meat cuts during chilled storage.

[ab]Means (±SD) within carcass dressing with different small letter differ significantly ($P < 0.05$)
[XY]Means (±SD) within storage period with different capital letter differ significantly ($P < 0.05$)
L-SK = leg skinning; S-SK = shoulder skinning; L-SG = leg singeing; S-SG = shoulder singeing.

Color (L*, a*, b*)

Color of Boer crossbred goat meat in term of lightness (L*), redness (a*), and yellowness (b*) from different carcass dressing and meat cut during storage is shown in **Figure 3**. The result shows that dressing caused significant differences in lightness, redness, and yellowness of samples ($P < 0.05$). Storage time resulted in significant dissimilarities in lightness and yellowness, while comparable results in meat cut-treated samples were obtained. A combination of dressing method and number of storage days resulted in a significant effect on lightness. At the same time, significant effects on redness and yellowness were obtained from all three combination factors (dressing method × meat cut, dressing method × storage day, and meat cut × storage day).

Singeing samples exhibited higher lightness and yellowness compared to those of skinning samples. At the same time, lower redness in singeing samples was shown. Lighter color in singeing samples compared to skinning samples was considerable in the meat color. This might be due to the noteworthy coagulation of myofibrillar protein, as well as alteration in its myoglobin state. Myofibrillar itself changed into a yellow color when heat was induced. Although no similar singeing treatment was done by others in order to support this result, this trend is still similar to a report which compared raw meat and grilled meat [28].

An increasing trend of lightness was found in samples with longer number of storage days. This fact might be due to the release of drip from the meat surface. A similar trend was also reported by another study in beef. The authors found that lightness of beef was increased from 41.87 (0 day) to 43.99 (7 days) [29]. A comparable result was also found in lightness of minced lamb meat during 14 days of refrigerated storage [30]. Moreover, the increased lightness and its relationship with increasing drip loss during storage were comparable with phenomenon in exudates meat. It is commonly known that exudates meat has a lighter color from the effect of drip from the surface of the meat.

The decreasing trend in redness during storage was associated with elevation of transformation of oxymyoglobin into metmyoglobin. From visual determination, a bright-red fresh meat color was reached after meat contacted free oxygen. This color was changed gradually into a brown color, a signal of higher metmyoglobin formation occurring in meat through longer number of storage days. This is similar to a study of beef in which a gradual significant decrease occurred at 1 to 5 days of storage in most of 19 muscles analyzed [31].

Oxymyoglobin and metmyoglobin

The oxymyoglobin and metmyoglobin of Boer crossbred goat meat from different fabrication methods are provided in **Figure 4**. The result reveals that dressing method, meat cuts, and number of storage days significantly affected myoglobin states ($P < 0.05$). Singeing samples exhibited a lower trend of oxymyoglobin and a higher trend of metmyoglobin than those of skinning samples ($P < 0.05$). Shoulder cuts had a lower oxymyoglobin percentage and a higher metmyoglobin percentage compared to leg cuts ($P < 0.05$). Decrease of oxymyoglobin and increase of metmyoglobin formation during storage were obtained in most samples ($P < 0.05$).

In carcass dressing, the higher trend of metmyoglobin in singeing samples might be due to more deoxymyoglobin transformed directly into metmyoglobin as heat was induced, while in skinning, the process firstly began with more deoxymyoglobin transformed into oxymyoglobin, and then transformed again into metmyoglobin. This phenomenon could be explained by trilateral myoglobin changes as common pattern of meat color changes [32]. Oxygenation of deoxymyoglobin (purple-red color) generated the formation of oxymyoglobin (red-pink color) and then could oxidize into metmyoglobin (brown color). Moreover, deoxymyoglobin could transform into metmyoglobin without passing through the oxymyoglobin state.

Lower metmyoglobin formation obtained in leg samples compared to shoulder samples is difficult to explain. Moreover, a slightly higher trend of drip loss (even though not significantly different) in leg samples might release more diluted myoglobin from the meat structure. Thus, less myoglobin percentage might be obtained in meat samples. With such an assumption, less remaining myoglobin stored in meat

samples causes less potency of metmyoglobin formation as transformed from deoxymyoglobin and oxymyoglobin.

In storage comparison, a gradual elevation of metmyoglobin formation of samples was obtained ($P < 0.05$). Meat discoloration from red to brown was produced by the changes of oxymyoglobin to metmyoglobin. This condition occurred when ferric formed from the oxidation of ferrous heme iron, in which molecules of water exchanged from oxygen discharged [33]. An increasing trend of metmyoglobin formation during storage is in agreement with the result found in bison and beef myoglobin during 7 days of storage [34].

PV and TBARS

PV and TBARS formation of Boer crossbred goat meat from different fabrication methods is presented in **Figure 5**. Dressing method contributed to generate a significant difference effect of PV and TBARS ($P < 0.05$). At the same time, meat cut significantly affected TBARS formation in samples ($P < 0.05$). However, a stable tendency of those oxidation products in most samples during storage was obtained. Furthermore, a combination of dressing method and meat cut resulted in a significant effect on TBARS ($P < 0.05$).

As noted in a reference, the sequence of lipid oxidation started with the formation of peroxides as the primary compound of the lipid oxidation process. Moreover, hydroperoxides are mostly used as a marker of primary oxidation products [35]. Higher peroxide formation in singeing samples compared to skinning samples was obtained. Significant heat induced by earlier carcass dressing of the singeing samples might accelerate degradation of lipids into peroxide formation. This condition is quite comparable with a report on research related to meat emulsions [36]. The previous study figured out a higher trend of peroxide production on heated samples than that of raw samples, although some fluctuations also happened during the storage period.

Malonaldehyde, which characterizes aldehydes-rich compounds, is a common substance analyzed to determine secondary oxidation products in foods [37]. The same condition as explained in peroxide formation is answerable for this malonaldehyde formation, particularly in singeing samples. This trend is similar to the result of a study on the effect of thermal conditions in beef [38]. Such research implicated that the TBARS formation of raw beef was increased 2 times after cooking, while its formation was increased more than 3 times at 3 and 7 days of a refrigerated storage period.

Conclusions

Heating applied to singed carcass resulted in decreasing consequences of moisture, ash, and redness, as well as increasing consequences in protein, pH, cook loss, lightness, and yellowness. The shoulder cut was characterized by its higher protein and shear force, but by lower ash content and cook loss, than those of the leg cut. Singeing samples continued to generate the breakdown of nature meat characteristics during storage. This thermal method triggered higher change in lightness, yellowness, PV, TBARS, and metmyoglobin, as well as lower results in redness and oxymyoglobin. The shoulder cut had higher shear force, TBARS, and metmyoglobin percentage, but lower cook loss and PV formation were indicated. Drip loss, cook loss, and metmyoglobin increased by longer number of storage days, while redness, shear force, and oxymyoglobin decreased. Some unexpected properties, such as higher discoloration rate and oxidation products, were found in singeing samples, which might limit the utilization of such meat. However, singeing could be an alternative dressing method for the traditional fresh meat market which prefers more specific attractive flavor in goat meat produced by flaming.

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