Open Access
Asian-Australas J Anim Sci
Vol. 30, No. 12:1711-1717 December 2017
https://doi.org/10.5713/ajas.17.0066
pISSN 1011-2367 eISSN 1976-5517

AJAS
Asian-Australasian Journal of Animal Sciences

Effect of supplementary glycerin on milk composition and heat stability in dairy goats

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Submitted Feb 4, 2017; Revised Mar 14, 2017; Accepted May 2, 2017

Objective: This experiment was studied the effects of various levels of crude glycerin (CG) in dairy goat diet on daily intake, milk yield, milk composition, some physical properties and some quality changes of goat milk after sterilization.
Methods: Twelve 75% Saanen dairy goats (body weight = 49±3 kg; days in milk = 60±12 d) were randomly assigned in a completely randomized design to evaluate the effects of three experimental diets consisting of 0%, 5%, and 10% CG (dry matter basis) which were formulated to meet or exceed the nutrient requirements of goats. Experimental dairy goats were evaluated for feed and milk yield. Milk samples were analyzed for their composition, including fatty acids, casein profile, fat globule size, and color, and were sterilized to evaluate milk heat stability.
Results: There were no significant differences between 0% and 5% CG treatments infeed. Increasing CG supplementation from 0% to 5% increased milk yield from 2.38±0.12 to 2.64±0.23 kg/goat/d. In addition, milk samples from 5% CG treatment had the highest total solids, fat content and lactose content, and largest fat globule size. Increasing CG to 10% resulted in a decrease in milk fat. After sterilizing at 116°C, F_0 = 3 min, goat milk samples from 5% CG treatment had slightly higher sediment content and comparatively higher degree of browning.
Conclusion: Considering milk yield, milk fat content and quality of sterilized milk, 5% CG supplementation in a total mixed ration has a potential for implementation in dairy goats.

Keywords: Glycerin; Goat Milk; Milk Composition; Milk Sterilization

INTRODUCTION

As an alternative feed for dairy animals, glycerin has become increasingly important for feed cost reduction and milk yield enhancement. Glycerin is a carbohydrate molecule ($C_3H_8O_3$) with gross energy 3,173 to 6,021 kcal/kg [1] or net engry concentration of 1.98 to 2.29 Mcal/kg, which is approximately equal to the energy contained in corn starch [2]. The glycerin used as a feed ingredient usually is a by product of biodiesel production via base-catalyzed esterification of vegetable oil, and amounts to approximately 10% wt of the total biodiesel production since 1 mol of glycerin is produced for every 3 mol of methyl esters. The refined glycerin is known as “glycerol” and can be used in the chemical, textile, pharmaceutical and food industries, whereas unrefined or crude glycerin (CG) can be used in the production of chemicals, fuel additives, hydrogen, ethanol, methanol, and animal feed [3]. Glycerin is recognized as a safe ingredient list for use in animal feeds. Some countries, e.g. Brazil, have defined standards for glycerin use in animal feed and have established specifications for CG (80% glycerin, methanol <150 ppm) that can be used as 10% of an animal feed ration [3].

Glycerin can be converted in the rumen into volatile fatty acid, particularly propionic acid, and butyric acid, which are precursors for glucose synthesis in the liver via gluconeogenesis. There are many reports on the use of glycerin as alternative energy feedstuff for dairy animals, e.g. using

9% glycerin in diets for lactating Nubian goats [4], using 120 g/kg dry matter (DM) as a partial substitute for ground corn in dairy cow rations [5], and supplementing glycerin in a Holstein dairy cow diet with 250 g/d dry glycerol as a top dressing [6].

In our previous study using CG up to 20% of DM in the diet of meat goats, we found no effect on feed intake, digestibility, ruminal fermentation patterns, blood metabolites, and nitrogen utilization [7]. For dairy goats, there is some data on the effect of CG in the diet on milk yield and milk composition, but its effect on milk quality has not been investigated. This is an important point since it is a raw material in milk processing, and ordinary goat milk is usually more sensitive to heat than cow milk [8] due to micellar structure and protein interaction [9]. Thus, the objective of this experiment was to study the effects of various levels of CG in the dairy goat diet on daily intake, milk yield, milk composition, and some physical properties and quality changes of goat milk after sterilization.

MATERIALS AND METHODS

Animals, feed, and management

All procedures involving animals were in accordance with the ethical principles for the use of animals for scientific purposes of the National Research Council of Thailand (NRCT). The experiment was carried out using 12 dairy goats,75% crossbred Saanen (Thai native×Saanen), with 60±10 d in milk and an average body weight (BW) of 49±3 kg. They were kept individually in pens under well-ventilated sheds where water and mineral salt were available at all times. Dairy goats were randomly assigned according to a completely randomized design to investigate the effects of CG on milk composition and certain physicochemical properties. The experimental diets consisted of 0%, 5%, and 10% CG (DM basis) as a replacementforcorn grain, and were formulated to be isonitrogenous at 18% crude protein (CP) and with metabolizable energy 2.90 Mcal/kg DM to meet or exceed the nutrient requirements of goats [10]. The goats were offered the treatment concentrate at a ratio to milk yield of 1:2. Ruzi grass was given on an *ad libitum* basis as roughage. The CG was produced in a palm diesel facility (New Biodiesel, Surat Thani province, Thailand) and contained 87.61% glycerin, 8.07% water, 1.56% chloride, 1.24% sodium, 0.64% methanol, 0.0059% phosphorus and 0.0045% calcium. Palm-derived glycerin from a single batch was added to the total mixed ration as liquid. The ingredients and chemical composition of each diet are presented in Table 1. Each experiment had a period for treatment adaptation of 14 d and an experimental period of 49 d. Milk samples were collected once a week for 7 weeks. During experimental period, daily intake was examined.

Sample collection

All goats were milked twice a day at 07.00 and 17.00 h. The milk yield of individual goats was measured and presented as one-day milk sampling. All samples were separated into two parts. The first part was analyzed for pH, fat globule size, color, and milk fat content on the day of milking. The second part was preserved with sodium acid 2-bromo-2-nitropropane-1 and kept at 4°C for

Table 1. Ingredients and chemical compositions of concentrated diets containing 0%, 5%, and 10% crude glycerin

Items	Dietary crude glycerin (% DM)			Ruzi grass
	0	5	10	
Crude glycerin[1)]	0.00	5.00	10.00	–
Ground corn	57.12	52.12	47.12	–
Leucaenaleafmeal	4.00	4.00	4.00	–
Soybean meal (44% crude protein)	22.38	24.00	24.00	–
Fish meal (55% crude protein)	1.00	1.00	1.00	–
Molasses	3.00	3.00	3.00	–
Palm kernel cake	10.00	8.37	8.21	–
Salt	0.20	0.20	0.20	–
Urea	0.00	0.01	0.17	–
Dicalcium phosphate	0.30	0.30	0.30	–
Mineral and vitamin mix[2)]	2.00	2.00	2.00	–
Chemical composition				
DM	86.43±0.22	86.21±0.08	83.74±0.20	33.32±0.11
Ash	5.74±0.27	5.99±0.22	6.23±0.21	6.62±0.15
CP	18.51±0.33	18.15±0.22	18.70±0.20	6.87±0.21
EE	2.91±0.13	2.71±0.23	2.46±0.03	1.27±0.20
NDF	22.24±0.12	20.98±0.23	20.42±0.14	68.65±0.26
ADF	12.68±0.06	12.04±0.13	11.86±0.15	45.67±0.19

DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; GE, gross energy.
[1)] Contained 87.61% glycerin, 8.07% water, 1.56% chloride, 1.24% sodium, 0.64% methanol, 0.0059% phosphorus and 0.0045% calcium; 3,989.82 GE kcal/kg (colorless, odorless, viscous liquid obtained from Biodiesel Producers, New Biodiesel, Surat Thani province, Thailand).
[2)] Minerals and vitamins: (each kg contains) vitamin A, 10,000,000 IU; vitamin E, 70,000 IU; vitamin D, 1,600,000 IU; Fe, 50 g; Zn, 40 g; Mn, 40 g; Co, 0.1 g; Cu, 10 g; Se, 0.1 g; I, 0.5 g.

analysis of chemical composition. All analysis was completed within 3 days after milking. Samples used for fatty acid and casein profile analysis were kept at –20°C until analyzed.

Chemical compositions of feed and milk samples

Feed samples were oven-dried at 60°C for 72 h and ground to pass through a 1 mm sieve, then analyzed for DM, ash, CP, and ether extract (EE) according to the recommended AOAC method [11]. Contents of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the procedure of Goering and Van Soest [12] for three replicates. Milk samples were analyzed for total solids, protein and fat content by the AOAC method [11], and for lactose content according to the method of Hinton and Macara [13] for three replicates. The total solids content was analyzed by evaporating samples in a water bath at 70°C for 30 min and then dryinginahot-air oven at 105°C until achieving a constant weight; the percentage of total solids = (weight of dried residue/weight of sample)×100. Milk protein content was determined by Kjeldahl method [11].

The percentage of each casein protein was determined by sodium dodecyl sulfate–polyacrylamide gel electrophoresis gel electrophoresis according to the method of Criscione et al [14], and quantitative analyses by densitometry (GS-800 calibrated densitometer; Bio-Rad Laboratories, Hercules, CA, USA). Each casein was calculated as the percentage of total casein protein. Fatty acid composition was analyzed by GC according to method of Lepage and Roy [15]. The fatty acid methyl esters were analyzed by GC (model 6890N, fitted with a flame ionization detector; Agilent Technologies, Santa Clara, CA,USA) on a SP-2560 fused silica capillary column (100 m×0.25 mm) (Sigma-Aldrich, St. Louis, MO, USA). The injector temperature was set at 280°C and the flame ionization detector at 250°C. Each fatty acid (FA) was identified by comparing the retention time with a fatty acid methyl ester standard (Supelco 47885-U; Sigma-Aldrich, USA) and was calculated as a percentage of total FA.

Physicochemical properties of milk

Milk samples were determined for certain physicochemical properties, e.g. fat globule size and color, which might be affected by the treatments. All samples were analyzed in triplicate. Fat globule size was determined under a microscope (CH30; Olympus, Tokyo, Japan). Each microscope field was marked and the area and radius measured for 50 to 60 fat globules. The average area and radius were calculated using the Motic Images Plus 2.0 program. The color of milk samples from each treatment was measured with a MiniScan EZ spectrophotometer (HunterLab, Reston, VA, USA). The results were expressed in accordance with the CIELAB system with reference to Illuminant D65 and with a visual angle of 10°. The L* value corresponded to lightness (0 = dark, 100 = light), a* represented green/red (–a* = greenness, +a* = redness) and b* denoted blue/yellow (–b* = blueness, +b* = yellowness).

Changes after sterilization

All milk samples were determined for % sediment and color after sterilization. Each sample was homogenized using atwo-stage pressure homogenizer (PHD-100, Scientific Promotion Co. Ltd., Bangkok, Thailand). Milk samples were sealed in cans (180 g capacity) and sterilized by steam retort at 116°C, F_0 = 3.4 min. All sterilized samples were analyzed for color and % sediment 1 d after processing. The sediment was analyzed according to the method of Heilig et al [16] by filtering the milk through Whatman No.1 filter paper and drying the sediment at 105°C. The sediment percentage was calculated by % sediment = (weight of sediment/weight of milk)×100. The color of milk samples was measured and expressed as L*, a*, and b* values. Total color differences (ΔE) between control milk (0% CG) and 5 or 10% CG-treated were determined according to the method of Guerra-Hernández [17], using the following equation:

$$\Delta E = (\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$$

Where $\Delta L = L_{\text{control milk}} - L_{\text{CG-treated sample}}$;
$\Delta a = a_{\text{control milk}} - a_{\text{CG-treated sample}}$;
$\Delta b = b_{\text{control milk}} - b_{\text{CG-treated sample}}$.

Statistical analysis

All data were subjected to analysis of variance (ANOVA) [18]. Significant differences between the various glycerin supplements were analyzed by Duncan's multiple range test [19] at a 5% probability level ($p<0.05$).

RESULTS AND DISCUSSION

Chemical composition of feed

The chemical compositions of roughage and experimental diets in the lactation study are presented in Table 1. Experimental diets contained similar concentrations of CP, EE and ADF, but varying amount of DM and NDF. The NDF content of CG treatments was slightly decreased compared with control ($p<0.05$) as the proportion of CG in diets increased due to feeding less corn grain. The differences in DM concentrations among the mixed diets are related to differences in the ingredients used in diet formulation. Diets were formulated to be 18% CP (DM basis).

The average chemical composition of fresh ruzigrass is presented in Table 1; it contained 6.87% CP (1.7% N), 68.65% NDF, and 45.67% ADF.

Daily intake and milk yield

The effects of CG level on feed intake of lactating dairy goats are presented in Table 2. Feed intake was not affected by CG level. Overall mean feed intake for the three diets in terms of dry matter intake (DMI), % BW and g/kg $BW^{0.75}$ was similar for all dietary treatments. However, there was a tendency toward increased DMI as goats were supplemented with CG when compared with goats

Table 2. Effect of dietary crude glycerin levels on daily intake and chemical composition of goat milk

Composition	Dietary crude glycerin (% DM)		
	0	5	10
Daily intake (kg/d)	1.29 ± 0.43	1.39 ± 0.18	1.44 ± 0.26
% Body weight (BW)	2.56 ± 1.04	2.98 ± 0.56	2.87 ± 0.50
g/kg $BW^{0.75}$	67.32 ± 20.33	79.38 ± 12.36	76.34 ± 13.38
Milk yield (kg/d)	2.38 ± 0.12	2.64 ± 0.23	2.54 ± 0.70
Total solids (%)	10.24 ± 0.13^{b}	11.35 ± 0.24^{a}	10.52 ± 0.07^{b}
Fat (%)	2.46 ± 0.16^{b}	3.29 ± 0.35^{a}	2.43 ± 0.12^{b}
Lactose (%)	4.68 ± 0.51	5.19 ± 0.73	5.30 ± 1.02
Protein (%)	2.83 ± 0.03^{a}	2.71 ± 0.09^{b}	2.77 ± 0.02^{ab}
Ash (%)	0.91 ± 0.01^{b}	0.91 ± 0.01^{b}	0.94 ± 0.00^{a}
Calcium (mg/kg milk)	$1,661.00 \pm 11.40^{b}$	$1,957.50 \pm 31.60^{a}$	$1,481.50 \pm 12.45^{b}$
Phosphorus (mg/kg milk)	$1,100.00 \pm 12.15^{a}$	$1,090.00 \pm 9.50^{a}$	910.00 ± 10.40^{b}
Fatty acid (% of total fatty acids)			
$C_{6:0}$	2.01 ± 0.10	2.08 ± 0.14	1.68 ± 0.36
$C_{8:0}$	2.41 ± 0.03	2.80 ± 0.19	2.43 ± 0.11
$C_{10:0}$	8.32 ± 0.10^{c}	10.53 ± 0.10^{a}	9.16 ± 0.06^{b}
$C_{12:0}$	4.85 ± 0.08^{c}	6.09 ± 0.07^{a}	5.39 ± 0.13^{b}
$C_{14:0}$	11.68 ± 0.02^{a}	10.65 ± 0.34^{b}	9.84 ± 0.44^{b}
$C_{15:0}$	1.10 ± 0.01	1.49 ± 0.33	0.95 ± 0.02
$C_{16:0}$	30.57 ± 0.07^{a}	28.21 ± 0.90^{b}	28.07 ± 0.05^{b}
$C_{16:1}$	0.91 ± 0.01^{c}	1.29 ± 0.05^{a}	1.08 ± 0.03^{b}
$C_{18:0}$	10.41 ± 0.21	9.85 ± 0.56	9.88 ± 0.12
$C_{18:1n9t}$	1.93 ± 0.06	1.42 ± 0.76	0.92 ± 0.06
$C_{18:1n9c}$	22.57 ± 0.03^{b}	22.16 ± 0.62^{b}	26.96 ± 0.18^{a}
$C_{18:2n6c}$	2.27 ± 0.06	2.76 ± 0.48	3.05 ± 0.32
$C_{18:3}$	-	-	-
Total CLA	0.97 ± 0.22	0.95 ± 0.28	0.95 ± 0.07
Casein protein (% of total casein protein)			
α_{s2}-casein	16.16 ± 1.03	15.38 ± 2.57	18.05 ± 1.45
β-casein	70.39 ± 1.28	70.25 ± 0.81	68.70 ± 1.05
κ-casein	5.31 ± 1.31	6.05 ± 1.72	5.11 ± 0.43
α_{s1}-casein	8.15 ± 0.85	8.32 ± 1.23	8.06 ± 0.76

DM, dry matter; CLA, conjugated linoleic acid.
a–c Means within rows followed bydifferent superscript letters are significantly different (p < 0.05).

not fed CG. No significant differences attributable to dietary treatment were observed in milk yield, although the average milk yield was numerically higher in glycerin-fed groups. Similar results for daily intake were found in dairy goats (9% CG added in diets) [4] and dairy cows (200 to 400 g glycerin/d) [6]. Comparing 5% and 10% CG supplementation, goats fed a diet with 5% CG added had higher % BW, g/kg $BW^{0.75}$ and milk yield, but the differences were not significant (p>0.05). This might be because CG has a mildly sweet taste, possibly increasing the palatability of the diets, as explained by Kass et al [20]. An interesting result of this study was an increase of milk yield, from 2.38 to 2.64 kg/d, when 5% CG was added to the diet.

Milk composition

Milk samples from supplementing goat diets with 5% CG had higher total solids (11.35%) compared with the 0% CG control (10.20%) (p<0.05) (Table 2). Similar results were obtained for fat content: 3.29% for 5% CG treatment vs 2.46% for the control (p<0.05). Increasing CG to 10% resulted in a decrease in total solids and fat content. CG supplementation also had a slight effect on the lactose content in milk. Increasing the CG level in diets from 0% to 5% and 10% tended to increased lactose in milk, but not significantly. Similar findings were reported by Kass et al [20]. CG supplementation had a slight effect on protein content. The protein in CG treatments was lower than the control, which may not be directly related to the effect of CG but may be a consequence of increased milk volume.

The increased fat content in milk in this case might be due to several reasons: i) an increase in daily intake, as shown in Table 1; ii) CG, a substrate of lactose, is changed to propionic acid (C_3) in the rumen and acts as a substrate for glucose synthesis in the liver via gluconeogenesis [21]; iii) intake of an adequate amount of CG with feed with a high lipid content increases digestibility of lipids [22,23]. Therefore, in addition to dietary lipid supplements which can increase the fat content in goatmilk [24], CG as a carbohydrate supplement tended to increase milk fat as well.

However, 10% CG supplementation in diets caused a decrease in total solids and fat content. A possible explanation was given by Roger et al [22], who showed that excess CG inhibited the growth and cellulolytic activity of ruminal bacteria *in vitro*, e.g. *Ruminococcus flavefaciens* and *Fibrobacter succinogenes*. In addition, AboEl-Nor et al [25] found that a high glycerin content resulted in decreased ruminal pH and affected the efficiency of bacterial fermentation.

Fatty acid and casein protein profile

The special fatty acids in goat milk are medium-chain triglycerides (MCT) C_6–C_{10}: caproic (C6:0), caprylic (C8:0), and capric (C10:0) acids. The combined content of these three FA in goat milk was higher than in cow milk and had widely discuss on effect of feeding on this MCT group. In this research, the MCT of milk samples from 5% CG supplementation was higher than the others (Table 2), and was related to milk yield and fat content. Other FA of interest are conjugated linoleic acids (CLAs); however, in this study total CLAs were not significantly different among treatments.

Milk casein profiles for each treatment are shown in Table 2. The pattern of casein proteins was: α_{s2}-casein, β-casein, κ-casein, and α_{s1}-casein in ranges of 15.38% to 18.05%, 68.70% to 70.39%, 5.11% to 6.05%, and 8.06% to 8.15% to total casein, respectively. Although increasing the CG content in diets tended to decrease protein content, casein profiles were not significantly different (p>0.05).

Physicochemical properties of goat milk

In milk processing, some physicochemical properties of raw milk are related to papatability and milk heat stability. Only milk that has high heat stability can be used in high heat treatment such as sterilization. Supplementing the diet with CG affected the pH, color and fat globule size of goat milk (Table 3). An increase of CG in the diet led to a decrease in milk pH.

Milk samples from 5% CG treatment had lower L* and b* values. This may not be directly related to the effect of CG, but is a consequence of the fat content in the milk. Even though the color values were slightly different, based on visual observations by the research team the milk color of all treatments appeared similar.

Milk from 0%, 5%, and 10% CG treatments contained fat globules with areas of 5.87, 6.22, and 5.32 m^2 and diameters of 2.70, 2.88, and 2.40 μm, respectively. A similar trend was found for fat content in milk, which was the highest for 5% CG. The high fat content in milk was related to larger-sized fat globules caused by triglyceride deposits [26]. Park et al [27] reported that more than 60% of the fat globules in goat milk had a diameter in the range of 2 to 3 μm, while fat globules in cow milk were about 4.5 μm.

Changes after sterilization

Sterilized milk in this study had a low content of dry sediment, ranging 0.15% to 0.23% of dry sample (Table 4); 5% CG treatmentresulted in the highest sediment level, 0.23%, vs 0.15% for the other treatments (p<0.05). The slightly higher sediment percentage in 5% CG-treated milk might be related to the high total solids, especially fat content, the high calcium content, and products of the Maillard reaction. However, although the difference in %sediment was significant, it was only a very small amount.

Another test was performed to check the heat stability of milk. Samples were heated at 100°C. After 90 min, 2 mL samples were pipetted into a test tube every 2 min. All samples showed a similar result. Some coagulant was found on the side of the test tube after heating for 108 min. Generally, high heat treatment affects the fat, protein and mineral balance in heated milk, which changes its physical properties [9]. In brief, sterilization by heating: i) induces an increase in casein micelle size [28]; ii) creates a complex between β-lactoglobulin and casein micelles [29]; iii) denatures the membranes of fat globules, affecting their agglomeration [30]; iv) increases the Maillard reaction between amino acids and reducing sugars in milk; and v) the solubility of calcium and phosphate was reduced due to their conversion into calcium phosphate salts [9]. In this study, we found a significant difference between 0% and 5% CG treatments in total solids content, fat content, calcium

Table 3. Some physical characteristics of goat milk as affected by dietary crude glycerin

Items	Dietary crude glycerin (% DM)		
	0	5	10
pH	6.62±0.01^a	6.60±0.01^b	6.54±0.01^c
Area (m^2)	5.87±0.37^b	6.22±0.49^a	5.32±0.48^b
Radius (μm)	2.70±0.17^a	2.88±0.10^a	2.40±0.16^b
L*	74.92±0.01^b	72.57±0.02^c	75.31±0.02^a
a*	–4.40±0.01^c	–4.54±0.01^a	–4.50±0.01^b
b*	7.16±0.01^b	5.82±0.01^c	7.64±0.01^a

DM, dry matter.
The L* value corresponded to lightness (0 = dark, 100 = light), a* represented green/red (–a* = greenness, +a* = redness) and b* denoted blue/yellow (–b* = blueness, +b* = yellowness).
$^{a-c}$ Means within rows followed by different superscript letters are significantly different (p<0.05).

Table 4. Effects of glycerin in goat ration on sediment and color of sterilized goat milk

Items	Dietary crude glycerin (% DM)		
	0	5	10
Sediment (% of dry sample)	0.15±0.03^b	0.23±0.03^a	0.15±0.01^b
L*	71.21±0.11^b	72.80±0.22^a	69.96±0.22^b
a*	4.91±0.19^b	4.61±0.21^b	6.13±0.25^a
b*	13.74±0.33^c	14.13±0.86^b	17.50±0.94^a
ΔE	-	1.74±0.14^b	3.92±0.52^a

DM, dry matter.
The L* value corresponded to lightness (0 = dark, 100 = light), a* represented green/red (–a* = greenness, +a* = redness) and b* denoted blue/yellow (–b* = blueness, +b* = yellowness).
$^{a-c}$ Means within rows followed by different superscript letters are significantly different (p<0.05).

content, and average fat globule size. This might be the reason for % sediment differences.

CG supplementation and sterilization also had an effect on milk color. Increasing the CG in diets resulted in a decrease in L* value and an increase in a* and b* values (Table 4), which indicated browning. Generally, the brown color of sterilized milk is from pyrrolysine and melanoidins, products of the Maillard reaction in which lactose and amino acids in milk are substrates. The differences in color among samples might result from the varying lactose content, similar to the results shown in a report by Shimamura and Ukeda [31]. This research foundthat milk from 10% CG treatment, which had the highest lactose content (Table 2), showed the highest degree of browning. There was a significant difference ($p<0.05$) in milk color (ΔE) between the 10% CG and 5% CG treatment groups (Table 4).

CONCLUSION

Supplementation of the dairy goat diet with CG at 0%, 5%, and 10% DM was studied in terms of feed intake, % BW, g/kg $BW^{0.75}$, milk yield, milk composition, and some quality changes of the sterilized goat milk. Feed intake was not affected by CG level. Other results indicated that 5% CG treatment resulted in slightly higher % BW and g/kg $BW^{0.75}$ ($p>0.05$) and significantly higher milk yield, total solids in milk, milk fat, and fat globule size ($p<0.05$). When the milk sample was sterilized, there was a positive relationship between total solids in milk and % sediment and also between lactose and degree of browning. The 5% CG treatment, which had the highest total solids and fat content, had the highest %sediment, whereas the 10% CG treatment, which had the highest lactose content, showed the highest color differences. However, the % sediment and color differences were very small. In summary, in this study 5% CG supplementation was the optimal concentration as a partial substitute for ground corn in dairy goat rations.

CONFLICT OF INTEREST

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

ACKNOWLEDGMENTS

The authors would like to thanks the Halal Food Science Center, Department of Food Science and Nutrition, Prince of Songkla University, Pattani Campus for providing the financial support for the research and the use of the research facilities.

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