Effect of Feeding Concentrate Containing Crude Glycerin and Castration on Carcass Characteristics and Meat Quality of Thai Native X Anglo-Nubian Goats

Anneke

A Thesis Submitted in Fulfillment of the Requirements for the Degree of Masterof Science in Animal Science
Prince of Songkla University
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Major Program	Animal Science

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I hereby certify that this work has not been accepted in substance for any degree, and is not being currently submitted in candidature for any degree.

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ABSTRACT

Twenty of Thai Native x Anglo-Nubian crossbred (50:50%) male goats with about 24.75 ± 1.33 kg of initial body weight at about twelve months old from Small Ruminant and Development Center, Prince of Songkla University were randomly from the flock and used in the study. The goats were allotted into 2x2 factorial arrangement in completely randomized design. The factors were sex (intact and castrated male goats) and type of concentrate diet (control concentrate and concentrate supplemented with 10% of crude glycerin (CG)). Goats were fed Atratum grass (*Paspalum atratum*) *ad libitum* and supplemented with concentrate at 2% of their body weight for 90 days. At the end of the study, three goats from each treatment combination were sampled and slaughtered for carcass determination and meat quality study. From the study, goats received diet with 10% of CG supplementation had higher ($P<0.01$) meat and fat percentages than those received control diet. The darker colour of loin muscle and lighter back fat colour were also found in goat received concentrate diet with CG supplementation. Cooking loss percentage of both loin (*Longissimus dorsi)* and *Biceps femoris* muscles from those received diet with CG supplementation had lower than those received the control diet ($P<0.05$). However, type of concentrate diets did not affect the shear force value of both raw and cooked muscles. Castration improved ($P<0.05$) carcass fat percentage and crude fat percentage of both muscle types when compared with the intact males. No effect on drip loss and cooking loss percentages of both muscle types ($P>0.05$) by castration. In conclusion, CG supplementation and castration could be alternative management for fattening goats since carcass and meat quality of goat could be improved.

Keywords: crude glycerin, concentrate supplementation, castration, goats

ชื่อวิทยานิพนธ์ ผลของการให้อาหารข้นที่ผสมกลีเซอรีนดิบกับการตอนต่อลักษณะซากและคุณภาพของเนื้อแพะลูกผสมพื้นเมือง x แองโกลนูเบียน

ผู้เขียน Miss Anneke

Major Program สัตวศาสตร์

ปีการศึกษา 2559

บทคัดย่อ

สุ่มแพะลูกผสมพื้นเมือง x แองโกลนูเบียน (50:50%) เพศผู้ จากศูนย์วิจัยและพัฒนาสัตว์เคี้ยวเอื้องขนาดเล็ก มหาวิทยาลัยสงขลานครินทร์ จำนวน 20 ตัว มีน้ำหนักตัวเฉลี่ย 24.75 ± 1.33 กก. เข้าศึกษาแบบ 2 x 2 แฟกตอเรียล ตามแผนการทดลองแบบสุ่มสมบูรณ์ แบ่งปัจจัยที่ศึกษาออกเป็น 2 ปัจจัย ได้แก่ ปัจจัยที่ 1 คือ สูตรอาหารข้น มี 2 ระดับ (อาหารข้นสูตรควบคุม และอาหารข้นสูตรที่เสริมกลีเซอรีนดิบในระดับ 10%) และปัจจัยที่ 2 คือ เพศ มี 2 ระดับ (เพศผู้ปกติและเพศผู้ตอน) ในระหว่างการเลี้ยงแพะทุกตัวได้รับหญ้าพลิแคททูลั่มสด (*Paspalum atratum*) และน้ำอย่างเต็มที่ และได้รับการเสริมอาหารข้นในปริมาณ 2 เปอร์เซ็นต์ของน้ำหนักตัว นาน 90 วัน จากนั้นจึงสุ่มแพะจำนวน 3 ตัว จากทุกทรีทเมนต์คอมบิเนชั่นมาทำการฆ่าเพื่อศึกษาลักษณะซากและคุณภาพเนื้อ ผลจากการศึกษาพบว่า แพะกลุ่มที่ได้รับอาหารข้นเสริมกลีเซอรีนดิบ มีเปอร์เซ็นต์เนื้อแดงและเปอร์เซ็นต์ไขมันมากกว่าแพะกลุ่มที่ได้รับอาหารข้นสูตรควบคุม ($P<0.01$) สำหรับลักษณะทางกายภาพของเนื้อสันนอก พบว่าแพะกลุ่มที่ได้รับอาหารข้นเสริมกลีเซอรีนดิบมีค่าความสว่าง (L*) น้อยกว่า แต่มีค่าความแดง (a*) มากกว่าเนื้อส่วนเดียวกันของแพะกลุ่มที่ได้รับอาหารสูตรควบคุม ($P<0.01$) สำหรับเปอร์เซ็นต์การสูญเสียน้ำขณะทำให้สุกของเนื้อสันนอกและเนื้อขาหลังส่วน *Biceps femoris* พบว่า แพะกลุ่มที่ได้รับอาหารข้นเสริมกลีเซอรีนดิบมีค่าต่ำกว่าเนื้อส่วนเดียวกันของแพะกลุ่มที่ได้รับอาหารข้นสูตรควบคุม ($P<0.05$) แต่ชนิดของอาหารข้นไม่มีผลทำให้กล้ามเนื้อทั้งสองส่วนทั้งเนื้อดิบและเนื้อสุก มีค่าแรงตัดผ่านแตกต่างกันทางสถิติ ($P>0.05$) สำหรับปัจจัยของเพศ พบว่าแพะกลุ่มที่ตอนมีเปอร์เซ็นต์ไขมันในซาก และไขมันรวมจากกล้ามเนื้อทั้งสองชนิดมากกว่าแพะกลุ่มที่ไม่ตอน ($P<0.05$) อย่างไรก็ตาม การตอนไม่มีผลต่อเปอร์เซ็นต์การสูญเสียน้ำขณะเก็บรักษา และเปอร์เซ็นต์การสูญเสียน้ำขณะทำให้สุกของกล้ามเนื้อทั้งสองชนิด ($P>0.05$) จากผลการศึกษาสรุปได้ว่า การเสริมกลีเซอรีนดิบในสูตรอาหารข้นและการตอนแพะเป็นทางเลือกในการจัดการขุน เนื่องจากแต่ละปัจจัยสามารถปรับปรุงคุณภาพซากและคุณภาพของเนื้อแพะได้

คำสำคัญ : กลีเซอรีนดิบ, การเสริมอาหารข้น, การตอน, แพะ

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Anneke

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
Introduction

1.1 Introduction

Crude glycerin is a by-product of oil processing in the biodiesel industries (Hansen *et al*., 2009; Mach*et al*.,2009; Gunn *et al*., 2010; Min *et al*., 2010; Jung and Batal, 2011; van Cleef *et al*., 2014). This by-product is a sugar alcohol which basically composed with glycerin (also known as glycerol) and varying amounts of water and other impurities such as alcohols and catalysts(Sattayasamitsathit*et* al., 2011; Settapong and Wattanachant, 2012; van Cleef *et al*., 2014). Due to its high content of energy which similar to corn (Donkin, 2008; Musselman *et al*., 2008) and wheat (Zijlstra *et al*., 2009), thus, it has a great potential to replace corn and wheat in animal diets (Zijlstra *et al*., 2009; van Cleef *et al*., 2014). However, not only used as an energy source in animal feed, crude glycerin also can be used as lubricant, fuel substitution and etc. (Gunn*et al*., 2010; Leoneti*et al*., 2012; Bartoň *et al*., 2013).

Crude glycerin has been used as a feed supplement in several animals, such as pigs(Hansen *et al*., 2009; Zijlstra *et al*., 2009), poultry(Dozier III *et* al., 2008; Lammers *et al*., 2008a; Swiatkiewicz and Koreleski, 2009; Min *et al*., 2010; Jung and Batal, 2011; Dozier III *et al*., 2011; Topal and Ozdogan, 2013; Boonwong*et al*.,2014),cattle (Donkin, 2008; Mach *et al*., 2009; El-Nor *et al*., 2010; Bartoň *et al*., 2013; Françozo *et al*., 2013; Wilbert *et al*., 2013; van Cleef *et al*., 2014), lambs (Musselman *et al*., 2008; Gunn *et al*., 2010; Lage *et al*., 2014b) and goats (Chanjula *et al*., 2015; da Rocha *et al*., 2015; Dias *et al*., 2016). However, there is least information related the used of crude glycerin supplementation in concentrate diets for fattening goat.

Although goat meat is claimed to be a healthy meat due to its less in fat content, but gamy odor is even concerned with the consumers. Meat from mature goat, particularly, tends to have a strong, unattractive flavor and odor. This odor contains with 4-methyloctanoic and 4-ethyloctanoic acids, which clearly occur in subcutaneous fat (Wong *et al*., 1975). Nevertheless, the odor could be reduced by

castration (Sugiyama *et al*., 1981; Salles *et al*., 2002; Whetstine *et al*., 2003; Kebede *et al*., 2008; McMillin, 2010; Zamiri *et al*., 2012).

Castration is a common management practice that improves meat quality (Segato *et al*., 2005; Webb*et al*., 2005; Haddad *et al*.,2006; El-Hag *et al*., 2007; Kebede *et al*., 2008). Improvement in carcass composition and meat quality was correlated with castration (Abdullah and Musallam, 2007). Meat from castrated male might contain more fat than meat from intact goat. Fat could be considerably improved tenderness and palatability of meat (Smith and Carpenter, 1976). Several methodologies were used to analyze the fat content in meat, such as analysis for fat content, marbling, intramuscular fat in live animal including biophysical method. Biophysical analysis has been done regarding fat content analysis, especially in meat. Confocal Laser Scanning Microscopy (CLSM) has been used to analysis the microstructure of meat and other food as well (Cardona *et al*., 2013).

However, there is little information available on meat quality of castrated male fattened with concentrate diet containing crude glycerin supplemented in Thailand. The objective of the study, therefore, is to investigate the effect of feeding concentrate containing crude glycerin and castration on carcass characteristics, meat compositions and quality characteristics of Thai Native x Anglo-Nubian (50:50) goat.

1.2 Review Literature

1.2.1 Role of goat in Thailand

Goats have been raised almost all part of the world. It is due to goats have great rusticity, great adaptability of varying environmental conditions and of consuming cell wall-rich plant resources, such as shrubs and trees (Williams, 2007; Stemmer *et al*., 2009; Aziz, 2010; Silva *et al*., 2014). Goat meat has gained acceptance mainly in developed countries because of the low-fat content (Peña *et al*., 2009). Its availability has been associated with religion(Nakavisut and Anothaisinthawee, 2014; Turner *et al*., 2014; Mad-Ali *et al*., 2016), especially with the Muslim majority population countries (such as Iran, Pakistan, and Indonesia) yet including countries which population do not eat beef or Buddhist or Hindu countries (such as India, Myanmar, Thailand, and Vietnam) as reported byFAO (2005 and

2010). In Thailand, goat has been one of the important domestic income animals for the farmersand predominantly used for meat production (90%) and milk production (10%) (DLD 2014).

1.2.1.1 Anglo-Nubian and its crossbred performance

Anglo-Nubian (AN) goat is named after its origin from England, a crossbred of British goats with African and Indian bucks. It is characterized by long droopy ears and a convex nose (Gurung and Solaiman, 2010; Silva *et al*., 2014). Gurung and Solaiman (2010) explained that AN goat is an all-purpose goat breed, used for meat, milk, and hide. Mia *et al*., (1994) explained that as a dairy goat, AN goat is known with high lactation length, lactation yield, milk yield per day (compared with Barbari goat and itscrossbred) especially contains high levels of fat (Gurung and Solaiman, 2010). This breed is also one of the best breed used in cross breeding to improve the meat production and have good quality in both meat and milk (Medeiros *et al*., 2012).

Gibb *et al*. (1993) compared the performance among AN, British Saanen and Boer x British Saanen crossbred goats. They found that when slaughter at 28, 33, and 38 kg of live weight, AN goat had the highest muscle weight at all slaughter weights compared with other breeds in their study. Moreover, Gibb *et al*. (1993) explained that AN breed might provide a carcass with heavier carcass weight contain a greater proportion of meat with a lower fat content than other breeds.

Ruvuna *et al*. (1992) studied the genetic effects on slaughter weight and carcass composition using sixty-seven goats consisted of AN, Toggenburg and indigenous crossbred. From this study, AN and Toggenburg goats were suggested to be one of the breed that can be used in the crossbreeding scheme for improving meat production. AN goat offered similar advantages with Toggenburg in growth and carcass characteristics in their crossbred. Moreover, in a semiarid region of Northeastern part of Brazil, Medeiros *et al*. (2012)found that AN goat was used for the crossbred purpose to improve the meat quality of indigenous goat meat (such as color, odor, flavor, juiciness). In Thailand, beside the Boer goat, Anglo-Nubian is one of the most acceptable meat goat breed that introduced to cross with indigenous goats in order to improve the meat yield.

1.2.1.2 Thai Native x Anglo-Nubian

The AN goat has been raised in many countries. In Thailand, AN is known as one of the imported breeds (the others are Boer, Saanen, Jamunapari, Kalahari Red and Black Bengal goats) that was used for crossbreeding scheme, in order to increase growth performance and economic value of indigenous breed or Thai Native (TN), due to its conformation, fertility, adaptability to tropical conditions and non-seasonal breeding (Ruvuna *et al*., 1992; Stemmer *et al*., 2009; Pralomkarn *et al*., 2011; Sanogo *et al*., 2012; Silva *et al*., 2014; Mad-Ali *et al*., 2016).

Pralomkarn *et al*. (1995), studied the crossbred of TN x AN goat (Figure 1) at the Faculty of Natural Resources, Prince of Songkla University, Southern Thailand. They found that the Anglo-Nubian goat was suitable for the crossbreeding scheme to improve the productivity of the southern Thai Native goat. This was due to the high ability of adaptation in the harsh environment of TN x AN (50:50) crossbred that could survive with the weather in Southern part of Thailand. In addition, this crossbred goat had higher multiple birth rate, body size milk yield, and better carcass yield than of TN or 25% and 75% AN crossbreds (Pralomkarn *et al*., 2011), however work from Khaokhaikaew *et al*.(2010) could not indicate any significant differences on meat and fat percentages in both TN and TN x AN (50:50) crossbred goats.

Figure1. Thai Native x Anglo-Nubian goat

In terms of nutritive value, Table 1 showed that meat from TN and TN x ANgoat contained about 78.07 to 77.48% of moisture, 20.06 to 20.54% of CP (crude protein), 0.79 to 0.76% of crude fat and 1.21 to 1.15% of ash (Anothaisinthawee *et al*., 2012). This was in agreement with the report ofSukniam*et al*.(2008) and Wattanachant*et al*.(2008)which is slightly differ from the report ofSchönfeldt *et al*. (1993) and Beserra *et al*. (2004). However, the often-quoted standard composition of normal adult mammalian muscle is 75% moisture, 19% CP, 2.5% fat and 0.6% ash (Lawrie and Ledward, 2014).

Table 1. Physical properties and chemical composition of TN goat and TN x AN goat muscle

	TN	TN x AN
Physical properties		
Cooking loss	25.61	24.45
Shear force (kg/cm^3)	3.38	3.42
Lightness (L^*)	42.39	44.29
Redness (a^*)	9.02	7.81
Yellowness (b^*)	10.08	8.99
Chemical composition		
Moisture (%)	78.07	77.48
Protein (%)	20.96	20.54
Fat (%)	0.79	0.76
Ash (%)	1.21	1.15

Source: Anothaisinthawee *et al*.(2012)

1.2.2 Crude glycerin

Crude glycerin, the main by-product from the manufacture of biodiesel (Hansen *et al*., 2009; Mach *et al*., 2009; Min *et al*., 2010; Gunn *et al*., 2010; Jung and Batal, 2011), is a colorless, odorless, hygroscopic and sweet-tasting viscous liquid (Schröder and Südekum, 1999; Donkin, 2008; Min *et al*., 2010). Crude glycerin is a 3-carbon compound (Figure 2)which can be produced from various feedstocks, such as used cooking oil, crude edible (or non-edible) oils, animal grease and biodiesel production processes (Sampattagul *et al*., 2009; Zijlstra *et al*., 2009; Dozier *et al*., 2011; Sattayasamitsathit *et al*., 2011; Settapong and Wattanachant, 2012).

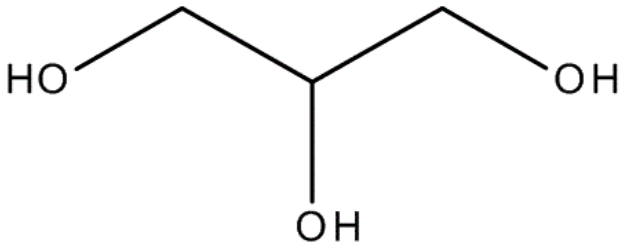

Figure 2. Chemical structure of glycerin

Source: SDA (1990)

Crude glycerin is a product of the transesterification process in the biodiesel production process. In this process (see Figure 3), oil(1) -that was extracted from feedstock- is hydrolyzed by short chain alcohol(2) (usually methanol (Min *et al*., 2010) but sometimes ethanol (Donkin, 2008)) and catalysts (sodium hydroxide; caustic soda or potassium hydroxide; potash (Donkin, 2008)); therefore it produced methyl ester(3) (biodiesel) and crude glycerin(4) (Donkin, 2008; Zijlstra *et al*., 2009; Min *et al*., 2010). A 79 g of crude glycerin may yield, while producing 1 L of biodiesel (Thompson and He, 2006) or approximately 9% of crude glycerin representing the starting feedstock weight (Dozier*et al*., 2011).

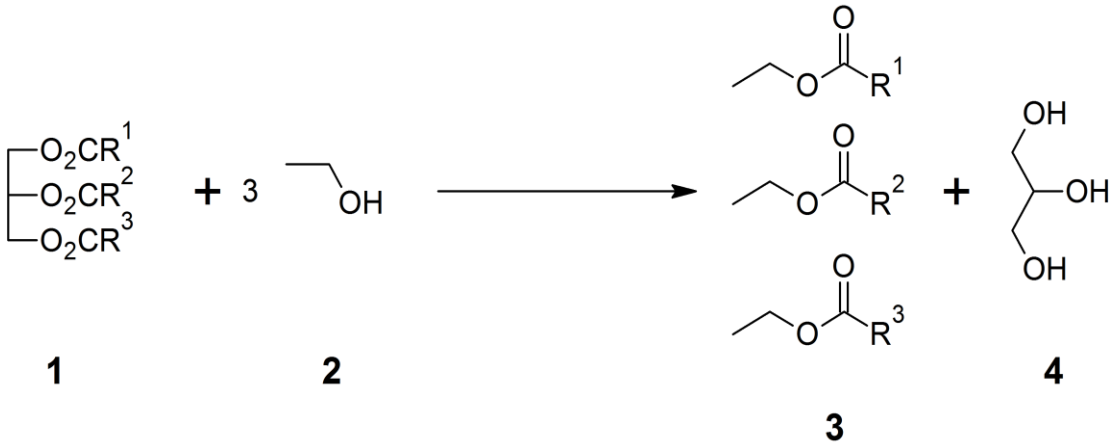

Figure 3. Biodiesel production process – transesterification process.

1. Feedstock (used cooking oil, crude edible (or non-edible) oils, animal grease); 2. Short chain alcohol (methanol or ethanol); 3. Methyl ester (biodiesel) and 4.Crude glycerin

Source: Anonymous (2015)

Thailand is one of among ASEAN countries that has biodiesel production. In this country, biodiesel production can be classified according to the production capacity into three production scales; small-scale production, medium-

scale production and large-scale production (Settapong and Wattanachant, 2012). Information from Settapong and Wattanachant (2012)revealed that a small-scale production produce approximately not more than 200 liters of crude glycerin per day whereas the medium and large production scales produce approximately 700liters and 160,000 liters of crude glycerin per day, respectively. The physical and chemical composition of the three biodiesel production scales in Thailand (Table 2).

Table 2. Physical and chemical characteristics of crude glycerin from 3 scales

Items	Biodiesel production scales		
	Small[1/]	Medium[2/]	Large[3/]
Physical characteristics			
Visual evaluation	Dark brown, high turbidity	Dark brown, high turbidity	Light yellow, transparent
Viscosity (cSt/c)	90.28	12.52	9.20
pH	8.99	6.29	6.40
Proximate composition			
Crude fat (%)	5.05	0.44	0.22
Crude protein (%)	0.65	0.85	0.48
Moisture (%)	3.93	13.85	4.27
Ash (%)	10.38	5.62	1.44
Heat of combustion (kcal/kg)	7553.61	4387.45	4650.22
Number of replication	6	6	6

[1/] Rattaphum Community's Biodiesel Plant

[2/] Specialized R and D Center for Alternative Energy from Palm Oil and Oil Crops. Faculty of Engineering, Prince of Songkla University and

[3/] New Biodiesel Co., Ltd., Suratthani

Source: Settapong and Wattanachant (2012)

In terms of physical or chemical properties, crude glycerin may contained of water, residual catalyst, salts, methanol, and fat depending on the processing technique (Thompson and He, 2006; Hansen *et al*., 2009; Settapong and Wattanachant, 2012). This impurity may cause a problem in feed supplemented with crude glycerin (Donkin, 2008; Hansen *et al*., 2009; Françozo *et al*., 2013). Salt, particularly, sodium or potassium that used as a catalyst in biodiesel production may remain substantially in crude glycerin depended on the refining process used (Hansen *et al*., 2009).Methanol, as explained byFrançozo *et al*. (2013), could not be completelyrecovered during the transesterification process. It is suggested that the

methanol content should not exceed 0.2% of crude glycerin in Germany as sited by Donkin (2008), 0.015% or 150 ppm in crude glycerin used as a feedstuff according to FDA (2015b). Methanol availability may cause toxicity effects (such as central nervous system depression, vomiting, severe metabolic acidosis, blindness and a Parkinson-like motor disease) due to the formation, accumulation and slow metabolism of formate in some species(Zijlstra *et al*., 2009; Dozier III *et al*.,2011; Jung and Batal, 2011; Françozo *et al*., 2013). In addition, Hansen *et al*. (2009) explained that there was no clinical symptom of a methanol toxicity in pigs with significant proportion of methanol evaporated from diets.

Nevertheless, crude glycerin is generally known as a safe substance in animal feed (FDA, 2015a). Crude glycerin has the potential to partially replace corn (Donkin, 2008; Musselman *et al*., 2008; Carvalho *et al*., 2014; Lage*et al*. 2014b), soybean hulls (Lage*et al*., 2014b) and wheat (Zijlstra *et al*., 2009) as a feed supplement. It contains approximately 3,000 – 6,000 kcal/kg of gross energy (Dozier *et al*.,2008; Lammers *et al*., 2008a; Lammers *et al*. 2008b; Swiatkiewicz and Koreleski, 2009; Kerr *et al*., 2011) which is potential beneficial energy source for pigs (Hansen *et al*., 2009; Zijlstra *et al*., 2009) poultry (Dozier III *et al*., 2008; Lammers *et al*., 2008a; Swiatkiewicz and Koreleski, 2009; Min *et al*., 2010; Dozier III *et al*.,2011; Jung and Batal, 2011; Boonwong*et al*.,2014); cattle(Donkin, 2008; Mach*et al*., 2009; El-Nor *et al*., 2010; Bartoň *et al*., 2013; Françozo *et al*., 2013; Wilbert *et al*., 2013; Carvalho *et al*., 2014; Lage *et al*., 2014a; van Cleef *et al*., 2014), lambs (Musselman *et al*., 2008; Gunn*et al*., 2010; Gomes *et al*., 2011; Lage*et al*., 2014b;Souza *et al*., 2015), goat (Chanjula *et al*., 2015; da Rocha *et al*., 2015; Dias *et al*., 2016) and other animal like rabbit (Iñigo *et al*., 2011).Moreover, including crude glycerin in concentrate diet effective to control dust and prevent segregation of the concentrate diet and benefit the farmer by minimize the cost of feed formulation (Donkin, 2008; Zijlstra *et al*., 2009).

1.2.2.1 Crude glycerin metabolism in non-ruminant animal

In non-ruminant animal, such as pigs and poultry, fat is hydrolyzed by pancreatic lipase to form free fatty acids and water soluble glycerol that could freely enter the portal blood. Once digested, absorbed and transferred to the liver and tissues, glycerol is converted or oxidized to glucose or energy via gluconeogenesis or

glycolysis and the citric acid cycle, respectively (Donkin, 2008; Dozier*et al*., 2008; Zijlstra *et al*., 2009; Kerr *et al*., 2011) as show in Figure 4. Supplementation of crude glycerin in diet, however, enhance the metabolism in non-ruminant animals since crude glycerin contains approximately 87.42% glycerol (Orengo *et al*., 2014) and directly convert to glucose.

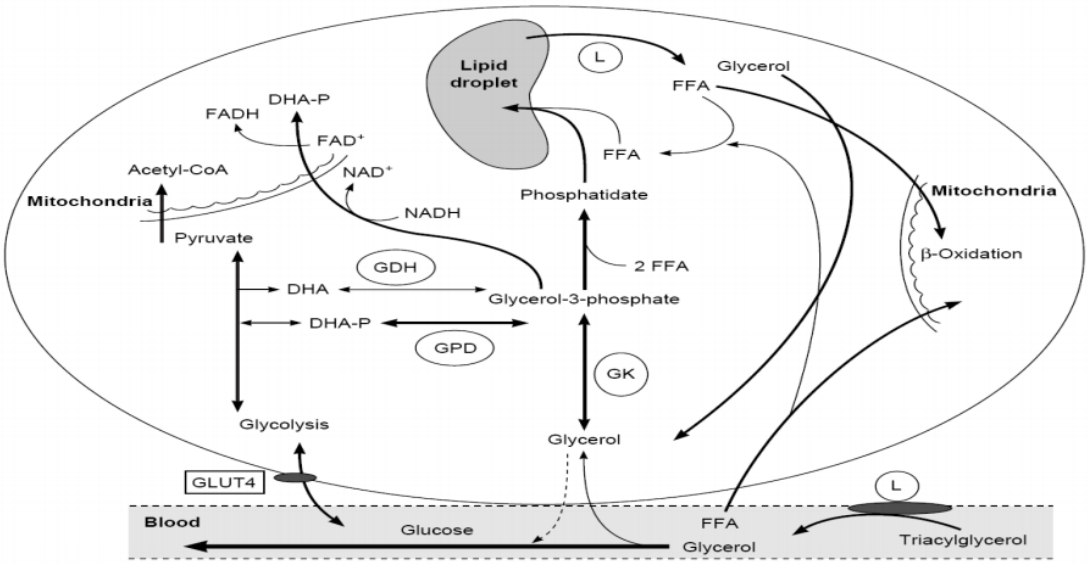

Figure 4. Biochemical reaction involved in glycerin synthesis in non-ruminant animal
Source: Kerr *et al*. (2011)

1.2.2.2 Crude glycerin metabolism in ruminant animal

In ruminant animal, crude glycerin is a gluconeogenic compound, which leads to increasing of meat marbling (Lage*et al*., 2014). Approximately 80% of crude glycerin is metabolized in rumen after 24 h intake. It is converted to propionate and acts as a precursor for hepatic glucose synthesis (Musselman *et al*. 2008; Mach, Bach, and Devant 2009; Gunn *et al*. 2010; Lage, Berchielli, *et al*. 2014). Schröder and Südekum (1999) and Drouillard (2008) have reported that including glycerin in ruminant diets both *in vitro* and *in vivo* could expense the acetate production and shift to volatile fatty acids (VFA).

Supplementing crude glycerin in ruminant animal may cause elevation of propionate,increase butyric acid (Schröder and Südekum, 1999) decreased acetate production (Lee *et al*., 2011) and also increase propionate:acetate ratio (Musselman *et al*., 2008; Françozo *et al*., 2013) in ruminal fluid. Propionate is a major precursor of

glucose synthesis in ruminants (Reshef*et al*., 1967; Hood*et al*., 1972). Propionate is known as an accelerator of metabolism of pyruvate in adipose tissue and also accelerate gluconeogenesis from lactate (by the kidney) and pyruvate (by the lactating cow) (Reshef*et al*., 1967). Acetate is one of the VFAswhich contributes 70 to 80% of the acetyl units in lipogenesis of the subcutaneous adipose tissue depotwhile intramuscular fat depots was primarily provided of 50-75% acetyl units of glucose (Gunn*et al*., 2010).

1.2.2.3 Crude glycerin effect in growth performance

In non-ruminant animals, Lammers *et al*. (2008b) included various amounts of crude glycerin in exchange of corn and sodium chloride according to NRC (1998) in 8 days post weaning pigs. The inclusion of crude glycerin did not significantly (P>0.05) affect the growth performance of the weaned pig. Final body weight and gain to feed ratio did not change with crude glycerin inclusion in diet. Average daily gain and average daily feed intake appeared to be increase with the crude glycerin inclusion. Orengo *et al*. (2014) included 0 and 10% of crude glycerin in the pig diet in trade of wheat to formulate 9,420 KJ diet. Their study reported that crude glycerin inclusion in diet did not affected (P>0.05) final body weight and gain to feed ration in pig yet crude glycerin significantly increased (P<0.05) average daily gain and average daily intake. The summary of crude glycerin inclusion effect on pig are presented in Table 3.

Table 3. Summary of growth performance of pig fed with crude glycerin inclusion

Animal	Reference	Animal age	CG* substitution	CG* amount	Growth performance
Pig	Lammers *et al*. (2008b)	8 days' post weaning	Corn and sodium chloride • Formulated to meet NRC (1998) requirement	0	[1](7.9 kg); [2](132.9 kg); [3](905 g); [4](2,333 g); [5](0.39 g/g)
				5	[1](8 kg); [2](134 kg); [3](913 g); [4](2,385 g); [5](0.38 g/g)
				10	[1](7.8 kg); [2](132.8 kg); [3](906 g); [4](2,400 g); [5](0.38 g/g)
	Orengo *et al*. (2014)	-	Wheat • Formulated to contain 9,420 kJ net energy	0	[1](54 kg); [2](103 kg); [3](0.47 kg); [4](2.32 kg);[5](0.203 kg/kg)
				10	[1](54 kg); [2](107 kg); [3](0.51 kg); [4](2.52 kg); [5](0.201 kg/kg)

*crude glycerin

[1]initial body weight; [2], final body weight; [3], average daily gain; [4], average daily feed intake; [5], gain to feed ratio

In ruminant animal, Françozo *et al*. (2013) in their experimental study about crude glycerin inclusion (0, 5 and 12% DM basis) found that crude glycerin inclusion in diet affected feedlot performance. Finalbody weight (BW) and average daily gain (ADG) and resulted higher score compared to bulls fed with no glycerin diet. Dry matter intake (DMI) and feed efficiency were not affected by the inclusion of various levels of glycerin in finishing Nellore bulls.

In goat,Chanjula*et al*. (2015) found no significant different (P>0.05) on growth performance of TN x AN goat fed with different levels (up to 20%) of crude glycerin inclusion in the diet. Thus, there was a tendency of crude glycerin inclusion on 10% level to increase weight gain as compared with goat fed with no crude glycerin. Boer goat was used by Dias *et al*. (2016) to investigate the effect of crude glycerin in goat. No significant different (P>0.05) in growth performance generated by the inclusion of crude glycerin in various levels. The summary of crude glycerin inclusion effect on sheep and goat' growth performance presented in Table 4.

1.2.2.4 Crude glycerin effect on animal products quality

To investigate milk yield, Donkin (2008)added crude glycerin in dairy cow diet as replacement of corn. The crude glycerin inclusion(in several levels at 0, 5, 10 and 15% DM) did not alter the milk production and composition of lactating dairy cows. Including crude glycerin up to 120g/kg of total DM intake in partial replacement of ground corn in the diet of Jersey cow has been done by Wilbert *et al.*(2013). The inclusion generated improvement in milk protein concentration without reducing the milk yield and milk composition produced. Whereas Paiva *et al*. (2016) in their study in mid-lactating Holstein cows suggested to include crude glycerin (contained 806g/kg glycerin obtained from ADM, Rondonopolis, Brazil) to partially replace starch in the diet not more than 140g/kg DM to avoid degradation of dairy cow performance. Feeding crude glycerin to lactating dairy cows decreased milk urea nitrogen, which is suggested to improve the use of dietary protein by rumen bacteria and reduce losses as ammonia.

In meat animals, Hansen *et al*. (2009)reported that crude glycerin could reduce drip loss and cooking loss in pig fed with 5% added glycerin in the diet. The meat quality of pigs fed with including various levels of crude glycerin showed no differences in pH, drip loss, cook loss, color and shear force. Egea *et al*. (2016) in

Table 4. Summary of growth performance of lambs and goats fed with crude glycerin inclusion

Animal	Reference	Animal information	Roughage	CG* substitution	CG* amount	Growth performance
Sheep	Musselman *et al*. (2008)	-	-	Corn	0	[1] (29.0 kg); [2] (54.83 kg); [3](0.32 kg); [5](0.12); [6](2.80 kg)
					15	[1] (28.7 kg); [2] (53.85 kg); [3](0.25 kg); [5](0.08); [6](2.92 kg)
					30	[1](29.2 kg); [2](56.40 kg); [3](0.21 kg); [5](0.08); [6](2.56 kg)
					45	[1](29.1 kg); [2](54.60 kg); [3](0.15 kg); [5](0.06); [6](2.13 kg);
	Gunn *et al*. 2010)	24 ewes 24 wethers	Ground hay	Formulated to be isonitro-genous with CP 14%	0	[1](28.9 kg); [2](54.8 kg); [3](0.273kg); [5](0.241); [6](1.13 kg)
					15	[1](28.6 kg); [2](53.8 kg); [3](0.263kg); [5](0.222); [6](1.19 kg)
					30	[1](29.2 kg); [2](56.7 kg); [3](0.220kg); [5](0.204); [6](1.08 kg)
					45	[1](29.1 kg); [2](55.5 kg); [3](0.165kg); [5](0.183); [6](0.90 kg)
	Gomes *et al*. (2011)	-	Oat hay (*Avena strigosa Schreb*)	CP 17%	0	[1](26.07 kg); [2](34.57 kg); [3](0.21 kg); [6](1.26 kg); [7](6.39)
					15	[1](26.19 kg); [2](35.65 kg); [3](0.24 kg); [6](1.30 kg); [7](5.73)
					30	[1](26.49 kg); [2](35.82 kg); [3](0.23 kg); [6](1.27 kg); [7](5.92)
Goat	Chanjula *et al*. (2015)	-		Isonitrogenous and isocaloric (DM basis) CP 15%	0	[1](17.08 kg); [2](25.20 kg); [3](0.090 kg); [5](0.137); [6](0.653 kg)
					5	[1](17.52 kg); [2](27.40 kg); [3](0.112 kg); [5](0.167); [6](0.674 kg)
					10	[1](16.76 kg); [2](27.44 kg); [3](0.120 kg); [5](0.164); [6](0.738 kg)
					20	[1](16.76 kg); [2](26.96 kg); [3](0.112 kg); [5](0.172); [6](0.654 kg)
	Dias *et al*. (2016)	8 months' old	Tifton-85 hay	Isoproteic and isoenergetic according to	0	[1](23.97 kg); [2](34.73 kg); [3](0.161 kg), [6](0.832 kg)
					5	[1](24.56 kg); [2](35.20 kg); [3](0.168 kg), [6](0.899 kg)
					10	[1](25.50 kg); [2](35.01 kg); [3](0.165 kg), [6](0.806 kg)
					20	[1](25.98 kg); [2](33.27 kg); [3](0.136 kg), [6](0.734 kg)

*, Crude glycerin

[1], Initial body weight; [2], final body weight; [3], average daily gain; [4], average daily feed intake; [5], gain to feed ratio; [6], daily dry matter intake; [7], feed conversion ratio.

their investigation of crude glycerin effect reported significant reduction of pork cooking loss in animals fed 10% crude glycerin inclusion, it also did not differ the chemical composition of the muscle.Françozo *et al*. (2013)included crude glycerin up

to 12% to investigate significant difference in meat quality. The elevation of crude glycerin inclusion up to 12% increased the total lipid of its *Longissimus*muscle. Although it has been reported (Mache*t al.*,2009; Françozo *et al*., 2013; Lage *et al*., 2014a; Lage*et al.*, 2014b) unable to affect the shear force of muscle in various levels of inclusion.

In the study with lamb, Musselman *et al*. (2008) stated that glycerin (90% purity) could be added to finishing lamb diet up to 15% (as corn substitution) without differing the feedlot performance and carcass composition. Their study resulted the highest dressing percentage, back fat thickness, and yield grade compared with the other diet treatments (30% and 45% crude glycerin substitution to corn).

In the practice on goat, Chanjula*et al.*(2015) included crude glycerin (in 0, 5, 10 and 20%) to the isonitrogenous and isocaloric diet. No significant effect was reported on carcass performance and chemical composition of *Longissimus dorsi* muscle. da Rocha *et al*.(2015) reported no significant different in chemical composition of crossbred Boer goat fed with different levels of crude glycerin inclusion (1, 40, 80 and 120 g/kgDM basis diet). Low toughness point yielded from the group fed with 40g/kg of crude glycerin. Dias *et al.*(2016) used crude glycerin in four different levels (0, 5, 10 and 15%) in replacing corn. The crude glycerin inclusion resulted not significant different ($P>0.05$) on carcass performance of Boer crossbred goat. Their research resulted an insignificant improvement to the goat fed with 5 and 10% crude glycerin but when included up to 15%, the warm carcass weight, chilled carcass weight and other parts weight decreased and yielded the lowest score compared with other groups.

1.2.3 Castration

Castration is one of the farm management practice which performs a removal or destruction of the testes, epididymis and a portion of each spermatic cord from a male animal.Castration involves cutting blood supply to the testes either by crushing the blood vessels, cutting, vaccinating and/or elevating temperature of the testes (Nsoso *et al*., 2004). Castration is mainly performed for its benefit in farm management, especially meat quality improvement.

The benefits of castration, in details, are to prevent inbreeding that can result in genetic defects, poor growth rate, and other problems; to avoid unwanted pregnancies and mating of young female before they are on adequate size and age for pregnancies and parturition; to enhance on-farm safety for animal (castrated animals are usually less aggressive and easier to manage); to reduce the odor problem (Webb *et al*., 2005; Zamiri *et al*., 2012); and improve carcass composition and better quality of meat compared with intact especially the marbling(Nsoso *et al*., 2004; Kebede *et al*., 2008; Coetzee *et al*., 2010).

1.2.3.1 Castration methods

There are several methods of castration; it is categorized as: (1) Physical, such as: surgical castration (spermatic cords torn; spermatic cords clamped and cut, with or without cautery), clamp castration (on each spermatic cord, using Burdizzo clamp see Figure5), ring castration (ring proximal to testes; normal ring, tight ring), ring + clamp castration (each spermatic cord clamped, full-width of scrotum clamped) and short scrotum castration (ring distal to the testes) and (2) Chemical (hormonal) (Molony *et al*., 1993; Mellor and Stafford, 2000; Nsoso *et al*., 2004; Stafford and Mellor, 2005; Coetzee *et al*., 2010; McMillin, 2010; Zamiri *et al*., 2012). Moreover, all the physical castration methods have negative side-effects as mentioned byStafford and Mellor (2005)which indicated excessive swelling with or without infection, edema or tetanus may occur after surgical, clamp, or rubber-ring castration.

The clamp castration is usually performed with a Burdizzo clamp. In clamp castration, Mellor and Stafford (2000) explained that the spermatic cords (Figure of Burdizzo castration technique available on Figure 6) are crushed through the scrotum. The clamp is applied to each cord once or twice while ensuring that medial scrotal tissues are uncrushed. Crushing the blood vessels of cords prevents blood flow to the testes which atrophy during the following 4 to 6 weeks.

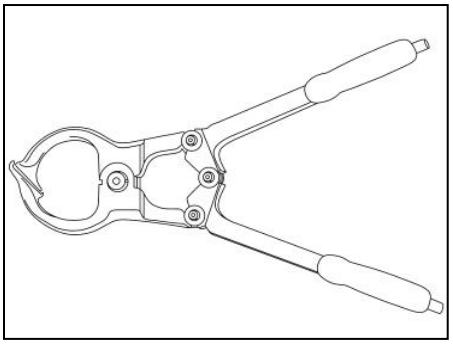

Figure 5. Nonsurgical castration equipment - Burdizzo clamp

Source: Grandin (2010)

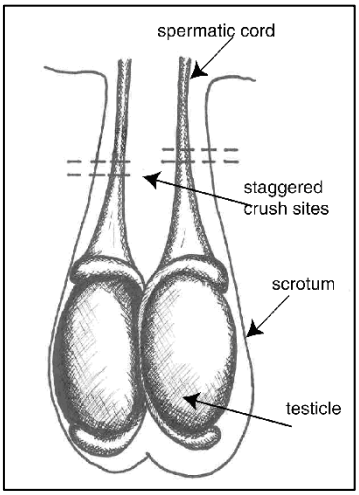

Figure 6. Burdizzo castration technique

Source: Anonymous(2016)

Aside from the technical methods of castration,Molony *et al*. (1993) suggested to consider about the time of castration. Kebede *et al*. (2008) and Zamiri *et al*. 2012)stated that castration could be performed as early as possible (at birth, one week of age, at 1.5 months of age, or between 3 and 5 months of age) or advisable to wait until goat reaches puberty (3-7 months of age) prior to the castration (Leite-Browning, 2009; McMillin, 2010). Moreover, Mellor and Stafford (2000) suggested that, it is better to castrate animals before the odor was produced. However, once a goat gets to their puberty, the mature male releases a specific odor from its hair, mainly in the head and neck during the breeding season. This odor is male-specific and may be an attractant to the opposite sex (Sugiyama *et al*., 1981).

1.2.3.2 Castration effect on hormone alteration and fat deposition

As an intact male becomes sexually mature or hit the puberty, the animal starts showing the male-specific sexual behavior, such as secreting a male specific odor or unpleasant taint (Squires, 2003). The taint is a chemical signal which induces various specifics reproductions stages, derived from urine or from anal and genital sebaceous gland secretions (Kelliher *et al*., 1998; Wakabayashi *et al*., 2000) and may be an attractant to the opposite sex (Sugiyama *et al*., 1986). However, goat castrated before puberty will not indicate any male-specific sexual behavior and it will gradually diminish when goat castrated after reaching puberty (Sariubang and Qomariyah, 2014).

Castration, which evolves the damage to spermatic cord and blood vessels to testes, leads to lack of blood supply to the testes. The lack of blood supply cause discontinuation of testosterone production, spermatogenesis and male-specific sexual behavior production. Castration also cause gonadotropin to accumulate in pars distalis hypophysis and cause basophil cells become castration cells. Regarding fat deposition, the absence or lack of testosterone may associate with the insulin resistance(Kelly and Jones 2013). Insulin is a hormone which control the regulation of blood glucose level and involved the storage of fat (Anonymous, 2017). The insulin resistance caused an increase of glycose storage which deposited in adipose tissue (Figure 7).

1.2.3.3 Castration on growth performance

Castration, however, did not significantly affect initial live (body) weights and the average daily gain (ADG) of Iranian goat in previous study which had done by Zamiri *et al*. (2012). The investigation of castration effect on Iranian goat feedlot performance(Table 5) revealeda significantly difference between the castrated and the intact goats. Body weight and ADG of castrated male was significantly lower compared with intact goat. McMillin (2010) stated that castration methods could reduce the growth rate, increase the potential of urinary calculi, and lead to complication risks include tetanus, damage of the penis, swelling, and failure of the testicle and scrotum to atrophy and slough.The reduction of growth rate was attributable to the lack of testosterone, which is considered as a growthpromoter and responsible for distinguishingcharacteristics of the masculine body.

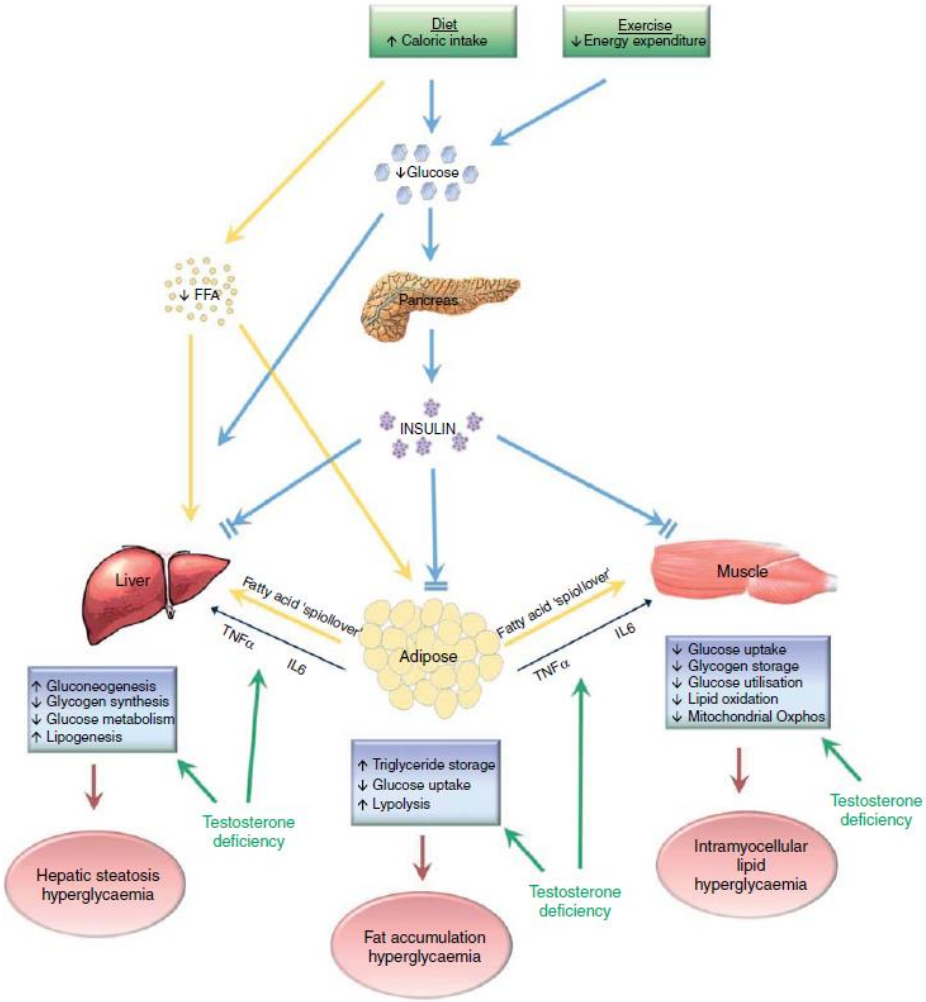

Figure 7. Insulin key roles in glucose metabolism and fat storage

Source: Kelly and Jones (2013)

Kebede *et al*. (2008) reported that castration in Arsi-Bale goats was suitable for increasing fat distribution for fattening or gaining body weight of goats. Similar work was reported by El-Waziry *et al*. (2011) who applied elastrator ring castration to male Ardhi goat kids foundhigher separable fat percentage and higher fat thickness of castrated male Ardi kids compared to the intact male kids. However, no significant effects on growth performance, body weight, total gain, and overall average daily gain were illustrated from those castrated or intact male goats. Castration also increased fat thickness the loin muscle of goats including lambs as compared to the intact males (Madruga *et al*., 2001; Amatayakul-Chantler *et al*.,2013; Dnekeshev and Kereyev, 2013; Guatteo and Guémené, 2014), although no significant effect was indicated in depth and width of loin muscle (Haddad *et al*., 2006). In

addition, higher total fat content and more subcutaneous fat were found in castrated male goats Madruga *et al*., 2001).

Table 5. The mean effect of sex (intact vs. castrated) and duration (months) of fattening period on feedlot performance of goat kids

Characteristic	Sex	Duration of fattening period (and age of slaughter)					
		1 (5 m.o.)	2 (6 m.o.)	3 (7 m.o.)	4 (8 m.o.)	5 (9 m.o.)	6 (10 m.o.)
Body weight (kg)	Intact	23.1 ± 2.2^{Da}	26.9 ± 1.9^{Ca}	28.2 ± 1.9^{Ca}	30.5 ± 3.2^{Ba}	33.1 ± 3.8^{Aa}	34.8 ± 4.5^{Aa}
	Castrate	20.9 ± 2.3^{Db}	24.7 ± 2.3^{Cb}	27.0 ± 3.5^{Cb}	28.8 ± 3.9^{Bb}	31.2 ± 5.7^{Ab}	32.7 ± 6.7^{Ab}
ADG (g)	Intact	149 ± 53^{Aa}	127 ± 26^{Aa}	45 ± 5^{Cb}	74 ± 48^{BCa}	89 ± 36^{Ba}	56 ± 39^{Ba}
	Castrate	105 ± 56^{Ba}	127 ± 37^{Aa}	75 ± 59^{Ca}	62 ± 36^{Ba}	77 ± 36^{Ca}	51 ± 33^{Ba}
Daily feed intake (g)	Intact	1086 ± 233^{Aa}	1027 ± 139^{Aa}	653 ± 190^{Ca}	804 ± 169^{Ba}	873 ± 139^{Ba}	633 ± 140^{Ba}
	Castrate	911 ± 193^{Ba}	1011 ± 124^{Aa}	710 ± 195^{Ca}	719 ± 152^{Ca}	752 ± 16^{Ca}	607 ± 165^{BCa}
FCR	Intact	7.3 ± 3.4^{Ca}	8.1 ± 2.6^{Ca}	14.5 ± 5.4^{Aa}	10.9 ± 4.2^{Ba}	9.8 ± 1.8^{Ba}	11.3 ± 4.8^{Ba}
	Castrate	8.7 ± 4.5^{Ca}	8.0 ± 2.7^{Ca}	9.5 ± 3.1^{Bb}	11.6 ± 3.7^{Aa}	9.8 ± 3.6^{Ba}	11.9 ± 3.9^{Ba}

A, B: within each row, differing superscripts indicate significant differences between fattening duration (P<0.05). a, b: within each column, differing superscripts indicate significant difference between sex (P<0.05).

Source: Zamiri *et al.* (2012)

1.2.3.4 Castration on meat quality

Castration has been reported to improve meat juiciness and tenderness scores and resulted in a relatively higher flavor score (El-Hag *et al*., 2007; Zamiri *et al*., 2012). Meat from castrates achieved significantly higher scores for juiciness and tenderness than meat from intact males, goat castrated at kid had higher juiciness and tenderness score than goat castrated at older age (Table 6). Some meat quality attributes (e.g. muscle tenderness) changed with castration (Pratiwi *et al*., 2007). The lack of the anabolic effects of testosterone in castrated animals is considered as metabolic condition that reduces muscle collagen deposition, even if its solubility could be also reduced and meat tenderness could be not influenced (Segato *et al.*, 2005).

Table 6. Acceptability of consumption intent and preferences for castrated and intact goats

Attribute	Castrated kid	Castrated goat	Intact goats
Colour before cooking	-	2.82^{2}	2.52^{2}
Acceptability of aroma^{x}	3.92^{1}	3.86^{1}	1.85^{2}
Acceptability of tenderness^{x}	4.06^{1}	3.80^{1}	2.19^{2}
Acceptability of flavour^{x}	4.22^{1}	4.02^{1}	2.01^{2}

[x] Hedonic scores ranged from 5 (extremely acceptable) to 1 (extremely unacceptable).
Source:[1]Webb*et al.* (2005)and [2]Zamiri*et al.* (2012)

Early castration as explained byHaddad*et al*. (2006) and Kebede *et al*.(2008) can improve carcass quality, especially on marbling degreeand remove undesirable odor. Webb *et al*.(2005) and El-Hag *et al*.(2007) reported that castration affected the aroma and the flavor of goat meat. Castration, moreover, improved meat juiciness and tenderness (tenderness is one of the meat quality attributes that could be changed with castration (Pratiwi *et al*., 2006)) scores and resulted in a relatively higher flavor score(El-Hag *et al*., 2007; Zamiri *et al*., 2012). Early castration on goats could lead to higher values of aroma and flavor which means high acceptance value. The higher aroma and flavor score, the higher acceptability of the meat. Meat from castrates achieved significantly higher scores for juiciness and tenderness than meat from intact males. Segato *et al.*(2005), Pratiwi *et al.*(2006) and El-Hag *et al.*(2007) reported that tenderness was improved by the castration treatment in their study.

1.3 Objectives

1. To investigate the effects of feeding concentrate containing crude glycerin on carcass characteristics and meat quality of TN x AN goat.
2. To investigate the effects of castration on carcass characteristics and meat quality of TN x AN goat.
3. To study the effect of interaction between crude glycerin supplementation and castration on carcass characteristics and meat quality of TN x AN goat.

CHAPTERII

Materials and Methods

2.1 Experimental site

The study was conducted at the Small Ruminant Research and Development Center (SRRDC) Khlong Hoi Kong, Animal Science Department, Faculty of Natural Resources, Prince of Songkla University. Itis locatedat 7^{o} N, 100^{o} 30' E. The region has an annual rainfallof 1,120-2,800 mm with a dry period extending frommid-January to March/May with marked increases inrainfall in May/June and October/November. The areais 20 m above sea level with temperatures of 20-35^{o}C,relative humidity of 63-88% and has 50 min differencein daylength between solstices.

2.2 Animals and their management

Twenty crossbred Thai Native x Anglo-Nubian(TN x AN)malegoatswere used, with average 19.32 ± 2.48 kg body weight and aged of 10 months.The goats were given Ivermectin (Iversat$^{@}$, L.B.S. Laboratory LTD., PART., Thailand)with 1cc/50kg dosage and Abendazole (ABENTEL$^{@}$, Atlantic Labratories Corp. LTD. Thailand) with 1cc/20kg dosage (to control the internal and external parasites) and vitamin A, D_3, E (Phenix, PhenixPharmaceuticals N. V., Belgium) with 1cc/10 kg dosage.

Ten goats then were randomly selected and were castrated using Burdizzo clamp. After castration, they were raised separately from the intact ones. However, both groups receivedfresh Atratum grass(*Paspalum atratum*) and supplemented with 1.5% DM concentrates diet during approximately 2 months of adjusting period (recovering time from the castration).The experiment lasted 90days and the goats were kept in individual cages (the cages environment can be found in Appendices 2.1.1).

2.3 Experimental design

After two months of adjusting period, goats were at 24.75 ± 1.33 kg average body weight and assigned to 2 x 2 factorial arrangement in a complete randomized design. Factors were sex (intact and castrated male goats) and type of

concentrate diet (control concentrate diet and concentrate diet supplement with 10% of crude glycerin), with five replicates per treatment.

2.3.1 Dietary Treatment

Table 7 showed the percentage of the ingredients of the concentrate. The concentrate (Appendices 1. 1. 4.) consistedof Soybean meal 12%, palm kernel cake 26%, ground corn 54.3%, minerals 4.7% (di-calcium phosphate 1.2%, shell flour 25 and salt 1.5%) and vegetable oil 3% while experimental concentrate was the concentrate diet supplemented with 10% crude glycerin. The crude glycerin was obtained from New Biodiesel Ltd. Co., Suratthani province. The goats were fed two times daily (8:00 am and 4:00 pm.) with *ad-libitum*Atratum grass and supplemented with 2% DM concentrates diet(NRC, 1981).

Table 7. Percentage of ingredients and nutrient composition of concentrate (%DM)

Items	Concentrate	
	Control	Experiment
Soybean meal	12	12
Palm kernel cake	26	26
Ground corn	54.3	54.3
Crude glycerin	0	10
Di-Calcium Phosphate	1.2	1.2
Shell flour	2	2
Salt	1.5	1.5
Vegetable oil	3	3
Total	100	110
Nutrient composition		
CP	16.43	16.44
TDN	80.24	88.00

CP: crude protein; TDN: Total Digestible Nutrient

2.4 Slaughtering

After 90 days of experimental diet, goats were fasted with free access to water and then transported to the Meat Lab. of Faculty of Natural Resources to be slaughtered (goats condition could be seen in Appendices 2.1.3). Goats were slaughtered according to Thai Agricultural Standard in Halal Food 8400-2007 and Good Manufacturing Practice (GMP) 9040-2013 for goat and sheep abattoir based on Islamic procedures (ACFS, 2007; ACFS, 2013). It is performed by severing jugular vessels, esophagus and trachea without stunning. The dressed carcass comprised the

body after removing skin, head, fore feet, hind fed and the visceral. Lung, heart, liver, spleen, kidney, kidney and pelvic fat, testes and scrotal fat were also removed.

2.5 Carcass characteristics

2.5.1 Carcass profile

Criteria included in carcass profile were slaughter weight, carcass weight and percentage, carcass length, carcass width, carcass thickness, loin muscle area, back fat thickness, meat, fat, bone and connective tissue percentage and the ratio of meat to fat and meat to bone.Warm carcass weight (WCW) was determined and recorded after the skinning and evisceration of between 30 to 45 minutes' postmortem. Chilled carcass weight (CCW) was recorded after overnight (24h) chillingin 4^{o}C andcarcass percentage (for warm and chilled carcass)was determinedas the ratio of carcass weight to slaughter weight). Carcass length was measured from the point of the hock to the point of shoulder, carcass width was measured from widest carcass measurement at ribs while carcass thickness was measured on 5 inch from the ventral edge of m. *Longissimus*.Loin muscle (LM) area section from ribbed section between 12th and 13thribs were drawn on tracing paper and then measured using Placom KP90 Digital Planimeter, Japan (Figure 8).Back fat thickness was measure from the subcutaneous fat of the loin muscle 12th and 13th ribs. Influence

Figure 8. Digital Planimeter - Placom KP90, Japan.

2.5.2 pH

Carcass pH data were collected during warmandchilled carcass weight measurement. The pH was measured for pH_0 and pH_uusing a Mettler Toledo pH meter AG CH 8630 with Lot 406-M6DXK-S7/25 probe,Schwerzenbach, Switzerland (Figure 9). A 2 g of goat meat (taken from the loin muscle between 12th and 13th ribs) was minced and dissolved in 10 ml of distilled water and the probe was inserted into

the mixture to analyze both pH_0 (45 minutes post-slaughter) and pH_u (after 24 h chilling in 4^oC). Calibration buffer pH 4 and pH 7 also distilled water were applied tocalibrate and clean the probe, respectively, prior to analyze other samples.

Figure 9. Mettler Toledo pH meter AG CH 8630 equipped with Lot 406-M6DXK-S7/25 probe (Schwerzenbach, Switzerland).

2.5.3 Color

Muscle colors were evaluated during the dissection of the carcasses. Carcasses were left in room temperature for an hour to allow to contact with oxygen. Color was determined by the L^*(lightness), a^* (redness) and b^*(yellowness) of CIE system (CIE, 1978) using a CR-10 Chromo meter (Minolta Color Meter, Osaka, Japan) as shown at Figure 10. White standard was used for standardizing prior to the determination. L^*, a^* and b^* were shown in the monitor and color value were calculated by the mean value of three color determinations. Carcasses were then dissected according to (ACFS, 2008).

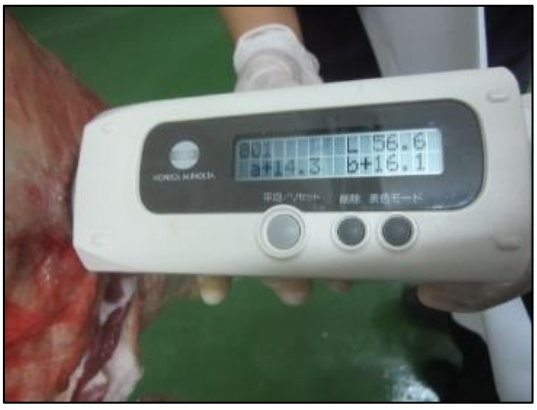

Figure 10. CR-10 Chromo meter (Minolta Color Meter, Osaka, Japan).

2.6 Meat quality characteristics

Muscle samples, dissected from *Longissimus dorsi* and *Biceps femoris* muscle were analyzed for meat composition and quality characteristics with three replications.

2.6.1 Physical characteristics of muscles

2.6.1.1 Drip loss

Drip loss were determined according to the method ofWattanachant (2004). Small pieces of two different muscles (3 x 1.5 x 1 cm dimension) were blotted with paper towels, weighed (as weight 1/dw1), put in the sealed plastic bag for drip loss and cooking loss analysis (Appendices 1. 3). The drip loss samples were then kept in the 4^{o}C for 24 h. After 24h samples were removed from the plastics bag, blotted again with paper towels and reweighed (as weight 2/dw2). Drip loss score was calculated from the difference of the weight.

$$Drip\ loss = \frac{dw1 - dw2}{dw1}\ x\ 100\%$$

2.6.1.2 Cooking loss

Cooking loss was determined according to the method of Wattanachant (2004). Small pieces of two different muscles (3 x 1.5 x 1 cm dimension) were blotted with paper towels, weighed (as weight 1/cw1), put in the sealed plastic bag prior to cooking loss determination. Cookingloss samples were cooked in water bath at 80^{o}C for 10 min. Samples were then cooled to room temperature under running water, removed from the plastic bag and blotted with a towel paper and weighed (cw2). Cooking loss score was calculated from the difference of the weight.

$$Cooking\ loss = \frac{cw1 - cw2}{cw1}\ x\ 100\%$$

2.6.1.3 Shear force (Warner-Bratzler Shear Force)

Shear force was determined on raw and cooked muscle samples following the method of Wattanachant (2004) with slight modification. The samples were prepared from the drip loss and cooking loss samples and analyzed using a Texture Analyzer (TA-XT plus Stable Micro System Texture Analyzer, UK)

equipped with a Warner-Bratzler apparatus (Figure 11) on speed of 2 mm/s and a 50kg load cell with three replications each type of muscle.

Figure 11. Texture Analyzer equipped with a Warner-Bratzler apparatus
(a) Warner Bratzler blade (b) TA-XT plus Stable Micro System Texture Analyzer, UK and (c) Texture analyzer set.

2.6.2 Chemical composition of muscles

The chemical composition of muscle samples ware measured for moisture, protein, lipid and ash according to AOAC (2000) (supported pictures are available in Appendices 1. 3). Samples were collected from both *Longissimus dorsi* and *Biceps femoris* muscle. Muscles were trimmed from the intermuscular fat and excess flesh prior to chemical composition analysis.

2.6.3 Fat distribution in loin muscle (Confocal Laser Scanning Microscope)

Fat distributions in loin muscle fat distribution were determined using Confocal Laser Scanning Microscope (CLSM) (Model FV300; Olympus, Tokyo, Japan) equipped with IX70 Olympus Microscope (Tokyo, Japan) as shown in Figure 12.*Longissimus dorsi* samples in 2 x 2 x 2 mm dimension were soaked in Nile Blue A 0.01% solution for 5-10 min. Samples were rinsed with distilled water and then put on a microscope slide, covered with cover slip and observed under CLSM operated in fluorescence mode with 533 nm excitation wavelength and 400x magnification(Putra, 2016).

Figure 12. Confocal Laser Scanning Microscope (Model FV300 equipped with IX-70 Microscope, Olympus, Tokyo, Japan).

2.7 Statistical data analysis

The effect of sex and type of concentrate were analyzed by Analysis of Variance (ANOVA) according to Walpole (1997). $P<0.05$ was considered as significant different and Duncan's new multiple range test was used to compared the mean differences. Moreover, two-tailed Pearson Correlation was used to determine the correlation between fat deposition in carcass and m. *longissimus dorsi* fat content.

CHAPTER III

Results

3.1 Carcass characteristics

The effect of feeding concentrate containing crude glycerin and castration on carcass characteristics of Thai Native x Anglo-Nubian goats is presented in Table 8 and 9.

3.1.1 Carcass profile

The effect of feeding concentrate containing crude glycerin and castration on initial weight, final weight, slaughter weight, WCW, CCW, carcass (warm and chilled) dressing percentage, back fat thickness, loin muscle (LM) area, percentage of meat, fat bone and connective tissue, ratio of meat to fat, and meat to bone were presented in Table 8.

The results of the study indicated that goats fed concentrate with 10% of crude glycerin supplementation had significantly higher final weight, slaughter weight, warm and chilled carcass weight, and fat percentages ($P<0.01$), but had significantly lower meat and bone percentages, including meat to fat ratio than those received the control diet($P<0.01$). No significant difference on warm and chilled carcass percentages, length, width and thickness of carcass, LM area, and back fat thickness were found ($P>0.05$), although it tended to be higher for goats received concentrate with 10% of crude glycerin supplementation than those received control diet. Results from this study confirmed that supplementing concentrate diet with 10% of crude glycerin could improve carcass profile of goat, although dressing percentage (in both warm and chilled carcass percentage) was not clearly affected ($P>0.05$) on the carcass measurements (carcass length, width, thickness and loin area).

The results also showed that castration could improve the carcass traits of the male goats, particularly final weight, slaughter weight, warm and chilled carcass weight, LM area, and fat percentage when compared with intact males ($P<0.01$). Castrated male goats tended to have thicker carcass and back fat thickness than those of the intact male goats ($P>0.05$). However, castrated male goats had significantly lower meat and bone percentages, and meat to fat ratio than the intact

Table 8. Effect of concentrate and sex on live weight, carcass weight, dressing percentage, and other carcass profiles of TN x AN goats

Carcass profiles	Diet		Sex		Treatment combination				*P-value*		
	Control	Supplemented	Intact	Castrated	TC1[1]	TC2[1]	TC3[1]	TC4[1]	Diet	*Sex*	Combination
Initial weight, kg	25.21 ± 1.27	24.46 ± 1.57	26.19 ± 1.35	25.43 ± 1.63	25.73 ± 1.69	26.88 ± 0.11	24.68 ± 0.59	26.18 ± 2.16	0.193	0.374	0.851
Final weight, kg	35.51 ± 1.84	38.14 ± 1.09	35.26 ± 1.76	37.91 ± 1.35	34.13 ±1.18	36.95 ± 0.14	36.83 ± 1.19	38.93 ± 0.08	0.003	0.004	0.508
Slaughter weight, kg	34.39 ± 2.07	37.00 ± 1.16	33.95 ± 1.92	36.93 ± 1.13	32.68±1.15	35.85±0.35	36.10±0.83	37.77±0.65	0.002	0.001	0.190
Warm carcass weight, kg	16.20 ± 0.68	18.08 ± 0.48	16.45 ± 1.17	17.56 ± 0.91	15.62±0.32	17.71±0.18	16.78±0.24	18.33±0.45	0.000	0.003	0.226
Chilled carcass weight, kg	15.64 ± 0.69	17.38 ± 0.47	15.88 ± 1.16	16.89 ± 0.81	15.05±0.30	17.13±0.18	16.23±0.23	17.54±0.57	0.000	0.010	0.135
%Warm carcass	47.16 ± 1.80	48.88 ± 0.92	48.46 ± 2.06	47.51 ± 1.27	47.84±2.56	49.39±1.00	46.48±0.41	48.54±0.87	0.091	0.272	0.787
%chilled carcass	45.54 ± 1.68	46.98 ± 1.28	46.77 ± 2.01	45.72 ± 1.19	46.11±2.43	47.78±0.97	44.98±0.41	46.45±1.32	0.139	0.235	0.922
Carcass length, cm	63.42 ± 1.77	65.00 ± 1.46	63.60 ± 1.64	64.58 ± 1.88	63.00±1.32	64.50±2.12	63.83±2.36	65.33±1.26	0.213	0.471	1.000
Carcass width, cm	26.75 ± 1.21	27.10 ± 0.55	27.10 ± 0.82	26.75 ± 1.08	27.17±1.04	27.00±0.71	26.33±1.44	27.17±0.58	0.615	0.615	0.456
Carcass thickness, cm	1.20 ± 0.26	1.30 ± 0.37	1.06 ± 0.19	1.40 ± 0.30	1.10±0.26	1.00±0.00	1.30±0.26	1.50±0.36	0.777	0.079	0.407
Loin muscle area, cm^2	11.02 ± 0.47	11.21 ± 0.59	10.75 ± 0.21	11.70 ± 0.24	10.72 ± 0.12	10.78 ± 0.30	11.63 ± 0.11	11.75 ± 0.31	0.439	0.000	0.817
Back fat thickness, mm	1.15 ± 0.20	1.20 ± 0.45	1.04 ± 0.09	1.28 ± 0.40	1.07 ± 0.11	1.00 ± 0.00	1.23 ± 0.25	1.33 ± 0.58	0.939	0.272	0.703
%Meat	60.20 ± 4.23	57.32 ± 1.55	61.98 ± 2.88	56.31 ± 0.36	64.03±0.60[c]	58.92±1.05[b]	56.36±0.53[a]	56.26±0.21[a]	0.000	0.000	0.000
%Fat	13.80 ± 6.07	17.84 ± 4.98	9.95 ± 2.49	20.37 ± 1.19	8.27±0.55	12.48±1.75	19.33±0.47	21.42±0.17	0.000	0.000	0.060
%Bone	20.57 ± 1.51	19.94 ± 2.90	22.36 ± 0.66	18.56 ± 1.00	21.90±0.23[c]	23.04±0.25[c]	19.24±0.62[b]	17.87±0.85[a]	0.754	0.000	0.010
%Connective tissue	5.44 ± 0.78	4.92 ± 1.03	5.72 ± 0.30	4.77 ± 1.02	5.81±0.20	5.59±0.47	5.07±1.03	4.47±1.13	0.453	0.114	0.728
Meat/fat ratio	5.34 ± 2.68	3.49 ± 1.23	6.57 ± 1.73	2.77 ± 0.17	7.77±0.55[c]	4.77±0.75[b]	2.92±0.91[a]	2.63±0.01[a]	0.000	0.000	0.001
Meat/bone ratio	2.98 ± 0.59	2.76 ± 0.49	2.97 ± 0.69	2.80 ± 0.41	3.36±0.61	2.40±0.24	2.61±0.26	2.99±0.49	0.333	0.792	0.045

[1] TC1, Control group;TC2, Intact group fed with 10% crude glycerin supplementation;TC3, Castrated group fed with control diet and TC4, Castrated group fed with 10% crude glycerin supplementation.

[a-c] means with different superscript within the same row indicated significantly different (P<0.05).

male goats (P<0.01) whereas no significantly effect on the carcass percentages, connective tissue percentage, carcass length and width, and meat to bone ratio were found in either intact or castrated male goats (P>0.05).

Furthermore, an interaction between castration and types of concentrate diet on meat and bone percentages, and meat to fat ratio were observed (P<0.01). In terms of meat percentage, this study showed that TC1 (intact male group and fed control concentrate diet) had the highest meat percentage (64.03%) followed by TC2 (intact male group and fed concentrate diet with 10% crude glycerin inclusion, 58.92%) TC3 (castrated male group and fed control concentrate diet, 56.36%) and TC4 (castrated male group and fed concentrate diet with 10% crude glycerin inclusion, 56.26%). Both TC1 and TC2 had higher bone percentage (21.90% and 23.04%) followed by TC3 (19.24%) and TC4 (17.87%), respectively. In accordance with meat percentage, TC1 had the highest meat to fat ratio (7.77) followed by TC2 (4.77), TC3 (2.92) and TC4 (2.63).

3.1.2 pH

pH data generated from this study was illustrated in Table 9.The pH_0 of the treatments from the study were 6.46, 6.61, 6.05 and 6.05 while pH_u was 6.00, 6.39, 5.71 and 5,72 for TC1, TC2, TC3 and TC4group respectively.Crude glycerin supplementation in concentrate diet did not affect the pH_0 of TN x AN goat carcass (P>0.05). However, significant higher pH_u was found in TN x AN goat fed concentrate diet with crude glycerin supplementation compared with goat fed with concentrate control diet.

Castrationsignificantly affected (P<0.01) both $pH_0$and $pH_u$of TN x AN goat. Castrated male generated lower pH_0 than intact goat while crude glycerin supplementation did not statistically affect the pH_0 of TN x AN goat. However, goat fed control diet and 10% crude glycerin supplementation did not show any significant difference (P>0.05) in pH_0.Moreover,castrated male goatstended to have lower pH_u compared with intact goat. The interaction between each treatment factors generated significant effect (P<0.01) on pH_u(Table 9). TC2 had the highest pH_uvalue (6.39 ± 0.01), TC2 was intact group fed with 10% crude glycerin supplementation. TC1

(intact group fed with control diet) had 6.00 pH_u and TC3 and TC4 were groups with lower pH_uvalue.

3.1.3 Color

The CIE color values of loin muscle and back fat weredetermined after 24 h post-mortem time, presented in Table 9. The back fat color referred to the color of the subcutaneous fat, which covered the loin muscle area, whereas the meat color referred to *Longissimus dorsi* muscle color.

3.1.3.1 Loin muscle color

The lightness (L^*) value was 28.60, 28.30, 30.43 and 30.06 for TC1, TC2, TC3 and TC4 respectively, while the redness (a^*) value was 10.20 (TC1), 12.1 (TC2), 12.38 (TC3) and 14.23 (TC4) and yellowness (b^*) value was 3.80, 3.45, 3.10 and 2.67 for TC4, TC3, TC2 and TC1, respectively. From this study, the L^*, $a^*$and b^*valuesof loin muscle tended to be affected (P<0.05) by castration.Loin muscle from goats fed concentrate diet with crude glycerin supplementation had higher color (L^*, $a^*$and b^*)value than goats fed concentrate control diet (P<0.01 for a^*). However, castrated male goats had significantly higher color values (L^*, $a^*$and b^*values P<0.05) than the intact male goats. Although both crude glycerin supplementation and castration generated significant difference in loin muscle redness, their interactions did not significantly differ (P>0.05) in all loin muscle color (L^*, $a^*$and b^*).

3.1.3.2 Back fat color

Crude glycerin supplementation, as presented in Table 9, significantly affected (P<0.01) in L^*, $a^*$and $b^*$of the back fat color. Goats fed concentrate with crude glycerin supplementation had significantly higher $L^*$and b^*but lower a^* in back fat color than those received control concentrate. Castrated male goat had significant lower (P<0.05) L^* anda^*but no significant difference in b^*(P>0.05). However, the interaction between dietary treatment and castration treatment generated significant different (P<0.01) in $L^*$and b^*values of back fat color.

Table 9. Effect of concentrate and sex on pH, loin muscle color and back fat color of TN x AN goats

Parameters	Diet		Sex		Treatment combination				*P-value*		
	Control	Supplemented	Intact	Castrated	TC1[1]	TC2[1]	TC3[1]	TC4[1]	*Diet*	*Sex*	*Combination*
pH_0	6.20 ± 0.30	6.20 ± 0.31	6.52 ± 0.16	6.06 ± 0.23	6.46 ± 0.18	6.61 ± 0.02	6.05 ± 0.26	6.05 ± 0.21	0.426	0.000	0.446
pH_u	5.83 ± 0.17	6.05 ± 0.37	6.19 ± 0.22	5.71 ± 0.05	6.00 ± 0.07^{b}	6.39 ± 0.01^{c}	5.71 ± 0.06^{a}	5.72 ± 0.02^{a}	0.000	0.000	0.000
Loin muscle color											
L^{*}[2]	29.29 ± 1.07	29.77 ± 0.76	28.55 ± 0.55	30.20 ±0.33	28.60 ± 0.60	28.30 ± 0.00	30.43 ± 0.31	30.06 ± 0.29	0.277	0.000	0.903
a^{*}[2]	11.65 ± 1.15	13.38 ± 1.18	11.15 ± 1.12	13.17 ± 1.01	10..20 ± 0.28	12.1 ± 0.28	12.38 ± 0.28	14.23 ± 0.06	0.000	0.000	0.893
b^{*}[2]	2.98 ± 0.47	3.38 ± 0.54	2.88 ± 0.36	3.63 ± 0.39	2.67 ± 0.25	3.10 ± 0.35	3.45 ± 0.07	3.80 ± 0.57	0.124	0.015	0.855
Back fat color											
L^{*}[2]	61.98 ± 1.35	67.67 ± 0.42	65.39 ± 2.27	63.12 ± 3.61	63.25 ± 0.29^{c}	67.53 ± 0.45^{b}	60.72 ± 0.25^{c}	67.93 ± 0.15^{a}	0.000	0.000	0.000
a^{*}[2]	4.83 ± 0.63	3.18 ± 0.56	4.06 ± 0.91	3.41 ± 0.98	5.00 ± 0.95	3.58 ± 0.41	4.67 ± 0.06	2.78 ± 0.35	0.000	0.035	0.353
b^{*}[2]	12.11 ± 0.65	14.06 ± 0.97	13.19 ± 1.64	12.92 ± 0.12	11.66 ± 0.21^{a}	14.72 ± 0.44^{c}	12.87 ± 0.15^{b}	12.97 ± 0.06^{b}	0.000	0.091	0.000

[1] TC1, Control group;TC2, Intact group fed with 10% crude glycerin supplementation;TC3, Castrated group fed with control diet and TC4, Castrated group fed with 10% crude glycerin supplementation.

[2] L^{*}, lightness; a^{*}, redness; b^{*}, yellowness.

[a-c] Means with different superscript within the same row was significantly different (P<0.05).

3.2 Meat quality characteristics

Physical properties and chemical composition generated from the study are presented in Table 10 for *Longissimus dorsi* muscle and Table 11 for *Biceps femoris* muscle.

3.2.1 Physical characteristics of muscles

3.2.1.1 Drip loss and cooking loss

The drip loss for *Longissimus dorsi* muscle was 1.40, 1.37, 1.33 and 1.30%while for *Biceps femoris* muscle was 1.51, 1.43, 1.42 and 1.30%for TC1, TC2, TC3 and TC4, respectively. The cooking loss yielded was 23.44, 17.76, 22.92 and 18.78% for *Longissimus dorsi* muscleand 21.37, 20.50, 22.13 and 21.09% for *Biceps femoris* of TC1, TC2, TC3 and TC4, respectively.

No significant difference found ($P>0.05$) in drip loss between goats fed control diet and goats fed 10% crude glycerin supplementation in both *Longissimus dorsi* and *Biceps femoris* muscles. Similar results found from castration, both *Longissimus dorsi* and *Biceps femoris* muscles of intact and castrated male goats did not significantly affect ($P>0.05$) in drip loss. Moreover, non-significant difference ($P>0.05$) was illustrated by the interaction of crude glycerin supplementation and castration, each treatment combination group had similar percentage of drip loss in both *Longissimus dorsi* and *Biceps femoris* muscles.

Unlike drip loss, cooking loss from both *Longissimus dorsi* and *Biceps femoris* muscles seemed to be affected by crude glycerin supplementation. Goats fed 10% crude glycerin supplementation had significantly lower cooking loss value ($P<0.05$) compared with those fed the control diet, while both castration and non-castration group had non-significant difference ($P>0.05$) in cooking loss percentage in both *Longissimus dorsi* and *Biceps femoris* muscles. An interaction between the effect of concentrate diet and sex had significantly difference ($P<0.05$) on cooking loss, particularly, loin musclefrom treatment combination group that fed concentrate diet with 10% crude glycerin supplementation (TC2 and TC4) had lower cooking loss value than those received the control diet.

3.2.1.2 Shear force (Warner-Bratzler Shear Force)

Table 10 and Table 11 showed the shear force value for *Longissimus dorsi* muscle and *Biceps femoris* muscle, respectively. Shear force value of raw *Longissimus dorsi* muscle was not affected (P>0.05) by both crude glycerin supplementation and castration and no interaction effect between crude glycerin supplementation and castration was found. Meat from TN x AN goat fed concentrate diet with 10% crude glycerin supplementation tended to have lower shear force value than meat from goat fed with control diet (P>0.05). Similarly, meat from castrated male goat tended to have lower shear force value than of the intact goat.

Unlike *Longissimus dorsi*, the shear force value of raw *Biceps femoris* muscle (Table 11) was statistically affected (P<0.01) by castration. Lower shear force value of meat from the castration male goats was found when compared with the non-castration. Nevertheless, the result was not applied to the effect of crude glycerin supplementation on shear force value of raw *Biceps femoris*. The lower value of muscle from goat received 10%crude glycerin supplementation was not statistically different (P>0.05) compared with muscle from goat fed with control diet. Which also gave non-significant different (P>0.05) from the interaction between crude glycerin supplementation and castration.

3.2.2 Chemical composition of muscles

Chemical composition of muscles was presented in Table 10 and Table 11 for *Longissimus dorsi* muscle and *Biceps femoris* muscle, respectively. The application of the treatments in the study did not have any significant difference (P>0.05) in moisture content percentage of *Longissimus dorsi* muscle. Supplementation of crude glycerin and castration generated insignificant difference in moisture content of *Longissimus dorsi* muscle from TN x AN goat. However, both crude glycerin supplementation and castration decreased the moisture content of the *Longissimus dorsi* muscle. Moreover, the insignificant different result also found in the interaction between crude glycerin supplementation and castration.

Table 10. Effect ofconcentrate diet and sex on physical properties and chemical compositions of m.*Longissimus dorsi* of TN x AN goats

Parameter	Diet		Sex		Treatment combination				*P-value*		
	Control	Supplemented	Intact	Castrated	TC1[1]	TC2[1]	TC3[1]	TC4[1]	*Diet*	*Sex*	*Combination*
Physical properties											
Drip loss, %	1.35 ± 0.10	1.33 ± 0.20	1.38 ± 0.09	1.31 ± 0.20	1.40 ± 0.03	1.37 ± 0.11	1.33 ± 0.12	1.30 ± 0.27	0.756	0.477	0.993
Cooking loss, %	22.12 ± 0.52	18.42 ± 0.46	20.45 ± 2.22	20.83 ± 1.92	22.04 ± 0.52	18.06 ± 0.33	22.20 ± 0.61	18.78 ± 0.11	0.000	0.213	0.406
Shear force, kg											
Raw	5.77 ± 0.44	5.62 ± 0.44	5.84 ± 0.50	5.60 ± 0.35	5.86 ± 0.57	5.78 ± 0.22	5.64 ± 0.12	5.56 ± 0.51	0.745	0.359	0.990
Cooked	5.73 ± 0.43	5.59 ± 0.50	5.84 ± 0.45	5.47 ± 0.40	5.96 ± 0.35	5.73 ± 0.53	5.53 ± 0.41	5.36 ± 0.41	0.277	0.040	0.883
Chemical composition											
Moisture, %	73.65 ± 0.54	73.94 ± 0.36	74.04 ± 0.52	73.46 ± 0.24	73.94 ± 0.64	74.23 ± 0.11	73.37 ± 0.22	73.50 ± 0.00	0.525	0.078	0.810
Protein, %	23.59 ± 0.40	23.25 ± 0.36	23.44 ± 0.46	23.44 ± 0.38	23.47 ± 0.59	23.40 ± 0.42	23.71 ± 0.11	23.03 ± 0.00	0.163	0.778	0.246
Crude fat, %	3.20 ± 2.17	5.46 ± 1.71	2.45 ± 1.31	5.91 ± 1.48	1.65 ± 0.17	4.05 ± 0.91	5.27 ± 1.68	6.87 ± 0.01	0.014	0.001	0.534
Ash, %	1.08 ± 0.09	1.04 ± 0.04	1.07 ± 0.09	1.05 ± 0.06	1.10 ± 0.12	1.04 ± 0.03	1.06 ± 0.06	1.03 ± 0.06	0.310	0.543	0.720

[1] TC1, Control group;TC2, Intact group fed with 10% crude glycerin supplementation;TC3, Castrated group fed with control diet and TC4, Castrated group fed with 10% crude glycerin supplementation.

[a-c] Means with different superscript within the same row was significantly different (P<0.05).

For *Biceps femoris* muscle, its moisture content was significantly affected ($P<0.01$) by both crude glycerin supplementation and castration including the interaction between crude glycerin supplementation and castration. Goat fed with 10% crude glycerin supplementation generated significantly lower moisture content than goat fed with control diet. It was also applied in castration treatment, castrated TN x AN goat generated significantly lower moisture content as compared with intact TN x AN goat. Similar result also expressed from the interaction between 10% crude glycerin supplementation with castration, moisture content was significantly affected ($P<0.05$) by crude glycerin supplementation and castration. TC4 (which was castrated group fed with 10% crude glycerin supplementation) generated the lowest moisture content (70.59 ± 0.37 %) compared with other treatment combination groups.

There was no significant difference ($P>0.05$) in protein content of both *Longissimusdorsi* and *Biceps femoris* muscle derived from crude glycerin supplementation, castration and from the interaction between crude glycerin supplementation and castration. Similar results were found for ash content of *Longissimus dorsi* muscle.

Crude fat content of *Longissimus dorsi* and *Biceps femoris* muscle varied among the treatments. The study indicated that crude fat content of *Longissimus dorsi* muscle was statistically affected ($P<0.05$) by crude glycerin supplementation and castration. Supplementation of 10% crude glycerin in concentrate diet significantly increased the fat content of TN x AN goat *Longissimus dorsi* muscle. Muscle from group fed with crude glycerin supplementation had higher percentage of fat content than goats fed with control diet. Moreover, *Longissimus dorsi* muscle fat content was affected ($P<0.05$) by castration. Muscles from castrated goats (TC3 and TC2) yielded significantly higher crude fat content in contrast with muscle from intact male groups (TC1 and TC2). In contrast with *Longissimus dorsi* muscle, fat content of *Biceps femoris* muscle was only affected ($P<0.05$) by castration. Castration treatment significantly increased the fat content of *Biceps femoris* muscle generated by castrated male as compared with intact male goats.

Table 11. Effect ofconcentrate diet and sex on physical properties and chemical compositions of m.*Biceps femoris* of TN x AN goats

Parameters	Diet		Sex		Treatment combination				*P-value*		
	Control	Supplemented	Intact	Castrated	TC1[1]	TC2[1]	TC3[1]	TC4[1]	*Diet*	*Sex*	*Combination*
Physical properties											
Drip loss, %	1.16 ± 0.18	1.15± 0.22	1.22± 0.17	1.11± 0.20	1.23± 0.13	1.22± 0.22	1.11± 0.20	1.09± 0.22	0.845	0.213	0.987
Cooking loss, %	21.75 ± 0.85	20.84 ± 0.69	21.00 ± 0.65	21.61 ± 1.01	21.37 ± 0.63	20.50 ± 0.21	22.13 ± 0.96	21.09 ± 0.86	0.033	0.114	0.819
Shear force, kg											
Raw	6.30 ± 0.69	5.99 ± 0.70	6.71 ± 0.38	5.58 ± 0.40	6.75± 0.50	6.65 ± 0.21	5.73 ± 0.42	5.47 ± 0.39	0.358	0.000	0.651
Cooked	5.74 ± 0.62	5.53 ± 0.65	5.83 ± 0.60	5.39 ± 0.60	5.93 ± 0.49	5.74 ± 0.70	5.49 ± 0.70	5.32 ± 0.53	0.250	0.009	0.969
Chemical composition											
Moisture, %	73.36 ± 1.49	72.81 ± 1.73	74.17 ± 0.40	71.33 ± 0.88	74.65 ± 0.18^{d}	73.92 ± 0.15^{c}	72.08 ± 0.09^{b}	70.59 ± 0.37^{a}	0.000	0.000	0.030
Protein, %	24.20 ± 0.32	24.60 ± 0.39	24.34 ± 0.27	24.42 ± 0.50	24.36 ± 0.35	24.33 ± 0.25	24.09 ± 0.29	24.87 ± 0.33	0.550	0.441	0.410
Crude fat, %	2.30 ± 1.89	3.09 ± 1.76	1.21 ± 0.59	4.34 ± 1.08	1.14 ± 0.70	1.33 ± 0.47	3.69 ± 1.70	4.41 ± 0.79	0.404	0.000	0.618
Ash, %	1.13 ± 0.08	1.18 ± 0.04	1.15 ± 0.09	1.16 ± 0.05	1.07 ± 0.10^{a}	1.21 ± 0.01^{b}	1.16 ± 0.05^{ab}	1.15 ± 0.05^{ab}	0.047	0.602	0.039

[1]TC1, Control group;TC2, Intact group fed with 10% crude glycerin supplementation;TC3, Castrated group fed with control diet and TC4, Castrated group fed with 10% crude glycerin supplementation.

[a-c]Means with different superscript within the same row was significantly different (P<0.05)

Considering the ash content, it varied for each treatment with the range of 1.03 to 1.10 percent for *Longissimus dorsi* muscle and 1.07 to 1.21 percent for *Biceps femoris* muscle. No significant difference (P>0.05) in ash content of *Longissimus dorsi* muscle affected by crude glycerin supplementation and castration were found. In contrast with *Longissimus dorsi* muscle, crude glycerin supplementation in *Biceps femoris* muscle statisticallyaffected (P<0.05) the ash content. This mean that muscle from group fed concentrate diet with crude glycerin supplementation had higher ash content than muscle from group fed with control diet. However, castration did not show any influence on the ash content of the *Biceps femoris*.

3.2.3 Fat distribution of loin muscle

Fat distribution in loin muscle were determined using Confocal Laser Scanning Microscope (CLSM) and presented in Figure 13.From Figure 13,the red color illustrated the fat globule inside the loinmuscle while black color represented the non-fat composition of the muscle.The fat distribution was higher in the muscle of castrated male than of the intact goats. Supplementing crude glycerin in goat concentrate diet could increase the fat content of the loin muscle which could be visually seen using CLSM.In addition, interaction between treatments (castration and dietary treatment) observed the highest loin muscle fat distribution (Figure 13(d)).

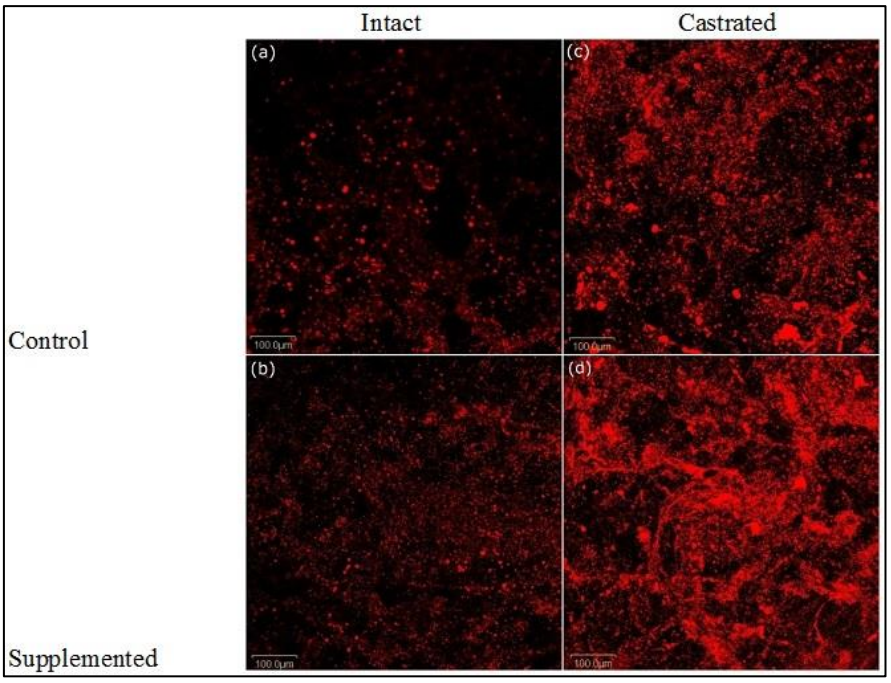

Figure 13. Loin muscle fat distribution of TN x AN goat treated with crude glycerin supplementation and castration.

(a) represented TC1 group, (b) TC2, (c) TC3 and (d) TC4

CHAPTER IV

Discussion

4.1 Carcass characteristics

4.1.1 Carcass profile

The study of effect of crude glycerin supplementation in the carcass profile indicated significantly differences (P<0.01) in final weight, slaughter weight, warm carcass weight and chilled carcass weight.Crude glycerin supplementation also generated significant difference (P<0.01) in carcass meat and fat percentage and the ratio of meat to fat of TN x AN carcass. Non-significantdifference was found by Chanjula*et al*. (2015)who included crude glycerin in Thai Native x Anglo-Nubian goat diet respectively, which was not indicated from the study. While in other study on Boer crossbred goat, Dias *et al*. (2016) also reported non-significant difference found from the inclusion of crude glycerin in concentrate diet.

Crude glycerin was included by Chanjula *et al*. (2015) and Dias *et al*. (2016) as substitution of other feed composition to meet the NRC 1981 and 2007 requirement, respectively.While in this study, crude glycerin was supplemented without substitutingany ingredient in the concentrate diet.It can be observed from the previous studies of Chanjula *et al*. (2015) and Dias *et al*. (2016)that the difference in crude glycerin inclusion methods in concentrate diet could affect the result. The method used in this study, provided a clear evidence of the effect of crude glycerin in goat which improve the carcass characteristics (final weight, slaughter weight, warm carcass weight and chilled carcass weight).

The improvement in final weight, slaughter weight, warm and carcass weight of the TN x AN goat fed concentrate diet with crude glycerin supplementation was concomitant with the increase of carcass fatpercentage.This increase of fat content influenced the meat, bone and connective tissue percentage. The meat and bone percentage decrease significantly (P<0.05) as the fat percentage increased which caused the ratio of meat to fat to decrease. Crude glycerin supplementation in concentrate diet increased carcass fat percentage of TN x AN goat up to 29%. It is likely because crude glycerinis a gluconeogenic compound (Lage *et al*., 2014a).

Supplementing crude glycerin for ruminants may cause elevation of propionate which is an accelerator in pyruvate metabolism in adipose tissue (Reshef*et al*., 1967).

Although slaughter weight and carcass weight were improved by the supplementation of crude glycerin, the carcass percentages were not affected ($P>0.05$). Even though no significant difference, the carcass percentages (warm and chilled) of goat fed concentrate diet with crude glycerin supplementation was higher compared with goat fed concentrate control diet. The study observed that carcass percentage difference might be affected by the fat percentage. Higher percentage of fat was deposited on carcass of goat fed concentrate diet with crude glycerin supplementation which caused higher carcass percentages. Gurung and Solaiman (2010) reported that carcass with high deposition of internal or external fat may lead to higher dressing percentage.

Concerning about sex factor, castration significantly affected carcass profile especiallyfinal weight, slaughter weight, carcass weight (warm and chilled carcasses), LM area, meat, fat and bone percentage and meat to fat ratio($P<0.05$). Although castration improved slaughter weight and carcass weight,castration did not statistically affect carcass percentage (warm and chilled), carcass length, width and thickness, connective tissue percentage and ratio betweenmeat and bone ($P>0.05$).Goat with higher slaughter weight tend to have higher non-carcass component weight, such as gastrointestinal, internal organs, inedible offal, etc.(Assan 2015). Assan (2015) also clarified that slaughter weight may significantly affect the dressing percentage, higher slaughter weight may lead to lower dressing percentage since animal with higher slaughter weight may have heavier non-carcass component weight. In addition, age may also influence the value of dressing percentage.

Lower weight in reproductive tract of the castrated male goats than in intact male goats (data not showed) could decrease the ability of testes to produce testosterone. Testosterone is considered as a growth promoter and responsible for the distinguishing characteristics of the masculine body (Sales, 2014). The absence of testosterone leads to lower growth rate of the castrated animal compare with intact (Guatteo and Guémené, 2014)and might have no difference in the carcass length, carcass width and body wall thickness.

The interaction between crude glycerin supplementation and castration significantly affected (P<0.01) meat and bone percentage and meat to fatand meat to bone ratios. The interaction between crude glycerin supplementation and castration (TC4)showed the lowest meat and bone percentage compared with other treatment combination groups. Similar with meat and bone percentage,meat to fat ratio generated by TC4 in the study was low compared with other treatment combination groups.This was,however, due to significantly high fat deposition in castrated male goat compared with intact goat. The same result was also reported by Tahir*et al.*(1994) that higher fat deposition could lower the bone percentage of castrated male goat.

4.1.2 pH

Crude glycerin supplementation in concentrate diet did not significantly affect (P>0.05) the $pH_0$of the carcass.The pH_0 of goat fed concentrate diet with crude glycerin supplementation was similar with pH_0 from goat fed control concentrate. Unlike pH_0,pHuof goats fed concentrate diet with crude glycerin supplementation was significantly higher (P<0.01) than those fed with control diet. This finding was similar to the work of Lammers *et al*. (2008b) who reported that ultimate pH elevation was the trend effect from the crude glycerin inclusion in animal diet compared with animal fed with no glycerin.

Crude glycerin supplementation in concentrate significantly increased carcasspH_u compared with goats without crude glycerin supplementation. Many researchers (Lammers *et al*., 2008b; Hansen *et al*., 2009; Françozo *et al*., 2013; Lage *et al*., 2014b) have worked on crude glycerin supplementation in animal diet yet there was no work reported on pH analysis regarding the effect of crude glycerin supplementation in goat diet. Result from pH determination may reflex the pre- and post-slaughter handling system whereas some intrinsic factors such as species of animal and health are also needed to be concerned (Lawrie and Ledward, 2014). The study of $pH_u$is not in accordance with the previous studies of crude glycerin inclusion effect on pig (Lammers *et al*., 2008b; Hansen *et al*., 2009), bull (Françozo *et al*., 2013) and lamb (Lage *et al*., 2014b) which resulted non-significant different (P>0.05) in both pH_0 and pH_u of loin muscles.

Both pH_0 and pH_u were significantly affected ($P<0.01$) by castration. Castrated male goatshad significantly lower pH_0 and pH_u compared with intact ones. In male animal, testosterone promotes the aggressiveness of the animal (de Lima Júnior *et al*., 2016) and distinguishes the masculinity of male animal (Sales, 2014). Castrated males have less ability to produce testosterone and the sexual activity become less which cause the glycogen depleted steadily (de Lima Júnior *et al*., 2016). Muscle with high ultimate pH tend to have no residual glycogen (Lawrie and Ledward, 2014) or because the glycolytic enzymes are not active due to acidic conditions (Young *et al*., 2004). Glycogen level is predicted as the starting point of the changing of ultimate pH for glycogen level can accelerate glycolysis in muscle. The ultimate pH would get higher when the glycogen level in the muscle gets lower (Merthayasa*et al*., 2015). Furthermore, apart from sex, some factors including species, type of muscle, variability of animals, pre-slaughter circumstances such as transportation or long time fasting and environmental temperature are also responsible for differences in pH value (Duarte *et al*., 2011; Lawrie and Ledward, 2014).

4.1.3 Color

4.1.3.1 Loin muscle color

Color has been mentioned as an important criteria influencing consumers purchase decisions of meats (Pearson, 2014; Suman and Joseph, 2013). Regarding of the effect of the supplementation of crude glycerin in loin muscle color, no significant differences were found in the lightness and yellowness of the color ($P>0.05$). However, goats fed concentrate diet with crude glycerin supplementation tended to have higher loin muscle CIE color than goats fed with concentrate control diet. Crude glycerin supplementation significantly affected ($P<0.01$) the redness of the loin muscle color though it did not affect ($P>0.05$) the lightness and yellowness of loin muscle color. Crude glycerin supplementation significantly darkened (lowering the L^*) the loin muscle of TN x AN goats compared with group fed without crude glycerin.

The darken color (low inL^*) in loin muscle could be partially explained by higher $pH_u$of the muscle. The pH_u of the loin muscle of group fed with crude glycerin supplementation was 6.05 which was higher than the standard point of

ultimate pH for 24h postmortem (5.4-5.8 reported by Young *et al*. (2004) and Duarte *et al*. (2011)). When the ultimate pH is high, muscle protein levels will be above its isoelectric point causing the protein to bind with water more strongly. When it binds to the water, muscle fibers are swollen and increase the water retention and leaving less water to reflect the light which lead to a darker color (Lage*et al*., 2014).

Meat color is affected by endogenous and exogenous factors explained by Suman and Joseph (2013). The endogenous factors are pH, muscle sources, lipid oxidation and mitochondrial activity and exogenous factor are antioxidant, and prooxidants presence. Myoglobin and hemoglobin were associated with color changes (Toplu *et al*., 2013). Increasing slaughter age, as reported by Huff-Lonergan and Lonergan (2005) and Duarte *et al*. (2011), is able to change the color of the meat as muscle pigment concentration increased. Long exposure of oxygen might also lead to discoloration of meat or known as metmyoglobin (Pearson, 2014).

4.1.3.2 Back fat color

Fat color could determine the color and appearance of meat (Lebret, Povše, and Ĉandek-Potokar 2015). Crude glycerin supplementation, in the study, however, tended to affect the backfat color. Higher lightness and yellowness generated from the group fed with crude glycerin supplementation. The study disagreed with the previous study of Lage *et al*. (2014). Lage *et al*. (2014) included 5% of crude glycerin in Nellore bulls and reported that the inclusion of crude glycerin only affected the redness of subcutaneous fat color without affecting lightness and yellowness of the subcutaneous fat color. Diet, reported by Kerth *et al*. (2007)could affect the fat color . Yellow color in fat is generated by the carotenoids contained in forage/roughage diet(Lage*et al*., 2014). Lebret*et al*. (2015)added that in some pathological cases, the excess of bilirubin generated from hemoglobin degradation could also cause the yellow color on fat.

4.2 Meat quality characteristics

4.2.1 Physical characteristics of muscles

4.2.1.1 Drip loss and cooking loss

The drip loss of both muscles was showing statistical non-significance ($P>0.05$) for castration and crude glycerin supplementation treatment. Neither crude

glycerin supplementation nor castration did not show significant different value in drip loss. Theseresults were similar with Hansen *et al*. (2009) who reported no significant difference (P>0.05) found in drip loss of *Longissimus dorsi* muscle of growing-finishing pigs fed with various levels of crude glycerin inclusion. Lammers *et al*. (2008b) also reported no significant difference in cooking loss of LM chops from pigs fed with crude glycerin. Moreover, Françozo *et al*. (2013) reported a similar result (P>0.05) of drip loss from finishing Nellore bulls fed crude glycerin in three different levels. However, significantly difference was found in cooking loss of *Biceps femoris* muscle affected by crude glycerin supplementation (P<0.05). The founding in cooking loss of *Biceps femoris* muscle may be the first report of cooking loss of *Biceps femoris* muscle of crude glycerin effect in goats.Mourot *et al*. (1994) explained that crude glycerin inclusion in animal diet may reduce the water loss when the animals are allowed to overnight rest, moreover, glycerin could increase cell osmotic pressure which increase the intercellular water content and reduce water loss of non-ruminant meat although in ruminant meat crude glycerin might not alter the water loss.

No significant differences (P<0.05) were found from castration. Castration did not significantly affect the drip loss and cooking loos for both *Longissimus dorsi* and *Biceps femoris* muscle.However, it tended to be lower by castration. Fischer (2007) explained that drip loss means the expelled water from a piece of meat caused by gravity and without mechanical force. Fischer (2007) also explained that mainly drip loss is affected by (1) Post time and duration of drip loss measurement, (2) Geometry or the dimension of the meat, (3) Temperature during drip loss measurement, (4) Condition of package, either opened or closed and (5) The position of sample inside the package. Cooking loss in castrated male goats tended to be higher compared with the intact ones. This was probably due to the high fat content in the muscles of castrated male goats as described by Schönfeldt *et al*. (1993). Thus, used of heat might melt the fat which caused cooking loss to be increased.

The interaction between crude glycerin supplementation and castration did not have significant affect (P>0.05) in both drip loss and cooking loss. However, goats received concentrate with crude glycerin (TC2 and TC4) tended to have lower drip loss values compared with goats fed with control concentrate. Similar with drip

loss, cooking loss values were lower in goats fed concentrate with crude glycerin (TC2 and TC4) compared with goat fed with control concentrate.

4.2.1.2 Shear force (Warner-Bratzler Shear Force)

Crude glycerin supplementation in concentrate did not significantly affect shear force of either raw or cook *Longissimus dorsi* and *Bicaps femoris*muscle.In contrast, sex of goat significantly affected (P<0.05) shear force in raw muscle of *Longissimus dorsi* and both raw and cooked *Biceps femoris* muscle.It indicated lower valuecompared with muscle from goat fed concentrate without crude glycerin. Similar with crude glycerin, non-significant difference (P>0.05) was found on raw *Longissimus dorsi* muscle and significant difference (P<0.05) on cooked *Longissimus dorsi* muscle regarding sex factor. Moreover, castration treatment appeared to affect the shear force of both raw and cooked *Biceps femoris* muscle.

Results of this study are in agreement with the previous studies of which resulted non-significant difference (P>0.05) generated by crude glycerin inclusion in muscle shear force. Hansen *et al*. (2009) in their study with growing-finishing pigs found no effect in *Longissimus dorsi* muscle of pigs fed with crude glycerin inclusion. Mach*et al*. (2009) found no significant different of 8% crude glycerin inclusion in shear force value of Holstein bulls' *Longissimus* muscle. Françozo *et al*. (2013) reported no significant different found in raw and cooked LM shear force of finishing Nellore bulls fed with three different levels (0, 5 and 12%) of crude glycerin. Lage*et al*. (2014a) observed no different of 10% crude glycerin inclusion in young Nellore bulls diet to shear force of the *Longissimus* muscle. Lage*et al*. (2014b) who studied crude glycerin supplementation with contamination of high concentration of crude fat in lamb diet reported no significant difference (P>0.05) generated regarding the crude glycerin inclusion in the diet.

In this study, significant difference in muscle shear force affected (P<0.05) by castration. The results of significant effect of sex on muscle shearing force were in agreement with the previous study of muscle shear force affected by castration on sheep (Pratiwi *et al*., 2006) and goat (El-Hag *et al*., 2007; Kebede *et al*., 2008; Zamiri*et al*., 2012). Those researchers reported higher tenderness on castrated animals compared with the intact animal.

Overall, the low shear force value of the treated groups, group fed concentrate diet with crude glycerin supplementation and castrated group, was mostly as the result of high content of fat yielded from the treated groups. When supplemented in diet, crude glycerin increased the fat content of the muscle due to it is broken down to propionate which accelerated pyruvate metabolism in adipose tissue (Reshef*et al*., 1967). Moreover, castration could improve the fat content, reduces muscle collagen deposition and increase muscle fat(Segato *et al.*, 2005). In addition, muscle fat loosens up the micro structure of meat which cause meat to be tender (den Hertog-Meischke*et al*., 1997).

4.2.2 Chemical composition of muscles

No significant difference from crude glycerin supplementation on moisture, protein and ash content of *Longissimus dorsi* muscle has been expected in the study. Crude glycerin supplementation was expected to significantly affect ($P<0.05$) the fat content of the muscles. In *Biceps femoris* muscle, crude glycerin did not significantly affect ($P>0.05$) the fat content, yet it affected ($P<0.05$) moisture and ash content. Although crude glycerin supplementation did not statistically affect in *Biceps femoris* muscle, the fat content from group fed with crude glycerin supplementation was higher compared with group fed with control diet.

The significant difference found in moisture and ash contents could be explained from the high fat content on the muscle. da Rocha *et al*. (2015)included crude glycerin in goat diet and indicated non-significant difference on meat chemical composition but in the study found that crude glycerin significantly ($P<0.05$) affected crude fat content of *Longissimus dorsi* muscle. Moreover, the study disagreed with the previous studies of crude glycerin inclusion in other ruminant such as bulls which generated non-significant difference, especially the fat content. Mach*et al*. (2009) reported no significant different in muscle fat content of LM Holstein bulls fed with various level of crude glycerin supplementation while Lage *et al*. (2014a)also reported no significant different in lipidcontent of beef receiving 10% inclusion of crude glycerin in exchange of corn.

Higher fat content also found by Egea *et al*. (2016) in castrated males Iberian x Duroc pig compared with females. Madruga *et al*. (2001) reported that

castrated male goats had higher fat content compared to intact lamb. Gispert *et al*. (2010) as cited by Egea *et al*. (2016) explained that castration could improve the muscle fat which affect the marbling (Amatayakul-Chantler *et al*., 2013; Dnekeshev and Kereyev, 2013; Guatteo and Guémené, 2014) and meat tenderness (Segato *et al*., 2005; Pratiwi *et al*., 2006; El-Hag *et al*., 2007).

4.2.3 Fat distribution in loin muscle (Confocal Laser Scanning Microscope)

Effect of crude glycerin supplementationin concentrate diet showed significant difference (P<0.05) in carcass fat (Table 10) and muscle fat (Table 12).Results confirmed that, goats fed concentrate diet with crude glycerin supplementation had significantly higher fat content compared with goat fed the control diet.In addition, castration treatment significantly affected (P<0.05) the total amount of fat of the TN x AN goat. This was due to the lack of testosterone production, which evidence from reduction in weight of testes in castrated male goats (data not shown), caused the castrated male goathas less physical activities(Kim *et al*., 2016). In addition, the lack of testosterone could lead to increase of deposition of glucose which is then stored as fat.

Total muscle fat is related to the amount of total fat in the carcass. It was confirmed by a positive correlation between carcass fat and muscle fat (Table 12). The significant value of both carcass and muscle fat content correlation was 0.005 (P=0.005) and the correlation value was 0.807 closed to +1 which means a positive correlation between the two fat contents. These positive correlations could be used as an information to conduct further analysis related to the fat content in goat.

Table 12. Correlation between carcass fat yield and fat content of loin muscle of TN x AN goat treated with crude glycerin supplementation and castration

		Carcass fat	Musclefat
Carcass fat	Pearson Correlation	1	0.807**
	Sig. (2-tailed)		0.005
	N	12	12
Muscle fat	Pearson Correlation	0.807**	1
	Sig. (2-tailed)	0.005	
	N	12	12

[1]Carcass fat, total fat in carcass (visceral fat, kidney fat, pelvic fat, heart fat, subcutaneous fat and intermuscular fat).

[1]Muscle fat, crude fat contained in *Longissimus dorsi* muscle.

**. Correlation is significant at the 0.01 level (2-tailed).

Microstructure or fat distribution of muscle was determined using Confocal Laser Scanning Microscope (CLSM) to investigate further effect of crude glycerin supplementation in concentrate diet and castration on fat composition in *Longissimus dorsi* muscle of. Figure 12illustrated the visual micro appearance of the loin muscle fat. With the use of fluorescent dye (Nile Blue A) in the sample, CLSM produced a point-by-point in-focus intramuscular fat droplet images (Damez and Clerjon, 2008). Image obtained from the pinhole focusing of laser refraction originating from the fluorescence dye in the sample which is collected by the objective lens(Dürrenberger *et al*., 2001).Loin muscle fat droplets distribution increased in every treatment. The effect of crude glycerin supplementation was able to be visually seen usingCLSM. Fat droplets were stored more in muscle of goats fed with crude glycerin supplementation compared with goat fed control diet. Supplementing crude glycerin in animal concentrate diet, might increase the muscle fat content since crude glycerin would be fermented as propionate (Musselman *et al*., 2008; Mach*et al*., 2009; Gunn*et al*., 2010) which is main carbon source for fat tissue deposition (Reshef*et al*., 1967; Hood*et al*., 1972; da Rocha *et al*., 2015). In addition, muscle fat is considered to contribute in the visibility of marbling in a muscle, especially LM (Font-i-Furnols *et al*., 2012; Amatayakul-Chantler *et al*., 2013; Dnekeshev and Kereyev, 2013).

With regard to castration, castrated male goat distributed more loin muscle fat droplets which indicated that castrated male goat contained more fat compared with intact goat. Castrated showed marked distribution of fat droplets in muscle compared with muscle from intact group which was coincided with high chemical fat composition of *Longissimus dorsi* muscle. Mudalal *et al*. (2014)reported that muscle fat distribution is affected by castration. Castrating goat in early aged (as suggested by Madruga *et al*., 2001; Haddad*et al*., 2006; Kebede *et al*., 2008)might benefit the farmer or meat producers by the improved marbling and consumer acceptance,\. This was due to the longer condition of testosterone deficiency occurs the higher fat deposition (Kiyma *et al*., 2000).

CHAPTER V

Conclusion and Suggestion

5.1 Conclusion

The results from this study indicated that dietary treatment was able to improve the final weight, slaughter weight, WCW and CCW of the goat. It also significantly improved ($P<0.01$) meat percentage, carcass fat percentage and meat to fat ratiowhile dressing percentage of neither warm nor chilled carcass were notaffected ($P>0.05$) by crude glycerin. Supplementation of crude glycerin had significant effect onCIE color, especially L^* and a^*. Longissimus dorsi muscle from those received concentrate diet with crude glycerin supplementation had statistically darker color, but significantly higher redness. This was likely due to the significant higher pH_u of goat fed with crude glycerin supplementation. Cooking loss of both *Longissimus dorsi* and *Biceps femoris* muscle was significantly reduced by the 10% supplementation of crude glycerin in concentrate diet. Moreover, fat content of *Longissimus dorsi* muscle and water content of *Biceps femoris* muscle were the only chemical composition that was affected ($P<0.05$) by crude glycerin supplementation.

The castration treatment in TN x AN goat did not affect the carcass profile but increased the LM area of the carcass. $pH_0$and pH_u were low in castrated male goat with higher carcass color value compared with the intact ones. Same as crude glycerin supplementation, castration also improved fat content of both muscle and also moisture content of *Biceps femoris* muscle. Drip loss and cooking loss were unaffected by castration. Nevertheless, castration was significantly able to improve the shear force value of the cooked muscles.

The implication of the treatments, crude glycerin supplementation and castration, could be alternative fattening treatment for farmers and goat meat producers. The use of crude glycerin as supplementation in diet could be the alternative management treatment to improve goat carcass and meat quality for those who concern about theanimal welfare since doing castration could cause severe pain to the goat. While castration could be the alternative management for those who does not want to invest more for the feed.

5.2 Suggestion

The experiment provided clear evident that crude glycerin supplemented in concentratewas capable to improve the slaughter weight and carcass weight, it also is a good feedstock to improve the quality of TN x AN goat meat. However, further study on long chained fatty acid profile need to be done to analyze the effect of crude glycerin supplementation in goat meat.

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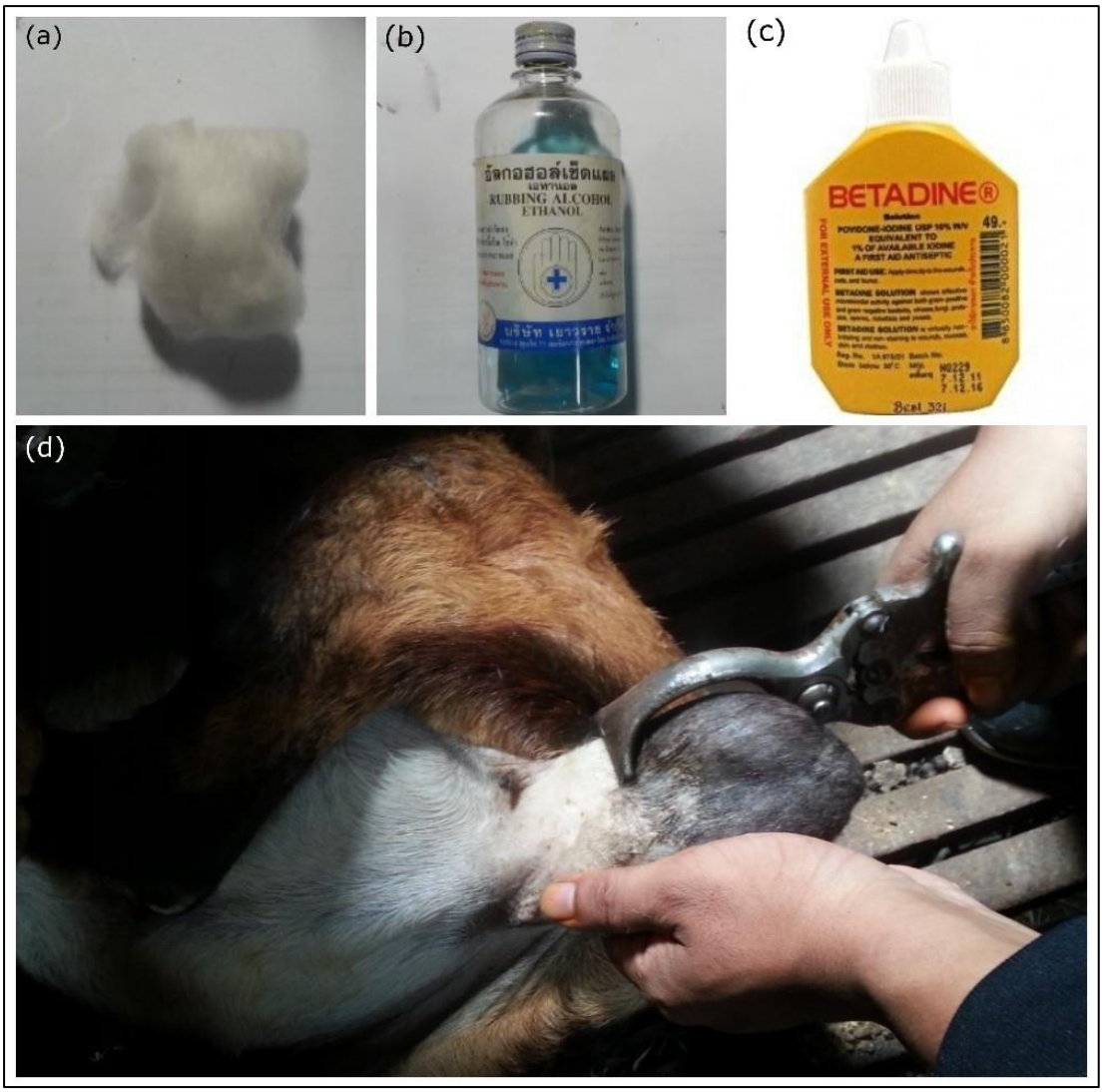
APPENDICES

Appendices 1. Figures during experimental period

Appendices1.1. Figures during feeding period

Appendices 1. 1. 1. The cage situation before had been used, (a) the aisle of the individual cages, (b) front view of the cage, (b) inside view of the cage and (d) feed and water containers prepared for the goats.

Appendices 1. 1.2. Figures of goat condition in Small Ruminant Research Center during experimental study. (a) Selected goats from SRRDC, (b) intact goat was separated from thecastrated male goat to avoid stress, (c) showed that goat was grassing Atratum grass(*Paspalum atratum*)as the roughage during the experimental study period and (d) goats were in resting area of the slaughter house before being slaughtered.

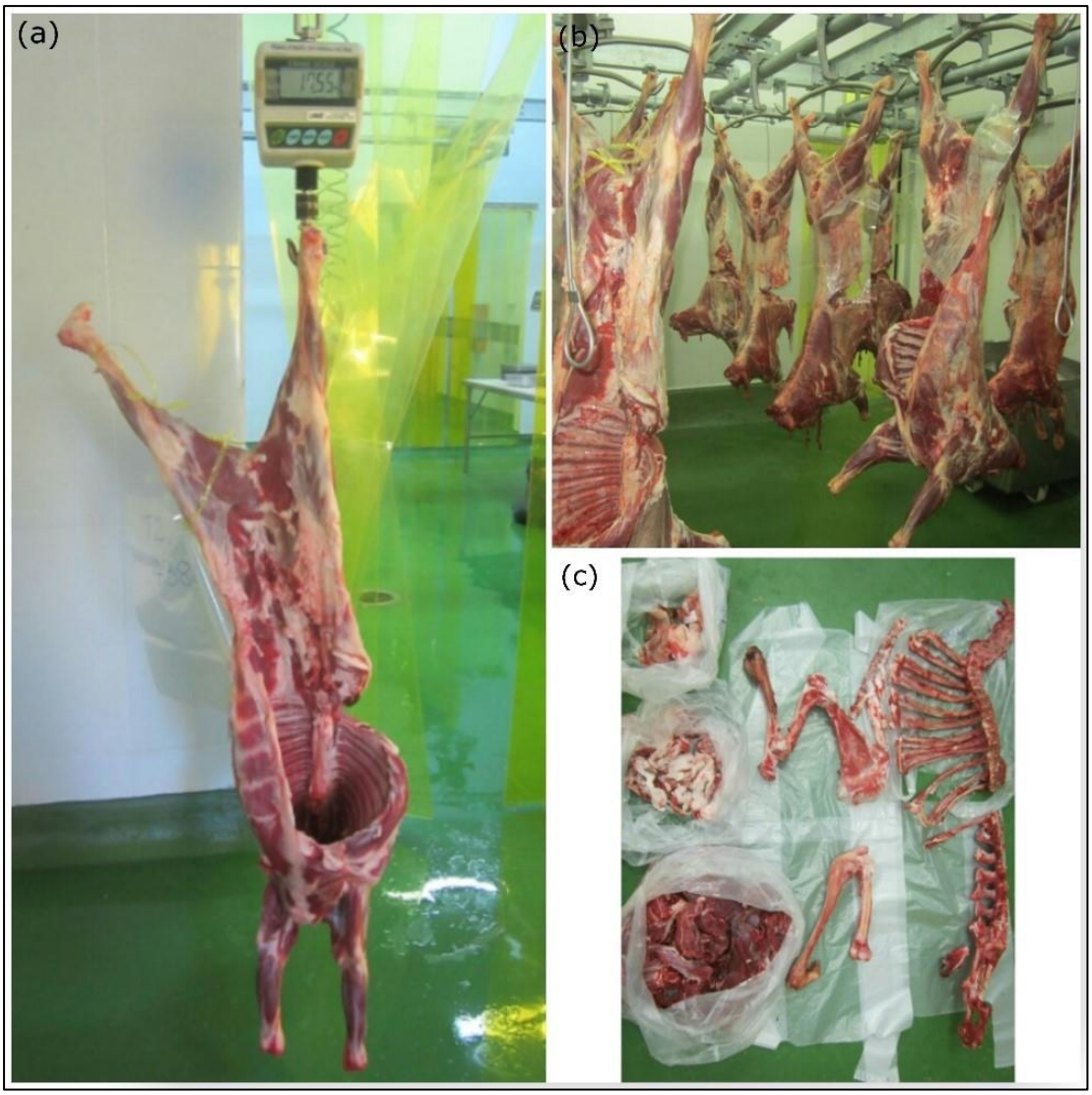


Appendices 1. 1. 3. Castration equipment and procedure. (a) cotton ball, (b) rubbing alcohol ethanol and (c) iodine to rub on the scrotum before and after castration while (d) was the castration process, the figure showed that the spermatic cord was crushed using burdizzo clamp

Appendices 1. 1. 4. The feed composition of the experimental study. a. soybean meal, b. ground corn, c. palm kernel cake,d. di-calcium phosphate, e. shell flour, f. salt, g. vegetable oil and h. crude glycerin.

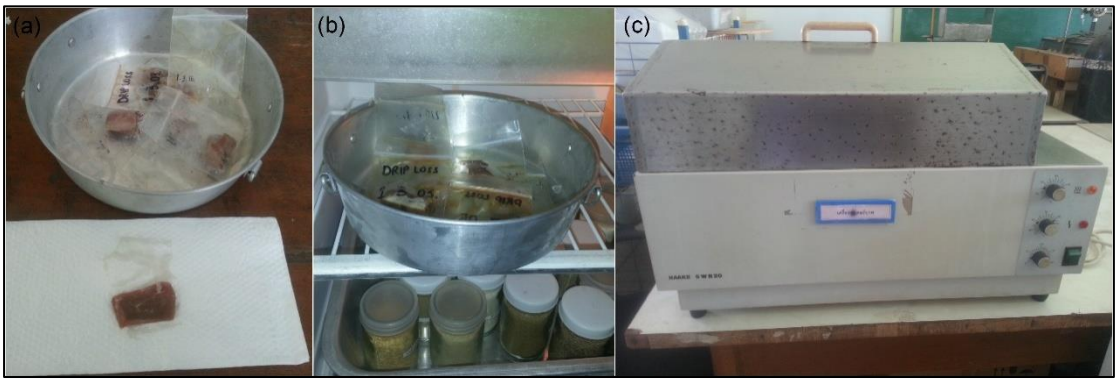
Appendices 1.2. Figures during slaughtering process

Appendices 1. 2. 1. Slaughtering process. (a) The goat had been weighted before slaughter, (b) exsanguination process, (c) carcass was hung upside down to enhance exsanguination process, the head then separated from the carcass before skinning (d) and (e) evisceration process started.

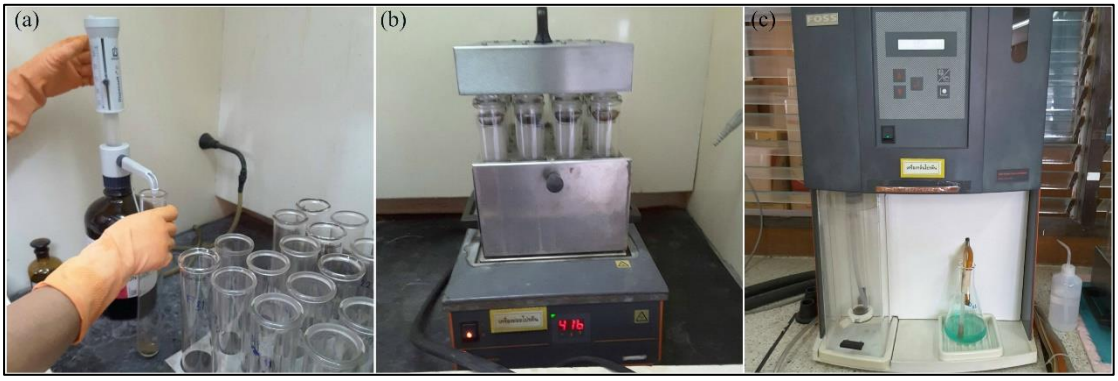


Appendices 1. 2. 2. Carcass figure (a) showed that the carcass was weighted, this procedure was used to determine both warm carcass weight and chilled carcass weight, (b) the condition of the carcasses while kept at chilling room and (c) was the deboned half cut carcass.

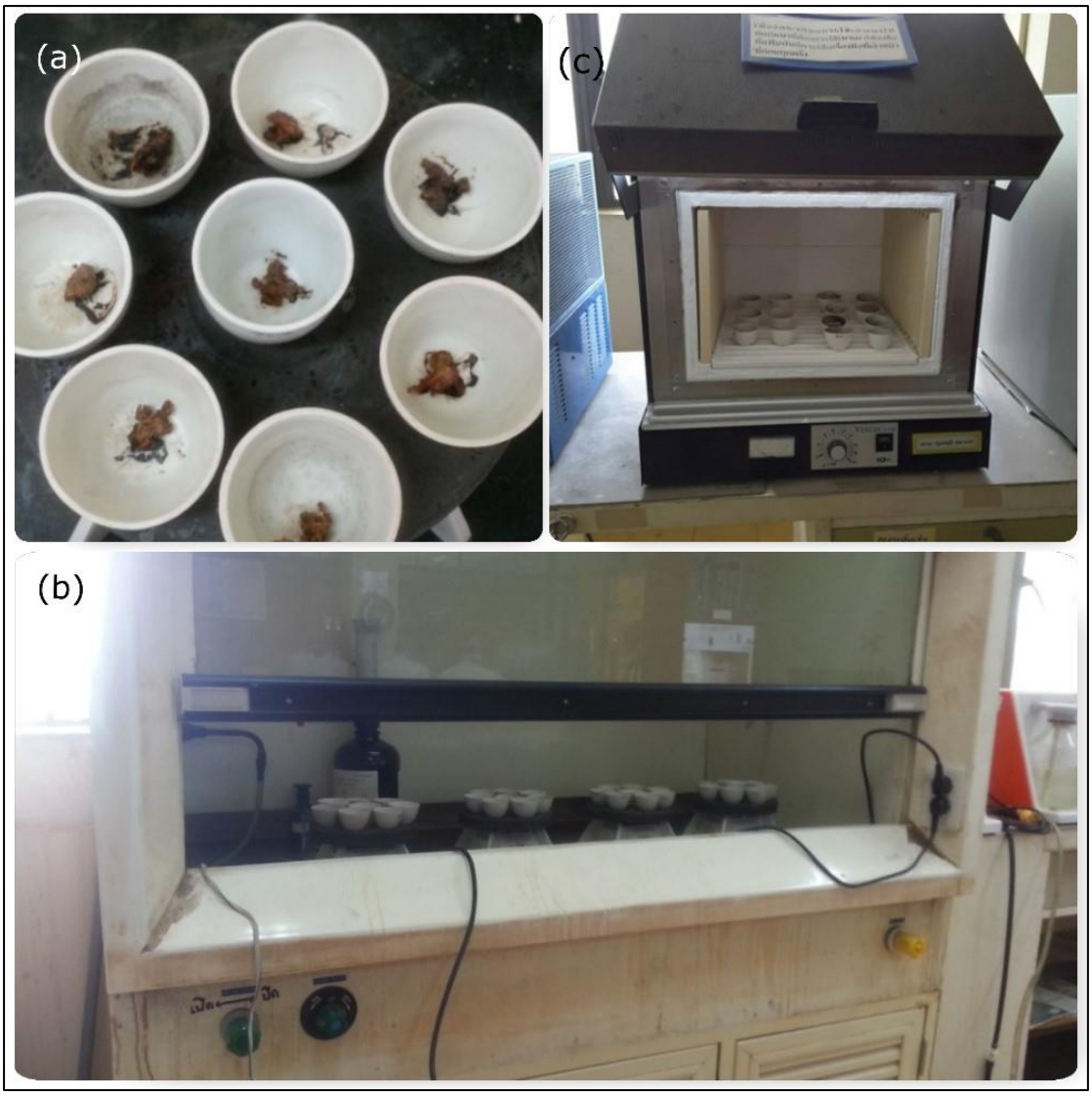
Appendices 1.3. Figures during meat analysis



Appendices 1. 3. 1. Drip loss and cooking loss determination procedure. (a) cut muscle sample was blotted with towel paper and put in sealed plastic bag, (b) drip loss samples were stored in 4^{o}C and (c) water bath that was used for cooking loss determination.



Appendices 1. 3. 2. The protein analysis procedure (Kjeldahl method) as determined based on AOAC (2000). (a) The inclusion of sulfuric acid (H_2SO_4) to the sample inside the Kjeldahl flask, (b) digestionprocess which is one the process in Kjeldahl method and (c) the distillation process of Kjeldahl method.



Appendices 1. 3. 3. Ash content analysis. (a) samples were put into ceramic crucible, (b) samples were burned on the hot plate to enhance the ashing process and (d) the ceramic crucibles inside the furnace before ashing.

Appendices 1. 3. 4. Fat content (ether extract) analysis and Confocal Laser Scanning Microscope apparatus. (a) cellulose thimble, (b) and (c) The Soxtec^{TM} Avanti automated system, (d) Inclusion of Nile blue A 0.01% to m. *Longissimus dorsi* sample (e) soaking sample in Nile blue A 0.01% for 5-10 minutes and (f) Confocal Laser Scanning Microscope.

Appendices 2. Analysis of variance for the mean of collected data

Appendices 2. 1. Analysis of variance for carcass profile data

Appendices 2. 1. 1. Analysis of variance for the mean of initial weight

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	6.501	2.167	0.967	0.460
Intercept	1	7138.050	7138.050	3184.345	0.000
Sex	1	2.022	2.022	0.902	0.374
Diet	1	4.652	4.652	2.075	0.193
Sex X Diet	1	0.086	0.086	0.038	0.851
Error	7	15.691	2.242		
Total	11	7331.337			
Corrected Total	10	22.192			

Appendices 2. 1. 2 Analysis of variance for the mean of final weight

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	34.952	11.651	14.473	0.002
Intercept	1	14386.407	14386.407	17871.313	0.000
Sex	1	14.936	14.936	18.554	0.004
Diet	1	15.790	15.790	19.614	0.003
Sex X Diet	1	0.392	0.392	0.487	0.508
Error	7	5.635	0.805		
Total	11	14860.048			
Corrected Total	10	40.587			

Appendices 2. 1. 3. Analysis of variance for the mean of slaughter weight

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	40.473	13.491	18.951	0.001
Intercept	1	13518.507	13518.507	18989.207	0.000
Sex	1	18.963	18.963	26.637	0.001
Diet	1	15.574	15.574	21.877	0.002
Sex X Diet	1	1.500	1.500	2.107	0.190
Error	8	4.983	0.712		
Total	12	13968.623			
Corrected Total	10	45.457			

Appendices 2. 1. 4. Analysis of variance for the mean of warm carcass weight

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	12.186	4.062	38.001	0.000
Intercept	1	3121.929	3121.929	29206.149	0.000
Sex	1	2.132	2.132	19.946	0.003
Diet	1	8.857	8.857	82.862	0.000
Sex X Diet	1	0.188	0.188	1.763	0.226
Error	7	0.748	0.107		
Total	11	3212.026			
Corrected Total	10	12.934			

Appendices 2. 1. 5. Analysis of variance for the mean of chilled carcass weight

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	10.514	3.505	25.576	0.000
Intercept	1	2899.748	2899.748	21162.000	0.000
Sex	1	1.710	1.710	12.481	0.010
Diet	1	7.639	7.639	55.747	0.000
Sex X Diet	1	0.390	0.390	2.847	0.135
Error	7	0.959	0.137		
Total	11	2980.867			
Corrected Total	10	11.473			

Appendices 2. 1. 6. Analysis of variance for the mean of warm carcass weight percentage

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	11.724	3.908	1.718	0.250
Intercept	1	24637.906	24637.906	10828.999	0.000
Sex	1	3.232	3.232	1.420	0.272
Diet	1	8.712	8.712	3.829	0.091
Sex X Diet	1	0.179	0.179	0.079	0.787
Error	7	15.926	2.275		
Total	11	25308.330			
Corrected Total	10	27.650			

Appendices 2. 1. 7. Analysis of variance for the mean of chilled carcass weight percentage

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	9.669	3.223	1.360	0.331
Intercept	1	22893.609	22893.609	9658.907	0.000
Sex	1	4.007	4.007	1.691	0.235
Diet	1	6.594	6.594	2.782	0.139
Sex X Diet	1	0.024	0.024	0.010	0.922
Error	7	16.591	2.370		
Total	11	23501.405			
Corrected Total	10	26.261			

Appendices 2. 1. 8. Analysis of variance for the mean of carcass length

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	8.712	2.904	0.910	0.483
Intercept	1	43918.519	43918.519	13765.506	0.000
Sex	1	1.852	1.852	0.580	0.471
Diet	1	6.000	6.000	1.881	0.213
Sex X Diet	1	0.000	0.000	0.000	1.000
Error	7	22.333	3.190		
Total	11	45279.250			
Corrected Total	10	31.045			

Appendices 2. 1. 9. Analysis of variance for the mean of carcass width

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.409	0.470	0.438	0.733
Intercept	1	7728.074	7728.074	7212.869	0.000
Sex	1	0.296	0.296	0.277	0.615
Diet	1	0.296	0.296	0.277	0.615
Sex X Diet	1	0.667	0.667	0.622	0.456
Error	7	7.500	1.071		
Total	11	7974.000			
Corrected Total	10	8.909			

Appendices 2. 1. 10. Analysis of variance for the mean of carcass thickness

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.387	0.129	1.673	0.258
Intercept	1	16.007	16.007	207.494	0.000
Sex	1	0.327	0.327	4.235	0.079
Diet	1	0.007	0.007	0.086	0.777
Sex X Diet	1	0.060	0.060	0.778	0.407
Error	7	0.540	0.077		
Total	11	17.990			
Corrected Total	10	0.927			

Appendices 2. 1. 11. Analysis of variance for the mean of loin muscle area

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	3.932	1.311	24.368	0.000
Intercept	1	2120.226	2120.226	39419.867	0.000
Sex	1	3.747	3.747	69.663	0.000
Diet	1	0.034	0.034	0.634	0.439
Sex X Diet	1	0.003	0.003	0.056	0.817
Error	14	0.753	0.054		
Total	18	2229.130			
Corrected Total	17	4.685			

Appendices 2. 1. 12. Analysis of variance for the mean of carcass meat percentage

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	119.008	39.669	112.575	0.000
Intercept	1	36994.960	36994.960	104986.406	0.000
Sex	1	70.933	70.933	201.297	0.000
Diet	1	18.108	18.108	51.387	0.000
Sex X Diet	1	16.745	16.745	47.519	0.000
Error	7	2.467	0.352		
Total	11	38269.827			
Corrected Total	10	121.474			

Appendices 2. 1. 13. Analysis of variance for the mean of carcass fat percentage

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	324.016	108.005	181.755	0.000
Intercept	1	2520.270	2520.270	4241.196	0.000
Sex	1	266.711	266.711	448.831	0.000
Diet	1	26.446	26.446	44.504	0.000
Sex X Diet	1	2.992	2.992	5.034	0.060
Error	7	4.160	0.594		
Total	11	3017.005			
Corrected Total	10	328.176			

Appendices 2. 1. 14. Analysis of variance for the mean of carcass bone percentage

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	43.757	14.586	42.869	0.000
Intercept	1	4488.500	4488.500	13192.231	0.000
Sex	1	40.838	40.838	120.027	0.000
Diet	1	0.036	0.036	0.107	0.754
Sex X Diet	1	4.211	4.211	12.377	0.010
Error	7	2.382	0.340		
Total	11	4571.823			
Corrected Total	10	46.138			

Appendices 2. 1. 15. Analysis of variance for the mean of carcass connective tissues percentage

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	3.067	1.022	1.443	0.310
Intercept	1	292.509	292.509	412.770	0.000
Sex	1	2.306	2.306	3.255	0.114
Diet	1	0.448	0.448	0.633	0.453
Sex X Diet	1	0.093	0.093	0.131	0.728
Error	7	4.961	0.709		
Total	11	305.988			
Corrected Total	10	8.028			

Appendices 2. 1. 16.Analysis of variance for the mean of carcass meat:fat ratio

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	50.255	16.752	97.721	0.000
Intercept	1	218.145	218.145	1272.547	0.000
Sex	1	32.659	32.659	190.515	0.000
Diet	1	7.199	7.199	41.997	0.000
Sex X Diet	1	4.875	4.875	28.438	0.001
Error	7	1.200	0.171		
Total	11	274.142			
Corrected Total	10	51.455			

Appendices 2. 1. 17. Analysis of variance for the mean of carcass meat:bone ratio

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.416	0.472	2.310	0.163
Intercept	1	85.972	85.972	420.815	0.000
Sex	1	0.015	0.015	0.075	0.792
Diet	1	0.221	0.221	1.080	0.333
Sex X Diet	1	1.213	1.213	5.935	0.045
Error	7	1.430	0.204		
Total	11	94.038			
Corrected Total	10	2.846			

Appendices 2. 2. Analysis of variance for the mean of pH_0, pH_u, loin muscle color and back fat color

Appendices 2. 2. 1. Analysis of variance for the mean of loin muscle pH_0

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.226	0.409	8.879	0.000
Intercept	1	839.294	839.294	18236.868	0.000
cas	1	1.225	1.225	26.615	0.000
Diet	1	0.030	0.030	0.659	0.426
cas X Diet	1	0.028	0.028	0.602	0.446
Error	22	1.012	0.046		
Total	26	1000.811			
Corrected Total	25	2.238			

Appendices 2. 2. 2. Analysis of variance for the mean of loin muscle pH_u

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.969	0.323	125.270	0.000
Intercept	1	453.565	453.565	175888.617	0.000
Sex	1	0.731	0.731	283.435	0.000
Diet	1	0.130	0.130	50.260	0.000
Sex X Diet	1	0.114	0.114	44.210	0.000
Error	9	0.023	0.003		
Total	13	458.729			
Corrected Total	12	0.992			

Appendices 2. 2. 3. Analysis of variance for the mean of loin muscle color (L^*, lightness)

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	18.053	6.018	36.861	0.000
Intercept	1	10952.760	10952.760	67088.832	0.000
Sex	1	12.535	12.535	76.779	0.000
Diet	1	3.843	3.843	23.538	0.001
Sex X Diet	1	0.460	0.460	2.818	0.121
Error	11	1.796	0.163		
Total	15	12786.100			
Corrected Total	14	19.849			

Appendices 2. 2. 4. Analysis of variance for the mean of loin muscle color (a^*, redness)

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	19.931	6.644	117.986	0.000
Intercept	1	1510.753	1510.753	26829.434	0.000
Sex	1	11.723	11.723	208.192	0.000
Diet	1	8.921	8.921	158.430	0.000
Sex X Diet	1	0.001	0.001	0.019	0.893
Error	7	0.394	0.056		
Total	11	1721.620			
Corrected Total	10	20.325			

Appendices 2. 2. 5. Analysis of variance for the mean of loin muscle color (b^*, yellowness)

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.724	0.575	4.986	0.045
Intercept	1	101.660	101.660	881.871	0.000
Sex	1	1.320	1.320	11.452	0.015
Diet	1	0.368	0.368	3.194	0.124
Sex X Diet	1	0.004	0.004	0.036	0.855
Error	6	0.692	0.115		
Total	10	103.540			
Corrected Total	9	2.416			

Appendices 2. 2. 6. Analysis of variance for the mean of back fat color (L^*, lightness)

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	185.689	61.896	577.096	0.000
Intercept	1	80766.785	80766.785	753035.841	0.000
Sex	1	5.461	5.461	50.919	0.000
Diet	1	158.700	158.700	1479.653	0.000
Sex X Diet	1	10.325	10.325	96.269	0.000
Error	17	1.823	0.107		
Total	21	87333.600			
Corrected Total	20	187.512			

Appendices 2. 2. 7. Analysis of variance for the mean of back fat color (a^*, redness)

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	12.977	4.326	18.332	0.000
Intercept	1	257.068	257.068	1089.490	0.000
Sex	1	1.284	1.284	5.444	0.035
Diet	1	10.890	10.890	46.153	0.000
Sex X Diet	1	0.218	0.218	0.923	0.353
Error	14	3.303	0.236		
Total	18	267.160			
Corrected Total	17	16.280			

Appendices 2. 2. 8. Analysis of variance for the mean of back fat color (b^*, yellowness)

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	23.704	7.901	95.453	0.000
Intercept	1	2555.843	2555.843	30875.952	0.000
Sex	1	0.280	0.280	3.385	0.091
Diet	1	9.361	9.361	113.092	0.000
Sex X Diet	1	8.214	80.214	99.230	0.000
Error	12	0.993	0.083		
Total	16	2765.220			
Corrected Total	15	24.697			

Appendices 2. 3. Analysis of variance for the mean of *Longissimus dorsi* muscle physico-chemical characteristics

Appendices 2. 3. 1.Analysis of variance for the mean of drip loss of *Longissimus dorsi* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.019	0.006	0.204	0.891
Intercept	1	23.331	23.331	756.312	0.000
Sex	1	0.017	0.017	0.545	0.477
Diet	1	0.003	0.003	0.102	0.756
Sex X Diet	1	0.000002801	0.000002801	0.000	0.993
Error	10	0.308	0.031		
Total	14	25.569			
Corrected Total	13	0.327			

Appendices 2. 3. 2. Analysis of variance for the mean of cooking loss of *Longissimus dorsi* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	33.425	11.142	46.999	0.000
Intercept	1	3944.850	3944.850	16640.500	0.000
Sex	1	0.460	0.460	1.939	0.213
Diet	1	32.872	32.872	138.665	0.000
Sex X Diet	1	0.189	0.189	0.799	0.406
Error	6	1.422	0.237		
Total	10	4295.480			
Corrected Total	9	34.848			

Appendices 2. 3. 3. Analysis of variance for the mean of shear force of *Longissimus dorsi* rawmuscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.298	0.099	0.480	0.701
Intercept	1	499.985	499.985	2413.602	0.000
Sex	1	0.185	0.185	0.895	0.359
Diet	1	0.023	0.023	0.110	0.745
Sex X Diet	1	0.00003602	0.00003602	0.000	0.990
Error	15	3.107	0.207		
Total	19	623.443			

Corrected Total	18	3.406			

Appendices 2. 3. 4. Analysis of variance for the mean of shear force of *Longissimus dorsi* cookedmuscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.065[a]	0.355	1.854	0.170
Intercept	1	725.969	725.969	3792.966	0.000
Sex	1	0.920	0.920	4.806	0.040
Diet	1	0.239	0.239	1.249	0.277
Sex X Diet	1	0.004	0.004	0.022	0.883
Error	20	3.828	0.191		
Total	24	776.001			
Corrected Total	23	4.893			

Appendices 2. 3. 5. Analysis of variance for the mean of moisture content of *Longissimus dorsi* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.253	0.418	2.091	0.190
Intercept	1	43523.563	43523.563	217948.631	0.000
Sex	1	0.848	0.848	4.248	0.078
Diet	1	0.089	0.089	0.447	0.525
Sex X Diet	1	0.012	0.012	0.062	0.810
Error	7	1.398	0.200		
Total	11	59823.488			
Corrected Total	10	2.650			

Appendices 2. 3. 6. Analysis of variance for the mean of protein content of *Longissimus dorsi* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.557	0.186	1.214	0.373
Intercept	1	5842.304	5842.304	38213.538	0.000
Sex	1	0.013	0.013	0.085	0.778
Diet	1	0.372	0.372	2.431	0.163
Sex X Diet	1	0.245	0.245	1.605	0.246
Error	7	1.070	0.153		
Total	11	6043.990			
Corrected Total	10	1.627			

Appendices 2. 3. 7. Analysis of variance for the mean of crude fat content of *Longissimus dorsi* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	43.354	14.451	15.380	0.002
Intercept	1	201.066	201.066	213.982	0.000
Sex	1	26.174	26.174	27.855	0.001
Diet	1	10.093	10.093	10.741	0.014
Sex X Diet	1	0.402	0.402	0.427	0.534
Error	7	6.577	0.940		
Total	11	228.018			
Corrected Total	10	49.932			

Appendices 2. 3. 8. Analysis of variance for the mean of crude fat content of *Longissimus dorsi* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.012	0.004	0.593	0.629
Intercept	1	19.443	19.443	2955.316	0.000
Sex	1	0.003	0.003	0.387	0.543
Diet	1	0.007	0.007	1.106	0.310
Sex X Diet	1	0.001	0.001	0.133	0.720
Error	15	0.099	0.007		
Total	19	21.501			
Corrected Total	18	0.110			

Appendices 2. 4. Analysis of variance for the mean of *Biceps femoris* muscle physico-chemical characteristics

Appendices 2. 4. 1. Analysis of variance for the mean of drip loss of *Biceps femoris* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.169	0.056	0.577	0.634
Intercept	1	67.597	67.597	690.434	0.000
Sex	1	0.097	0.097	0.987	0.328
Diet	1	0.080	0.080	0.822	0.372
Sex X Diet	1	0.005	0.005	0.046	0.831
Error	32	3.133	0.098		
Total	36	77.271			
Corrected Total	35	3.302			

Appendices 2. 4. 2. Analysis of variance for the mean of cooking loss of *Biceps femoris* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	4.854	1.618	2.853	0.086
Intercept	1	6682.314	6682.314	11780.727	0.000
Sex	1	1.674	1.674	2.951	0.114
Diet	1	3.356	3.356	5.916	0.033
Sex X Diet	1	0.031	0.031	0.055	0.819
Error	11	6.239	0.567		
Total	15	6830.509			
Corrected Total	14	11.094			

Appendices 2. 4. 3. Analysis of variance for the mean of shear force of *Biceps femoris* raw muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	5.839[a]	1.946	12.092	.000
Intercept	1	672.436	672.436	4177.297	.000
Sex	1	5.391	5.391	33.488	.000
Diet	1	.146	.146	.905	.358
Sex X Diet	1	.034	.034	.213	.651
Error	14	2.254	.161		
Total	18	687.853			
Corrected Total	17	8.093			

Appendices 2. 4. 4. Analysis of variance for the mean of shear force of *Biceps femoris* cooked muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	3.409[a]	1.136	3.092	.034
Intercept	1	1865.854	1865.854	5076.929	.000
Sex	1	2.712	2.712	7.380	.009
Diet	1	.496	.496	1.349	.250
Sex X Diet	1	.001	.001	.002	.969
Error	56	20.581	.368		
Total	60	1924.655			
Corrected Total	59	23.989			

Appendices 2. 4. 5. Analysis of variance for the mean of moisture content of *Biceps femoris* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	22.166	7.389	178.814	0.000
Intercept	1	48468.161	48468.161	1172971.523	0.000
Sex	1	19.942	19.942	482.614	0.000
Diet	1	2.797	2.797	67.695	0.000
Sex X Diet	1	0.328	0.328	7.935	0.030
Error	6	0.248	0.041		
Total	10	53359.144			
Corrected Total	9	22.414			

Appendices 2. 4. 6. Analysis of variance for the mean of protein content of *Biceps femoris* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	1.057	0.352	3.831	0.051
Intercept	1	7626.856	7626.856	82940.673	0.000
Sex	1	0.060	0.060	0.650	0.441
Diet	1	0.446	0.446	4.850	0.055
Sex X Diet	1	0.521	0.521	5.661	0.041
Error	9	0.828	0.092		
Total	13	7732.295			
Corrected Total	12	1.884			

Appendices 2. 4. 7. Analysis of variance for the mean of crude fat content of *Biceps femoris* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	33.293	11.098	10.322	0.001
Intercept	1	108.203	108.203	100.641	0.000
Sex	1	30.631	30.631	28.490	0.000
Diet	1	0.803	0.803	0.747	0.404
Sex X Diet	1	0.281	0.281	0.262	0.618
Error	12	12.902	1.075		
Total	16	157.023			
Corrected Total	15	46.195			

Appendices 2. 4. 8. Analysis of variance for the mean of ash content of *Biceps femoris* muscle

Source	df	Sum of Squares	Mean Square	F	Sig.
Corrected Model	3	0.033	0.011	3.193	0.063
Intercept	1	19.426	19.426	5703.133	0.000
Sex	1	0.001	0.001	0.286	0.602
Diet	1	0.017	0.017	4.878	0.047
Sex X Diet	1	0.018	0.018	5.375	.039
Error	12	0.041	0.003		
Total	16	21.326			
Corrected Total	15	.073			

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- Graduate School Research Support Funding for Thesis Financial Support.

List of Publication and Proceeding

1. Anneke, C. Wattanachant and S. Wattanachant. 2016. Confocal Laser Scanning Microscopy: A biophysical method to determine fat content in goat meat. The 10th IMT-GT UNINET Conference 2016 (Bioscience: The Element of Life) 2016, December 1st-2nd, 2016; Songkhla, Thailand. Abstract ID AG-P100.
2. Anneke, C. Wattanachant and S. Wattanachant. Effects of Feeding Concentrate Diet Containing with Crude Glycerin and Castration on Carcass Characteristics and Meat Quality of Thai Native x Anglo Nubian Goats. (Submitted to Walailak Journal Science and Technology).