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Effects of adding crude glycerin in concentrate and castration on fattening performance and production return from raising Anglo-Nubian crossbred goats

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Abstract - Effects of adding crude glycerin in concentrate diet and castration on feed intake, growth performance, carcass characteristics, and production return of fattening 50% Anglo-Nubian x 50% Thai native goats were determined. Twenty male goats aged 12-13 months with 25.16±1.99 kg initial live weight were allotted into 2 x 2 factorial arrangement in CRD in which factor A was the type of concentrate diet (diet with no crude glycerin (CG) addition and diet with 10% of CG), and factor B was castration (intact and castrated males). Atratum (Paspalum atratum) grass was fed ad libitum, while 2% of concentrate diet was provided daily for 90 days. From the study, goats received diet with 10% CG addition had higher dry matter intake (DMI) and average daily gain (ADG) than those received a control diet (P<0.05). Castrated group had higher DMI and ADG than the non-castrated group (P<0.05). Higher slaughter weight and chilled carcass weight were observed in goats received concentrate plus 10% CG or castration while the carcasses had a higher fat percentage than the control group. Fattening goats with diet plus 10% CG and castration showed the highest economic return, but fattening goats with diet plus

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10% CG could be another option. This was due to not only the high economic return was noted, but it also reduced suffering of castration.

Keywords: Crude glycerin addition, concentrate, castration, fattening, goat

1. Introduction

Crude glycerin, a main by-product from oil biodiesel production, normally consists of about 50 to 90% of glycerol, and has approximately 3.6 to 4.2 Mcal of gross energy/kg (Dasari, 2007; Thompson & He, 2006). Results from various studies confirmed that crude glycerin could be used as an energy source either for non-ruminant or ruminant diets (5 to 10%) without any negative effects (Cerrate, et al., 2006; Lammer et al., 2008; Barton et al., 2013; Wilbert et al., 2013; Chanjula et al., 2015).

Since the global palm oil market is expected to grow with increasing biofuel production and reducing carbon footprints, crude glycerin from this production is expected to increase, including in Thailand. Crude glycerin from Thai palm oil is an option to substitute corn, sorghum, and broken rice as energy source in the livestock production industry, particularly when the price of energy feedstuffs increased. Consequently, it is possible to use this by-product as an alternative source of energy for fattening Thai meat goats. However, castration of goats before fattening may increase an eating quality of meat, resulting in increase fat deposition in the carcass and removing the taint of males (Solaiman et al., 2011). However, castration may not be accepted by some ethical and animal welfare groups depending on castration method, age of animal, and post-castration management (Marquette et al., 2023). Thus, fattening male goats with a high-energy diet could be the best choice. CG is an energy source could be used in ruminant diets. Therefore, this study aimed to assess the effects of adding CG at 10% in concentrate diet and castration on feed intake, digestibility, growth performance, carcass characteristics, and economic return from fattening goats using 50% Anglo-Nubian (AN) x Thai native (TN) goats as a study model.

2. Materials and methods

2.1 Location and experiment animals

This study was conducted at the Small Ruminant Research and Development Center (SRRDC), Faculty of Natural Resources, Prince of Songkla University, Khlong Hoi Kong district, Songkhla province, Thailand. This site is located at 6o51’31.0” N, and 100o21’50.1” E.

2.2 Management of animals

Twenty male AN x TN (50:50) goats at the age of 12-13 months with 25.16±1.99 kg initial live weight from the SRRDC were used for the study. During a three weeks preliminary period, they were de-wormed to eliminate external and internal parasites, treated with vitamin A, D3, E, and penned individually. All experimental procedures involving animals were approved by Research, Innovation and Social Responsibility Office, Faculty of Natural Resources, Prince of Songkla University.

2.3 Experimental design and treatments

Goats were allotted into a 2x2 factorial arrangement in a completely randomized design (CRD). Factor A represented the type of concentrate diet (control diet and diet added with 10% of crude glycerin), while factor B was castration (intact male and castrated male). There were four treatment combinations, each combination involving 5 goats. Each of them was kept in an individual pen and provided free access to Atratum grass and water. Additionally concentrate was added at 2% live weight (LW). The control diet consisted of 12% soybean meal, 26% palm kernel cake, 54.3% ground corn, 4.7% minerals (di-calcium phosphate 1.2%, shell flour 25 and salt 1.5%) and 3% palm oil (Table 1), while the experimental diet was the control diet with added 10% of CG from palm oil biodiesel production (New Biodiesel Ltd. Co., Suratthani province, Thailand). This CG consisted of 87.61 of glycerol and 8.01% water. Both diets in this study were formulated to meet the nutritional requirements of growing goats according to Kearl (1982).

Table 1. Ingredients and chemical composition concentrate diets

Items	Concentrate diets	
	Control	**+ 10% Crude glycerin addition**
Ingredient, %DM basis		
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		
Crude protein (CP), % [a]	16.01	15.98
Gross energy (GE), Mcal/kg	4.46 (18.73 MJ/kg)	4.73 (19.86 MJ/kg)
Metabolisable energy (ME), Mcal/kg [b]	2.85 (11.93 MJ/kg)	3.10 (13.00 MJ/kg)

a Isonitrogeous of both diet groups; b calculated with an estimated ME for glycerol of 3.47 Mcal/kg DM of Mach et al. (2009)

2.4 Feed intake and live weight

Feeding trial was carried out for 90 d which feed intake and live weight changes were determined. Feeding of concentrate diet and grass was done twice a day in two equal portions at 08.30 h in the morning and in the afternoon at 15.00 h. Refusals were collected and weighed every morning to obtain an estimate of intake. Daily feed intake was maintained throughout the experiment. In addition, water and mineral blocks were available free choice. Live weight of each goat was determined on the first day of the feeding trial and every biweekly in the morning before feeding until the last day of the experiment. In addition, the live weight of each period was measured twice, and mean of two consecutive weights was reported. Live weight change, average daily gain, feed per gain, body condition score (BCS), body circumstances, production cost, and economic return of fattening goats were determined. BCS was measured at day 90 using a scale of 1-5 as described by Detweiler et al. (2008). In addition, body length, heart girth, and height at wither were determined according to Chacón et al. (2011).

2.5 Digestibility trial

To measure DM digestibility (DMD), fecal grab samples from all experimental goats were collected two times a day, about the same time as when roughage was fed. The samples were collected for three days during day 88 through day 90. The fecal samples from the same goat were combined, weight, dried at 70o C, and ground through a 1 mm sieve and stored at -20o C until analysis.

2.6 Carcass determination

At the end of the experiment, three goats of each treatment combination group were randomly sampled and transferred to slaughter at Meat Laboratory of SRRDC, Khlong Hoi Kong Research Station, Faculty of Natural Resources. After fasting for about 20 h, goats were slaughtered, skinned and eviscerated according to TAS (2013). Then carcasses were hung and kept in a 4o C chilled room for about 20 h. Warm carcass weight was determined and recorded after the skinning and evisceration, while chilled carcass weight was recorded. The internal organs, including carcass fat content (heart fat, kidney fat, pelvis fat and visceral fat) were weighed within 1 h after slaughter, whereas body wall thickness and fat thickness were measured after chilling (Marques et al., 2014).

2.7 Chemical analysis

Samples of dried feeds, feces, and refusals were dried at 70o C for 48 h in a force-dried oven. Proximate composition was determined according to the Association of Official Analytical Chemists (Association of Official Analytical Chemists (AOAC, 1990), while Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to Van Soest et al. (1991). Acid insoluble ash (AIA) content of feed and fecal samples was determined using the procedure of Van Keulen & Yong (1997). The DMD was calculated as [1 - (%AIA in feed / %AIA in feces)] x 100, whereas the digestibility of nutrient was calculated as [1 - ((%AIA in feed / %AIA in the feces) x (%nutrient in feed / %nutrient in feces) (%AIA in feed / %AIA in the feces)] x 100.

2.8 Statistical analysis

All data were analyzed using SAS user's guide (SAS Institute Inc., 1997). The ANOVA procedure was used to analyze the main factors affecting feed intake, nutrient utilization, live weight gain, FCR, and carcass characteristics. Differences in means were compared using Duncan's New Multiple Range Test. Significant differences were declared if $p<0.05$.

3. Results and discussion

3.1 Chemical composition of the experimental feeds

The chemical composition of experimental diets is presented in Table 2. The DM content of Atratum grass was 27.19%, while the percentages of CP, NDF, ADF, and ADL based on dry matter were 5.5, 80.6, 66.9, and 16.4 respectively. The control diet consisted of 92.7% of OM, 16.0% of CP, 7.4% of EE, and 59.8% of NFE respectively, while the diet added with 10% CG consisted of 93.1% of OM, 16.0% of CP, 6.9% of EE, and 57.9% NFE. In addition, the GE and ME were respectively 4.46 Mcal /kg and 2.94 Mcal/kg for control diet, and 4.73 Mcal/kg and 3.12 Mcal/kg for the experimental diet. Higher ME content in the experimental diet was related to the high GE value of the glycerin that was added to the diet.

3.2 Dry matter and nutrient intake

From Table 2, no interactions among diet and castration were observed on DM and nutrient intake of goats. From the study, roughage, concentrate and total feed intakes (based on g/DM/d and g/kgLW0.75/d) of goats fed a diet with 10% added glycerin were significantly higher than those of the control group ($p<0.01$).

The total feed intake (TFI) as percent live weight (LW) was in the range of 2.5 to 2.9 which was in the same range that mentioned by Devendra & Burns (1983) of total DM intake (DMI) for growth of between 1.9 to 3.8% LW/d, while the values of CPI, and MEI of both diet groups were sufficient for the growing goat according to the recommendations of Kearl (1982). The present results of DMI of goats receiving the diet with 10% CG addition were higher (935.28 gDM/d) than those in the report of Chanjula & Cherdthong (2018), who fed goats with TMR containing 2, (768 gDM/d), 4 (784 gDM/d) and 6% of crude glycerin from waste vegetable oil (648 gDM/d), respectively. The average daily intakes of organic matter (OMI), CP (CPI) and ME (MEI) were increased in goats receiving the diet with 10% of GC addition ($p<0.05$). Consequently, the NDF and ADF intakes of goats receiving a diet with a 10% glycerin addition were significantly higher than those of goats fed control diet.

Table 2. Effects of adding crude glycerin in concentrate and castration on feed and nutrient intake of fattening goats

Parameter	Diet (D)		Castration (C)		Significant of factors		
	Control	+ 10% Glycerin	Intact	Castrated	D	C	D x C
Roughage intake							
gDM/day	264.22^b	353.44^a	276.16^b	341.50^a	*	*	ns
g/kgLW$^{0.75}$/day	23.67^b	31.66^a	24.48^b	30.85^a	*	*	ns
Concentrate intake							
gDM/day	566.28	581.83	564.07^b	584.04^a	*	*	ns
g/kgLW$^{0.75}$/day	50.43^b	51.85^a	49.84^b	52.44^a	*	*	ns

Table 2. Effects of adding crude glycerin in concentrate and castration on feed and nutrient intake of fattening goats (cont)

Parameter	Diet (D)		Castration (C)		Significant of factors		
	Control	+ 10% Glycerin	Intact	Castrated	D	C	D x C
Total feed intake							
gDM/day	830.50[b]	935.28[a]	840.24[b]	925.54[a]	*	*	ns
g/kgLW$^{0.75}$/day	74.10[b]	83.51[a]	74.32[b]	83.29[a]	*	*	ns
Organic matter intake							
gDM/day	772.42[b]	873.26[a]	782.93[b]	862.74[a]	*	*	ns
g/kgLW$^{0.75}$/day	68.92[b]	77.97[a]	69.25	77.64[a]	*	*	ns
Crude protein intake							
gDM/day	105.15[b]	112.20[a]	105.29	112.06	*	ns	ns
g/kgLW$^{0.75}$/day	9.37[b]	10.01[a]	9.31[b]	10.07[a]	*	*	ns
NDF intake							
gDM/day	398.17[b]	453.77[a]	396.58[b]	455.36[a]	*	*	ns
g/kgLW$^{0.75}$/day	35.57[b]	40.57[a]	35.11[b]	41.04[a]	*	*	ns
ADF intake							
gDM/day	253.17[b]	317.84[a]	262.27[b]	308.74[a]	*	*	ns
g/kgLW$^{0.75}$/day	22.64[b]	28.44[a]	23.23[b]	27.85[a]	*	*	ns
ME intake							
Mcal/kgDM/day	2.08[b]	2.30[a]	2.07[b]	2.32[a]	*	*	ns
Mcal/kgLW$^{0.75}$/day	2.50	2.46	2.46	2.51	ns	ns	ns

# ns = not significant (P>0.05); NDF = neutral detergent fiber;
ADF = acid detergent fiber; ME = metabolizable energy

Table 3. Effects of adding crude glycerin in concentrate and castration on apparent digestibility coefficient of fattening goats

Parameter	Diet (D)		Castration (C)		Significant of factors #		
	Control	+ 10% Glycerin	Intact	castrated	D	C	D x C
Dry matter, %	67.79	66.60	66.74	67.64	ns	ns	ns
Organic matter, %	70.86	69.45	69.57	70.74	ns	ns	ns
Crude protein, %	62.01	58.49	59.85	60.65	ns	ns	ns
NDF, %	56.53	54.90	54.59	56.84	ns	ns	ns
ADF, %	47.21	50.87	47.49	50.59	ns	ns	ns

ns = not significant (P>0.05); NDF = neutral detergent fiber; ADF = acid detergent fiber

3.4 Growth performance

Table 4 shows the results of growth performance from each factor, while effect of treatment combinations on live weight change is presented in Figure 1. In this study, live weight gain and BCS of goats fed diet with 10% CG added were significantly higher than those of goats receiving a control diet (P<0.01). Better growth performance reflected the higher amount of TFI, OMI, CPI, and MEI per day of goats receiving diet with 10% of glycerin addition compared with those of goats fed control diet (Table 2). Results of better nutrient intake of goats fed diet with 10% of glycerin addition were not only illustrated in higher live weight gain (P <0.01) and BCS (P <0.05), but also in the better feed efficiency (low FCR) (P <0.05) than those of the control group. In addition, the better BCS could be illustrated by the larger heart girth and wither height in goats fed diet with glycerin than those of the control group (P <0.05), although diet did not affect body length (P >0.05).

Table 4. Effects of adding crude glycerin in concentrate and castration on growth performance of fattening goats

Parameter	Diet (D)		Castration (C)		Significant of factors #		
	Control	+ 10% Glycerin	Intact	castrated	D	C	D x C
Number of goats	5	5	5	5	-	-	-
Initial weight, kg	25.15	25.15	25.42	24.87	ns	ns	ns
Final weight, kg	34.74^b	37.48^a	34.72^b	37.50^a	*	*	ns
Live weight (LW) gain, kg	9.59^b	12.33^a	9.29^b	12.63^a	*	*	ns
ADG, g/d	106.53^b	137.00^a	103.25^b	140.28^a	*	*	ns
FCR	8.40	7.00	8.68^a	6.72^b	ns	*	ns
BCS	3.13^b	3.33^a	3.16	3.31	*	ns	ns
Body measurement							
Body length, cm	67.81	69.10	67.21^b	69.70^a	ns	*	ns
Heart girth, cm	73.16^b	74.80^a	72.41^b	75.55^a	ns	*	ns
Shoulder height, cm	65.29^b	67.60^a	66.49	66.40	*	ns	ns

ns = not significant (P>0.05); * = P<0.05; ADG = average dairy gain; FCR = feed conversion ratio; BCS = body condition score

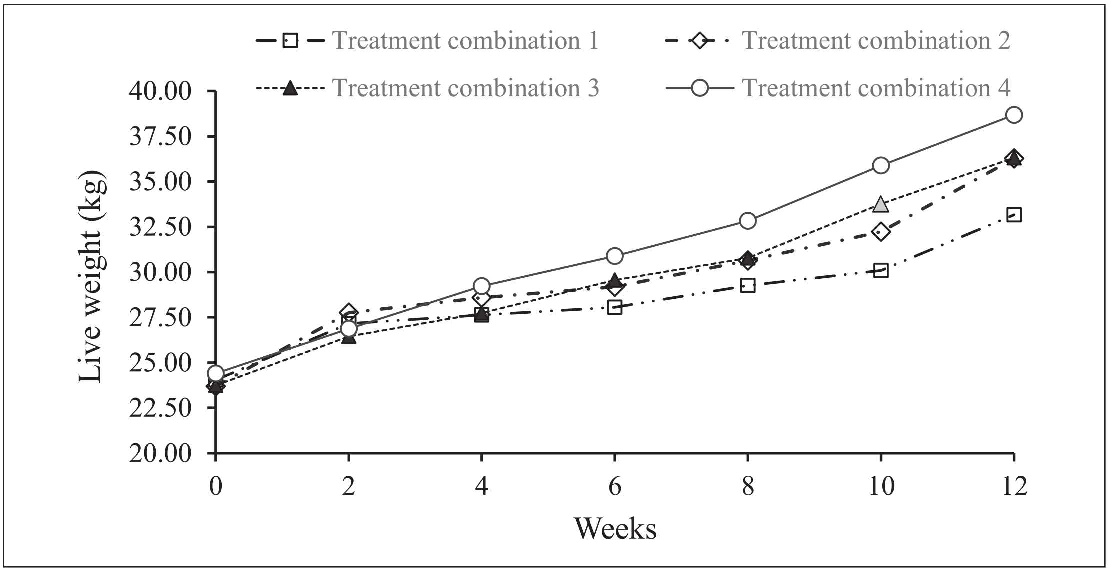

Figure 1. Treatment combination effects of diet and castration on live weight changes of goats (treatment combination 1 = control diet + intact males, treatment combination 2 = diet with 10% glycerin + intact males, treatment combination 3 = control diet + castrated males, and treatment combination 4 = diet with 10% glycerin + castrated males)

Considering the effect of castration on growth performance, although both groups showed no significant difference in initial live weight ($p>0.05$), but better final live weight, live weight change, FCR, body length, and heart girth of castrated male goats than the intact males ($p<0.01$) were found. Although the BCS value of the intact and castrated groups did not show a statistically significant difference ($p>0.05$), the castrated group tended to have better BCS than the intact group. A higher growth performance from the castrated male group in this study was similar to the work of Muhikambele et al. (1996), who found that castrated Saanen goats had a higher growth rate (from 2 to 3 days of age to the age at 36.5 kg) than the intact male goats ($P<0.01$). Similar results were reported in castrated male black goats by Abdullah & Musallam (2007), in castrated male Mestiço goats (Madruga et al., 1999), and in Iranian goats (Zamiri et al., 2012). This was probably related to the lack of testosterone and the higher DMI, and MEI of the castrated group than those of the intact group as described in the early part. Better BCS in castrated group than the intact male group ($P<0.05$). This was also related to the high amount of MEI per day of goats received, although the amount of MEI per kg0.75 did not show any significant difference (Table 2). In fact, the higher BCS in the castrated group may be related to the high amount of fat deposition in the goat's body, which was clearly seen in abdominal and subcutaneous parts (Table 5).

In this study, BCS of goats from both factors was in the range of 3.13 to 3.33 which means that goats from both groups were in a good physical condition (moderately lean) according to the idea BCS for meat goats as described by Detweiler et al. (2008). Nevertheless, the finding of better growth performance of castrated males than the intact males differed the reports of Allan & Holst (1985) and Mahgoub et al. (2004) who pointed out that the intact male goat grew faster and contained more meat than the castrated male and female goats. This was related to the inability to produce the male sex hormones, which were considered to be a growth promoter. Thus, the distinguishing characteristics of the masculine body resulted in castrated male (Mudalal et al., 1985).

Table 5. Effects of concentrate and castration on slaughter weight and carcass quality of fattening goats

Parameter	Diet (D)		Castration (C)		Significant of factors #		
	Control	+ 10% Glycerin	Intact	Castrated	D	C	D x C
Number of goats	3	3	3	3	-	-	-
Slaughter wt. (SW), kg	34.39[b]	36.76[a]	34.12[b]	37.03[a]	0.004	*	ns
Empty live weight (ELW), kg [1]	30.92[b]	33.54[a]	31.18[b]	33.28[a]	0.001	*	ns
Chilled carcass wt. (CCW), kg	15.64[b]	17.23[a]	16.09	16.79	0.001	Ns	ns
%Chilled carcass on SW	45.54	46.93	47.15	45.32	ns	Ns	ns
%Chilled carcass on ELW	50.62	51.39	51.58[a]	50.44[b]	ns	*	ns
%Abdominal fat on SW	8.85	9.16	7.41	10.61	ns	*	ns
%Abdominal fat on ELW	9.85	10.06	8.11[b]	11.81[a]	ns	*	ns
Body wall thickness, cm	1.24	1.35	1.13	1.59	ns	*	ns
Fat thickness, cm	0.23	0.33	0.10	0.48	ns	*	ns
Carcass components							
%Meat on CCW	61.20	58.00[b]	61.47[a]	56.00[b]	***	***	*
%Fat on CCW	13.89[b]	16.25[a]	10.45[b]	20.87[a]	***	***	ns
%Bone on CCW	20.50	20.39	22.47[a]	18.38[b]	ns	***	**
Meat/fat ratio	5.39	6.24	8.89[a]	2.74[b]	ns	***	ns
Meat/bone ratio	2.87	2.69	2.83	2.74	ns	ns	ns

1 live weight without ingesta and feces; # ns = not significant (P>0.05); * = P<0.05; ** = P<0.01; *** = P<0.001

3.5 Carcass characteristics

From Table 5, no interactions between two factors on slaughter weight (SW), empty live weight (ELW), chilled carcass weight (CCW), percent CCW, and percent abdominal fat (p>0.05) were observed. However, meat and fat percentages were affected by an interaction between dietary treatment and castration (p<0.05).

Goats fed diet with CG addition had higher SW, ELW, and CCW than those fed the control diet ($p<0.05$). Higher SW and ELW and CCW of those fed diet with glycerin were more likely related to high fat deposition, which in consistent with the biochemical change in the reticulorumen. According to this activity, glycerin is a gluconeogenic precursor that is synthesized to propionate (Chanjula et al., 2015), resulting in a high subsequent deposition of fat in subcutaneous and visceral parts. No significant differences in chilled carcass percentage based on SW, and ELW ($p>0.05$) were indicated, but goats fed diet with CG tended to gain more SW and ELW than the control group.

It was noticed that the castrated group had significantly higher SW, ELW and chilled carcass percentages based on ELW, and body wall and fat thicknesses than the intact group ($P<0.05$). Moreover, higher carcass fat percentage when meat percentage was oppositely lower was obtained in castrated group than in the intact group ($p<0.05$). This caused a lower meat-to-fat ratio in the castrated group ($p<0.01$). However, no difference in meat per bone ratio was indicated ($P>0.05$).

The higher amount of fat deposition in the abdominal and carcass was probably related to the higher ME content in goats receiving the experimental diet (shown in Table 1 and 2). The higher amount of body fat was related to the excess nutritional intake and quality that goats received (Al-Jalil & Al-Wahab, 1985; Allan & Holst, 1985; Mudalal et al., 1985; Mahgoub et al., 2004). With castration, goat would be able to deposit more fat percentage than the intact male. This was not only due to the lack of sex hormones, but also related to the high amount of feed intake in the castrated group. In this study, castrated goats fed diet with 10% of glycerin contained the highest fat percentage (21.42%) followed by castrated goats fed the control diet (19.33%), non-castrated goats fed with control diet (7.77%), and non-castrated goats fed diet with glycerin addition (7.37%), respectively. Castrated goat fed with control and experimental diets had lower meat (53.64 and 56.26%) than those fed diet with and without glycerin addition (58.77 and 61.71 %). per fat ratio in castrated goats fed diet with 10% glycerin was lower than that in goats fed diet with glycerin addition ($p<0.05$). Nevertheless, high fat deposition in goat body was not only influenced by sex and nutritional supply as shown in this work, but also by breed, age, and mature size (Goering & Van Soest, 1985).

3.6 Production cost and economic return from fattening goats

Production cost and economic return from fattening goats with and without a 10% CG addition are illustrated in Table 6. It was found that goats fed with experimental diet had higher production cost than those fed with the control diet (3,867.00 vs 3,852.90 Thai Baht [THB]), while lower production cost was obtained in castrated group than in the intact group (3,848.64 vs. 3,871.07 THB). Nevertheless, after calculation of the economic return when excluding the cost of land, veterinary drug, petrol for grass cutting, and opportunity cost of investment, the fattening castrated group yielded more economic return than the intact group (650.76 vs. 294.74 THB), whereas goats fed with diet with CG addition had a better economic return than the control group (630.20 vs. 315.30 THB).

In terms of the treatment combination effect, it was indicated that castrated goat with the experimental diet had the best economic return per goat (774.60 THB) followed by castrated goat with the control diet (526.92 THB), intact goat with the experimental diet (485.79 THB), and the intact goat with control diet had the lowest economic return (103.68 Baht). This was related to the final live weight as presented in Table 3. Results in Table 6 showed that, although diet supplemented with 10% glycerin without or with castration yielded higher economic return, it should be noted that adding glycerin in the concentrate diet or castration could increase the fat content of the fattening goat. This high fat deposition might not be of interest to some consumer groups, even though fat deposition in meat will increase the eating quality.

Table 6. Production cost and economic return from fattening intact or castrated male goats with concentrate diet without (control) and with 10% of glycerin addition

Parameter	Diet (D)		Castration (C)		Treatment combination			
	Control	+ 10% Glycerin	Intact	castrated	Intact with control diet	Intact with 10% glycerin	Castrated with control diet	Castrated with 10% glycerin
Production cost per head, THB (USD) [a]	3,852.90 (118.55)	3,866.81 (118.98)	3,871.07 (119.11)	3,848.64 (118.42)	3,875.52 (119.25)	3,866.61 (118.97)	3,830.28 (117.85)	3,867.00 (118.98)
Sale price of live goat, THB (USD) [b]	4,168.20 (128.25)	4,497.00 (138.37)	4,165.80 (128.18)	4,499.40 (138.44)	3,979.20 (122.44)	4,352.40 (133.92)	4,357.20 (134.07)	4,641.60 (142.82)
Economic return per goat, THB (USD) [c]	315.30 (9.70)	630.20 (19.39)	294.74 (9.07)	650.76 (20.02)	103.68 (3.19)	485.79 (14.95)	526.92 (16.21)	774.60 (23.83)
Economic return THB per kg of live weight gain	29.66 (0.92)	50.43 (1.55)	29.02 (0.90)	51.08 (1.57)	13.5 (0.42)	44.53 (1.37)	45.82 (1.41)	56.33 (1.73)

a calculated from cost of live goat, feed, and labour; b sale price of live goat in the year 2021 was 120 THB per kg of live weight (3.69 USD/kg LW) 1 USD = currency conversion was based on 32.50 THB/USD; c Return over price of live goat, feed, and labour without cost of land, veterinary drug for cutting grass, and opportunity cost of investment

4. Conclusion

The research findings indicate that introducing 10% CG into the diet or performing castration can enhance the carcass fat percentage compared to fattening intact goats on a control diet. However, fattening castrated goats with a diet supplemented with 10%

CG resulted in a higher economic return compared to fattening intact male goats with the same diet. The lowest economic return was observed when fattening intact goats with the control diet. Nevertheless, using a diet containing 10% CG for fattening goats may serve as an alternative for those seeking to avoid ethical and animal welfare concerns. In addition, fattening goats with a diet containing 10%GC could be a potential option for producers seeking a more commercially viable approach.

Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Animal Ethics Declaration

All experimental procedures involving animals were approved by the Unit of Research and Acadermic Services, Faculty of Natural Resources, Prince of Songkla University (20/03/2016).

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