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Effect of Feeding Discarded Durian Peel Ensiled with *Lactobacillus casei TH14* and Additives in Total Mixed Rations on Digestibility, Ruminal Fermentation, Methane Mitigation, and Nitrogen Balance of Thai Native–Anglo-Nubian Goats

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Abstract: The objective of this study was to evaluate the effect of fermented discarded durian peel with *Lactobacillus casei* TH14, cellulase, and molasses separately or in combination in total mixed rations on feed utilization, digestibility, ruminal fermentation, and nitrogen utilization in growing crossbreed Thai Native–Anglo-Nubian goats. Five crossbreed Thai Native–Anglo-Nubian goats (50%) at 9 to 12 months of age and 20 ± 1 of body weight (BW) were assigned to a 5 × 5 Latin square design. Evaluated treatments were fermented discarded durian peel without additives (FDP), fermented discarded durian peel with 5% of molasses (FDPM), fermented discarded durian peel with 2% of cellulase (FDPC), fermented discarded durian peel with 1.0×10^5 cfu/g fresh matter of *L. casei* TH14 (FDPL), and fermented discarded durian peel with 5% of molasses and 1.0×10^5 cfu/g fresh matter of *L. casei* TH14 (FDPML). This study showed that acid detergent fiber intake was different ($p < 0.05$) between goats fed FDP and those fed FDPLM, 0.24 g/d and 0.20 g/d, respectively. The FDPML ration had significantly ($p < 0.05$) greater apparent nutrient digestibility and a better propionate concentration compared with other treatments. FDPML treatment significantly ($p < 0.05$) decreased the acetate-to-propionate ratio, methane production, and urinary nitrogen. Therefore, treated discarded durian peel with molasses and *L. casei* TH14 in combination could add 25% of dry matter into the diet for growing goats without a negative impact.

Keywords: goat feeding; durian peel; silage additives; propionate; methane mitigation; nitrogen balance

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1. Introduction

Durian, a seasonal fruit, is grown widely in tropical countries, where Malaysia and Thailand are the main producers [1]. Approximately 20 to 30% of durian is appropriate for human consumption, and 80 to 70% accounts for the durian peel, which is discarded as waste [2]. Discarded durian peel (DP) contains 10.30% crude protein (CP), 3.24% fat, 22.33% crude fiber (CF), 50.51% nitrogen-free extract (NFE), 9.50% cellulose, and 10.32% acid detergent lignin (ADL) [3]. Due to a high NFE content, DP spoils shortly after discarding. Ensiling is a well-known technique and is used to preserve high-fermentable-containing feed resources using lactic acid bacteria (LAB), converting sugar into lactic acid, resulting in low pH [4]. Ensiling additives including *Lactobacillus* strains, cellulase, and molasses are usually added to improve fermentation quality [5–8]. *Lactobacillus casei* TH14 (*L. casei* TH14), LAB strain, is a local strain isolated from sweet corn silage, which has high lactic acid production with a low pH range [9]. Cellulase is a popular fibrolytic enzyme added to break down cellulose, releasing soluble carbohydrate for LAB growth [10,11], while

molasses is added as a carbon source for LAB to ensure adequate lactic acid production if ensiling materials contain low water-soluble carbohydrate numbers [5]. Using *L. casei* TH14, cellulase and molasses have been reported to improve quality of sorghum [4], rice straw [12], and sugarcane bagasse [5]. In addition to fermentation quality improvement, *L. casei* TH14, cellulase, and molasses addition also improves feed utilization, propionate production, and methane mitigation [7,8,13]. However, the effect of *L. casei* TH14, cellulase, and molasses on DP quality and using fermented DP as roughage source in goat rations have never been evaluated. This study hypothesized that *L. casei* TH14 combined with molasses could improve DP quality, nutrient digestibility, propionate production, and methane mitigation. The objective of this study was to evaluate the effect of fermented discarded durian peel with *Lactobacillus casei* TH14, cellulase, and molasses separately or in combination in total mixed rations on feed utilization, digestibility, ruminal fermentation, and nitrogen utilization in growing crossbreed Thai Native–Anglo-Nubian goats.

2. Materials and Methods

2.1. Animal Ethics

The use of goats in this study was approved (MHESI 68014/674) by Institutional Animal Care and Use Committee, Prince of Songkla University.

2.2. Animals and Experimental Design

Five crossbreed Thai Native–Anglo-Nubian goats (50%) at 9 to 12 months of age and 20 ± 1 of body weight (BW) were used in this study. All goats were injected with ivermectin (IDECTIN® The British Dispensary (L.P.) CO., Ltd., Bangkok, Thailand) with 1 mL dose per 50 kg of BW to kill parasites before starting the experiment. Goats were assigned to a 5×5 Latin square design. Treatments were fermented discarded durian peel without additives (FDP), fermented discarded durian peel with 5% of molasses (FDPM), fermented discarded durian peel with 2% of cellulase (FDPC), fermented discarded durian peel with 1.0×10^5 cfu/g fresh matter of *L. casei* TH14 (FDPL), and fermented discarded durian peel with 5% of molasses, and 1.0×10^5 cfu/g fresh matter of *L. casei* TH14 (FDPML).

2.3. Fermented Discarded Durian Peel Preparation

Discarded durian peel (Monthong-*Durio zibthinus Murray*) was obtained from Seahorse Intertrade Company Limited in Chana District, Songkhla Province, Thailand, and cut into 1 to 2 cm pieces. Then, discarded durian peel was fermented with the respective additives including molasses at 5% [5], cellulase at 2% [14], and *L. casei* TH14 at 1.0×10^5 cfu/g fresh matter [4]. Cellulase (powder form, 5×10^5 U/g activity, CAS number: 9004-34-6, Sinobios Imp. & Exp., Thanghai, China) and *L. casei* TH14 as a silage starter (composed of 80% trehalose, 15% lactose, and 1.0×10^{11} cfu/g *L. casei* TH14; Bio Ag Khon Kaen, Khon Kaen, Thailand) were used. Molasses was purchased from a local supplier located in Hat Yai District, Songkla Province, Thailand. Additives were dissolved in clean water, sprayed on discarded durian peel, mixed well, and fermented in 50 L plastic buckets (Changzhou Treering Plastics Co., Ltd., Changzhou, China) for 30 days. After fermenting for 30 days, fermented discarded durian peel samples were collected, dried at 60 °C for 72 h, and ground into 1 mm pieces to analyze the dry matter (DM), CP, and ash according to AOAC [15], and neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin according to Van Soest et al. [16]. The chemical composition of fermented discarded durian peel is provided under Table 1. Fermentation characteristics of fermented DP were assessed. pH was measured according to Chen et al. [14] using pH meter (HANNA instruments HI 98153 microcomputer pH meter, Kallang Avenue, Singapore); briefly, 20 g of fermented DP samples were taken and mixed with 80 mL of distilled water and kept at 10 °C for 24 h. Samples were prepared with ammonia nitrogen (NH_3–N) using spectrophotometer (UV/VIS Spectrometer, PG Instruments Ltd., London, UK) and volatile fatty acids (lactic acid, acetate, and butyrate) using gas chromatography and analyzed according to So

et al. [8] The pH, NH_3–N, lactate, acetate, and butyrate of fermented discarded durian peel are provided in Table 1.

Table 1. Nutrient composition of TMR diets, rice straw, and fermented discarded durian peel quality treated with or without additives.

Nutrient Composition (% of DM)	Treatments					Rice Straw
	FDP	FDPM	FDPC	FDPL	FDPML	
DM	42.50	42.72	37.20	37.77	37.53	92.12
OM	93.27	93.26	93.09	93.28	93.96	91.80
CP	15.51	15.39	15.80	15.39	15.69	2.81
NFC †	10.82	12.30	19.55	17.21	21.49	12.72
NDF	65.45	63.12	57.26	57.30	57.01	74.71
ADF	29.75	28.51	28.28	27.41	27.22	56.55
ADL	8.52	7.98	8.26	6.74	6.59	4.59
GE kcal/kg DM	4361.00	4306.26	4315.18	4363.60	4315.40	3501.53
Fermented discarded durian peel quality						
DM, %	17.0	17.3	16.5	16.5	17.4	
OM, % of DM	94.0	93.4	92.9	93.7	93.4	
CP, % of DM	7.3	8.3	7.2	7.2	7.5	
NDF, % of DM	62.5	61.0	73.4	61.9	65.5	
ADF, % of DM	41.7	38.6	45.8	43.9	42.3	
GE, kcal/kg DM	4413.8	4314.7	4737.4	4449.1	4205.4	
pH	3.74	3.79	3.66	3.73	3.74	
NH_3–N, % of CP	1.29	0.70	1.18	0.74	0.89	
Lactic acid, % of DM	10.12	10.79	10.89	10.54	10.98	
Acetic acid, % of DM	1.02	1.05	1.07	1.04	1.09	
Butyric acid, % of DM	1.32	1.30	1.37	1.29	1.28	

FDP = untreated discarded durian peel in TMR; FDPM = treated discarded durian peel with molasses in TMR; FDPC = treated discarded durian peel with cellulase in TMR; FDPL = treated discarded durian peel with *L. casei* TH14 in TMR; FDPML = treated discarded durian peel with molasses and *L. casei* TH14 in TMR. TMR compositions contain 25% fermented discarded durian peel with or without additives, 15% rice straw, 35.8% ground corn, 7.9% soybean meal, 0.4% fish meal, 5.4% leucaena meal, 7.2% palm kernel cake, 2.2% molasses, 0.3% dicalcium phosphate, 0.2% salt, and 0.6% premix. Premix per 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; and I: 0.5 g. DM = dry matter; OM = organic matter; CP = crude protein; NFC = non-fiber carbohydrate; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; GE = gross energy. † NFC = 100 − (% NDF + % CP + % EE + % ash) [17].

2.4. Feeding, Sample Collection, and Analysis

Feeding trial consisted of five 21-day periods, in which 14 days were used for dietary treatment adaptation and 7 days were used for sample analysis. Goats were separately stored in pens (0.11 × 0.95 m) with free access to clean water and mineral lick and fed daily *ad libitum* total mixed rations at a 40:60 ratio (25% fermented discarded durian peel, 15% rice straw, and 60% concentrate) at 8:00 a.m. and 16:00 p.m. The diets were formulated to meet the nutrient requirements of goats according to NRC [18], and chemical composition of dietary treatments is provided in Table 1. Diets offered and refusal were recorded daily to calculate DM intake. Goats were weighed at the beginning of the trial and at the end of each period throughout the trial to adjust DM intake and calculate the BW change of goats at the end of the trial.

During the last 7 days of each period, goats were kept in metabolism crate for sample collection and digestibility study. Diet and refusal data were collected throughout 7 days and divided into two portions. The first portion was used to analyze for DM content using oven drying at 100 °C, and second portion was deposited according to goat and period and stored at −20 °C for chemical composition analysis. Fecal and urine samples were gathered using total collection procedure. A total of 200 g of fecal sample was collected and oven-dried at 100 °C for DM analysis, and 5% of total feces was collected, deposited according to goat and period, and stored at −20 °C until analysis. Urine yield was collected using 5 L plastic tank consisting of 1 M H_2SO_4 to prevent nitrogen loss, and 10% of total

urine was taken, deposited according to goat and period, and stored at −20 °C. Before analysis, diet, refusal, and fecal samples were thawed, oven-dried at 60 °C for 72 h, and ground through a 1 mm screen to analyze for DM, CP, and OM using AOAC [15]. The NDF, ADF and ADL content were analyzed using Ankom fiber analyzer according to Van Soest et al. [16]. Gross energy content in diet, refusal, and fecal samples was analyzed using Bomb calorimetry (LECO, Berrien, MI, USA). Urine samples were thawed and analyzed for nitrogen content using AOAC [15] method to study nitrogen balance.

On day 21 of each period, at 0 h before feeding and 4 h after feeding, approximately 100 mL of ruminal fluid was collected using vacuum pump attached with stomach tube. Ruminal pH measurement was conducted immediately using pH meter (HANNA instruments HI 98153 microcomputer pH meter, Kallang Avenue, Singapore). Then, 60 mL of ruminal fluid samples was kept in plastic bottle containing 1 M H_2SO_4 at a ratio 1:10 (1 mL of H_2SO_4: 10 mL of ruminal fluid) and centrifuged at 3000× *g* for 15 min. Approximately 35 mL of supernatant was taken and stored at −20 °C to analyze NH_3–N using Kjeltec Auto 2200 analyzer (Foss, Tecator, UK) according to Bremner and Keeney [19] and volatile fatty acid including acetate, propionate, and butyrate were analyzed using gas chromatography (model HP6890, Hewlett-Packard, Palo Alto, CA, USA; column: Restek 1207384, Stabilwax −60 °C−250 °C, 30 m × 250 µm × 0.25 µm) according to Osaki et al. [20] as described by So et al. [8] Methane (CH_4) production was estimated using Moss et al. [21] equation, CH_4 (g/d) = 0.45 × acetate—0.275 × propionate + 0.4 × butyrate. Another 1 mL of ruminal fluid sample was kept in plastic bottle consisting of 9 mL of 10% formalin and stored in 4 °C in a refrigerator to count bacteria, protozoa, and fungi population using total direct count technique according to Galyean [22].

On day 21 of each period, samples of approximately 3 mL of blood were collected from the jugular vein at 0 h before feeding and 4 h after feeding and placed in heparinized tubes. Then, blood samples were centrifuged at 3000× *g* for 10 min, and plasma samples were taken and stored at −20 °C until analysis. Plasma samples were sent to Stanbio Laboratory (An EKF Diagnostics Company, Boerne, TX, USA) and used to analyze blood urea nitrogen (procedure no. 2020), glucose (procedure no. 1070), total protein (procedure no. 0250), and albumin (procedure no. 0285). Pack cell volume was measured using micro-hematocrit method, and mean corpuscular hemoglobin concentration, globulin, and albumin to globulin ratio were obtained by calculation. Hemoglobin was measured using commercial kits (Diamond Diagnostics, Egypt). Red blood cell count, mean corpuscular volume, and RBC distribution width were measured using hematological analyzer (ABX Micros 60, HORBA ABX, France).

2.5. Statistical Analysis

All data were analyzed using *Proc* Mixed model of SAS as follows:

$$Y_{ijkl} = \mu + \rho_i + \gamma_j + t_l + \tau_k + \varepsilon_{ijkl} \quad (1)$$

where Y_{ijkl} are the observation parameters, μ is the overall mean, ρ_i is the random effect of animal, γ_j is the random effect of periods, t_l is the random effect of time, τ_k is the fixed effect of treatments, and ε_{ijkl} is the error term. Differences among treatments were compared using Duncan's multiple range test, statistically accepted at $p < 0.05$.

3. Results

3.1. Nutrient Content of Diets

Dietary treatments were formulated to have approximately 15% CP content (Table 1). NFC, NDF, ADF, and ADL content varied among dietary treatments due to the quality of untreated and treated discarded durian peel used in the formulation. The diet containing untreated discarded durian peel (FDP) showed the highest NDF, ADF, and ADLs content and the lowest NFC content compared with FDPM, FDPC, FDPL, and FDPML diets. The chemical composition of untreated and treated discarded durian peel is provided (footnote of Table 1).

3.2. Nutrient Intake and Body Weight Change

Table 2 presents the intake of DM, OM, CP, NDF, and ADF, weight gain, and BW change in growing goats fed TMR containing untreated and treated discarded durian peel with additives. DM, OM, CP, and NDF intake were not different among treatments except ADF. ADF intake was different ($p < 0.05$) between FDP and FDPLM, which contained 0.24 g/d and 0.20 g/d, respectively. Weight gain and BW change in goats were not affected ($p > 0.05$) by dietary treatments.

Table 2. Effects of untreated and treated discarded durian peel in TMR on intake and body weight change in growing goats.

Items	Dietary Treatments					SEM	*p*-Value
	FDP	FDPM	FDPC	FDPL	FDPML		
DM intake							
kg/d	0.796	0.757	0.785	0.797	0.806	0.02	0.56
%BW	2.96	2.84	2.89	2.94	3.04	0.06	0.28
g/kg $BW^{0.75}$	67.39	64.44	66.08	67.66	68.98	1.56	0.35
			Nutrient intake, g/d				
OM	0.752	0.696	0.711	0.744	0.712	0.03	0.54
CP	0.125	0.115	0.120	0.123	0.119	0.01	0.42
NDF	0.528	0.471	0.437	0.457	0.432	0.02	0.05
ADF	0.236 ^{a}	0.215 ^{ab}	0.216 ^{ab}	0.216 ^{ab}	0.199 ^{b}	0.01	0.04
Weight gain, kg	2.40	1.90	1.90	2.80	2.30	0.38	0.45
BW change, kg/d	0.114	0.090	0.090	0.132	0.110	0.01	0.46
BW change,%	9.17	7.61	7.12	10.70	9.00	1.36	0.41

SEM = standard error of the mean; $BW^{0.75}$ = metabolic body weight; DM = dry matter, OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; BW = body weight. ^{a,b} Means in the same row with different letters differ ($p < 0.05$).

3.3. Apparent Nutrient Digestibility, Digestible Nutrient Intake, and Energy Intake

Apparent total tract digestibility was affected significantly ($p < 0.05$) by dietary treatments (Table 3). DM, OM, CP, NDF, and ADF digestibility were significantly lower in FDP compared with FDPML. FDPM, FDPC, FDPL, and FDPML were comparable in terms of DM, OM, CP, NDF, and ADF digestibility. Digestible nutrient intake including OM, CP, NDF, and ADF was not different ($p > 0.05$) among treatments. Estimated ME intake, expressed as Mcal/d, was not significant among treatments; however, estimated ME intake, expressed as per kg DM intake, was significant ($p < 0.05$) among treatments. ME intake, expressed as per kg DM intake, was significantly observed between FDP, FDPM and FDPML, in amounts of 2.55 Mcal/kg DM, 2.62 Mcal/kg DM, and 2.69 Mcal/kg DM, respectively.

Table 3. Effects of untreated and treated discarded durian peel in TMR on nutrient digestibility and digestible nutrient intake of growing goats.

Items	Dietary Treatments					SEM	*p*-Value
	FDP	FDPM	FDPC	FDPL	FDPML		
Apparent total tract digestibility, %							
DM	70.42 ^{b}	72.79 ^{a}	73.91 ^{a}	74.07 ^{a}	73.81 ^{a}	0.45	<0.01
OM	71.82 ^{b}	73.95 ^{a}	75.02 ^{a}	75.48 ^{a}	75.16 ^{a}	0.49	<0.01
CP	68.42 ^{c}	71.11 ^{b}	72.66 ^{ab}	73.07 ^{ab}	73.63 ^{a}	0.61	<0.01
NDF	63.83 ^{b}	70.48 ^{a}	70.23 ^{a}	70.96 ^{a}	71.03 ^{a}	0.47	<0.01
ADF	40.96 ^{b}	47.13 ^{a}	47.09 ^{a}	47.10 ^{a}	46.08 ^{a}	0.96	<0.01
Digestible nutrient intake, kg/d							
OM	0.543	0.515	0.534	0.562	0.536	0.02	0.47
CP	0.087	0.084	0.086	0.090	0.087	0.01	0.68
NDF	0.338	0.332	0.307	0.325	0.307	0.01	0.21
ADF	0.098	0.102	0.102	0.102	0.092	<0.01	0.38
Estimated energy intake †							
ME Mcal/d	2.06	1.96	2.03	2.14	2.04	0.07	0.48
ME Mcal/kg DM	2.55 ^{c}	2.62 ^{b}	2.65 ^{ab}	2.68 ^{ab}	2.69 ^{a}	0.02	<0.01

FDP = untreated discarded durian peel; FDPM = treated discarded durian peel with molasses; FDPC = treated discarded durian peel with cellulase; FDPL = treated discarded durian peel with *L. casei* TH14; FDPML = treated discarded durian peel with molasses and *L. casei* TH14; SEM = standard error of the mean; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ME = metabolizable energy. $^{a–c}$ Means in the same row with different letters differ ($p < 0.05$). † 1 kg DOM = 3.8 Mcal ME/kg [23].

3.4. Rumen Fermentation Characteristics

Dietary treatments significantly affected ruminal pH and NH_3–N but not ruminal temperature (Table 4). Mean ruminal pH and NH_3–N were significantly ($p < 0.05$) observed between FDP and FDPML but FDPM, FDPC, FDPL, and FDPML were comparable. Ruminal pH and NH_3–N were 6.71 and 22.58 mg/dL in FDP and 6.44 and 17.29 mg/dL in FDPML, respectively. Dietary treatments significantly affected propionate concentration, the acetate-to-propionate ratio and acetate—butyrate-to-propionate ratio except total VFA, acetate, and butyrate concentration. The propionate concentration was significantly higher, while the acetate-to-propionate ratio and acetate—butyrate-to-propionate ratio were significantly lower in FDPML than FDP, FDPM, FDPC, and FDPL. FDPML showed the highest mean propionate concentration (20.31%) and lowest mean acetate-to-propionate ratio (3.58) and acetate + butyrate-to-propionate ratio (3.94). CH_4 production was affected significantly ($p < 0.05$) by dietary treatments. Mean CH_4 production was significant between FDP and FDPML, at 32.93 g/d and 29.41 g/d, respectively, but FDP, FDPM, FDPC, and FDPL were comparable for CH_4 production.

Table 4. Effects of untreated and treated discarded durian peel on rumen characteristics in growing goats.

Items	Dietary Treatments					SEM	*p*-Value
	FDP	FDPM	FDPC	FDPL	FDPML		
Ruminal pH							
0 h	6.61	6.56	6.55	6.56	6.50	0.09	0.94
4 h	6.81	6.64	6.39	6.57	6.39	0.11	0.06
Mean	6.71 ^{a}	6.60 ^{ab}	6.47 ^{b}	6.56 ^{ab}	6.44 ^{b}	0.05	0.04
Temperature, °C							
0 h	39.0	39.2	39.0	39.2	39.2	0.15	0.50
4 h	39.6	39.4	39.2	39.2	39.6	0.25	1.00
Mean	39.3	39.3	39.1	39.2	39.4	0.19	0.78
Ammonia–nitrogen, mg/dL							
0 h	22.29 ^{a}	18.57 ^{b}	20.29 ^{ab}	19.14 ^{b}	18.00 ^{b}	0.78	0.02
4 h	22.86 ^{a}	18.57 ^{b}	18.29 ^{b}	18.57 ^{b}	16.57 ^{b}	0.63	<0.01
Mean	22.58 ^{a}	18.57 ^{b}	19.29 ^{b}	18.86 ^{b}	17.29 ^{b}	0.43	<0.01
Total volatile fatty acid, mM/L							
0 h	86.50	93.13	97.63	96.79	99.54	6.26	0.62
4 h	95.12	97.09	100.26	102.30	104.58	8.42	0.93
Mean	90.81	95.11	98.95	99.55	102.06	4.98	0.56
Acetate, %							
0 h	74.17	77.22	75.94	74.31	71.73	1.49	0.17
4 h	73.99	73.77	72.31	72.89	70.75	1.14	0.32
Mean	74.08	75.49	74.12	73.61	71.24	1.21	0.23
Propionate, %							
0 h	13.88 ^{b}	13.23 ^{b}	15.03 ^{b}	15.82 ^{b}	19.77 ^{a}	0.82	<0.01
4 h	16.28 ^{b}	16.83 ^{b}	18.17 ^{b}	17.92 ^{b}	20.85 ^{a}	0.73	<0.01
Mean	15.08 ^{b}	15.03 ^{b}	16.59 ^{b}	16.87 ^{b}	20.31 ^{a}	0.66	<0.01
Butyrate, %							
0 h	9.77	7.81	7.45	8.06	7.18	0.87	0.30
4 h	8.91	7.96	8.32	8.24	7.50	0.54	0.49
Mean	9.34	7.89	7.89	8.15	7.34	0.64	0.31
Acetate:Propionate ratio							
0 h	6.02 ^{a}	5.98 ^{a}	5.32 ^{a}	4.92 ^{a}	3.73 ^{b}	0.38	<0.01
4 h	4.62 ^{a}	4.49 ^{a}	4.16 ^{ab}	4.14 ^{ab}	3.42 ^{b}	0.27	0.05
Mean	5.32 ^{a}	5.23 ^{a}	4.74 ^{a}	4.53 ^{a}	3.58 ^{b}	0.27	<0.01
Acetate + Butyrate:Propionate ratio							
0 h	6.74 ^{a}	6.58 ^{a}	5.85 ^{a}	5.45 ^{a}	4.11 ^{b}	0.40	<0.01
4 h	5.18 ^{a}	4.96 ^{a}	4.62 ^{ab}	4.60 ^{ab}	3.78 ^{b}	0.28	0.04
Mean	5.96 ^{a}	5.77 ^{ab}	5.24 ^{ab}	5.03 ^{b}	3.94 ^{c}	0.27	<0.01
Methane, g/d							
0 h	33.47 ^{a}	34.23 ^{a}	33.02 ^{a}	32.32 ^{a}	29.72 ^{b}	0.65	<0.01
4 h	32.38 ^{a}	31.75 ^{a}	30.88 ^{a}	31.17 ^{a}	29.10 ^{b}	0.56	0.01
Mean	32.93 ^{a}	32.99 ^{a}	31.95 ^{a}	31.74 ^{a}	29.41 ^{b}	0.52	<0.01

FDP = untreated discarded durian peel; FDPM = treated discarded durian peel with molasses; FDPC = treated discarded durian peel with cellulase; FDPL = treated discarded durian peel with *L. casei* TH14; FDPML = treated discarded durian peel with molasses and *L. casei* TH14; SEM = standard error of the mean. $^{a–c}$ Means in the same row with different letters differ ($p < 0.05$).

3.5. Microbial Population

Dietary treatments did not affect ($p > 0.05$) the bacteria, fungal zoospores, total protozoa, *Holotrich* sp., or *Entodiniomorphs sp.* populations (Table 5). The mean total protozoal population was lowest in FDPML, at 2.46 $\times$ 10^6 cell/mL.

Table 5. Effect of untreated and treated discarded durian peel in TMR on ruminal microbe population in growing goats.

Items	Dietary Treatments					SEM	*p*-Value
	FDP	FDPM	FDPC	FDPL	FDPML		
			Bacteria, $\times 10^{10}$ cell/mL				
0 h	1.60	1.56	1.45	1.35	1.45	1.38	0.50
4 h	1.90	2.20	1.67	1.63	1.56	2.01	0.67
Mean	1.75	1.88	1.56	1.49	1.51	1.67	0.43
			Fungal zoospores, $\times 10^{6}$ cell/mL				
0 h	2.18	1.92	1.67	1.67	1.55	0.29	0.13
4 h	2.25	2.67	2.16	1.65	1.62	0.40	0.19
Mean	2.21	2.29	1.92	1.66	1.59	0.30	0.15
			Total Protozoa, $\times 10^{6}$ cell/mL				
0 h	2.88	2.51	2.47	2.21	2.29	0.26	0.11
4 h	3.16	3.47	3.15	2.63	2.61	0.32	0.13
Mean	3.02	2.99	2.81	2.41	2.46	0.26	0.09
			Holotrich sp., $\times 10^{5}$ cell/mL				
0 h	0.63	0.57	0.40	0.72	0.27	0.28	0.74
4 h	0.50	0.75	0.57	1.07	1.15	0.45	0.34
Mean	0.56	0.66	0.49	0.90	0.72	0.21	0.44
			Entodiniomorphs sp., $\times 10^{6}$ cell/mL				
0 h	2.82	2.45	2.43	2.14	2.26	1.47	0.11
4 h	3.11	3.40	3.09	2.52	2.50	1.44	0.10
Mean	2.96	2.92	2.76	2.32	2.39	1.45	0.13

FDP = untreated discarded durian peel; FDPM = treated discarded durian peel with molasses; FDPC = treated discarded durian peel with cellulase; FDPL = treated discarded durian peel with *L. casei* TH14; FDPML = treated discarded durian peel with molasses and *L. casei* TH14; SEM = standard error of the mean.

3.6. Blood Metabolites

Dietary treatments did not affect ($p > 0.05$) blood metabolites such as glucose, pack cell volume, BUN, total protein, albumin, globulin, the albumin-to-globulin ratio, red blood cells, hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin concentration, or the RBC distribution width (Table 6). FDPML had a lower BUN concentration and higher blood glucose concentration compared with FDP, FDPM, FDPC, and FDPL.

Table 6. Effects of untreated and treated discarded durian peel in TMR on blood metabolites in growing goats.

Attribute	Dietary Treatments					SEM	*p*-Value
	FDP	FDPM	FDPC	FDPL	FDPML		
Glu, mg/dL	68.70	70.00	69.90	70.00	70.20	1.68	0.99
PCV, %	28.40	28.70	29.30	29.40	28.20	0.57	0.51
BUN, mg/dL	20.97	20.09	20.54	20.45	17.62	1.24	0.10
TP, g/L	6.21	6.19	6.33	6.24	6.20	0.08	0.82
ALB, g/L	3.67	3.68	3.71	3.69	3.70	0.03	0.92
GLB, g/L	2.53	2.51	2.62	2.54	2.50	0.06	0.73
A/G ratio	1.46	1.50	1.44	1.49	1.50	0.03	0.61
RBC, $10^{6}/\mu L$	4.39	4.52	4.68	4.36	4.17	0.12	0.05
Hb, g/dL	10.60	10.65	10.92	10.84	10.87	0.23	0.67
MCV, fL	64.92	63.62	62.97	67.69	67.93	1.42	0.05
MCHC, g/dL	37.28	37.21	37.27	36.99	37.11	0.32	0.96
RDW, %	29.10	29.20	29.50	29.12	29.25	0.29	0.87

FDP = untreated discarded durian peel; FDPM = treated discarded durian peel with molasses; FDPC = treated discarded durian peel with cellulase; FDPL = treated discarded durian peel with *L. casei* TH14; FDPML = treated discarded durian peel with molasses and *L. casei* TH14; SEM = standard error of the mean; Glu = glucose; PCV = pack cell volume; BUN = blood urea nitrogen; TP = total protein; ALB = albumin; GLB = globulin; A/G ratio = albumin-to-globulin ratio; RBC = red blood cell; Hb = hemoglobin; MCV = mean corpuscular volume; MCHC = mean corpuscular hemoglobin concentration; RDW = RBC distribution width.

3.7. Nitrogen Utilization

Dietary treatments did not affect ($p > 0.05$) nitrogen intake, total nitrogen loss, fecal nitrogen, nitrogen absorption, or nitrogen retention but significantly affected urinary nitrogen (Table 7). Urinary nitrogen was significantly observed between FDP and FDPML, 2.58 g/d and 2.32 g/d, respectively. Apparent nitrogen absorption expressed as % of nitrogen intake was significant among treatments, in which FDPML had the highest apparent nitrogen absorption, 73.63% of nitrogen intake, respectively.

Table 7. Effects of untreated and treated discarded durian peel in TMR on nitrogen utilization in growing goats.

Items	Dietary Treatments					SEM	*p*-Value
	FDP	FDPM	FDPC	FDPL	FDPML		
Balance, g/d							
N intake	20.03	18.39	19.31	19.65	19.03	0.60	0.41
Total N loss	8.34	7.55	7.55	7.77	7.23	0.37	0.40
Fecal N	5.77	5.27	5.24	5.25	4.97	0.15	0.05
Urine N	2.58 ^{a}	2.28 ^{b}	2.32 ^{b}	2.52 ^{a}	2.32 ^{b}	0.30	0.03
Absorbed N	14.27	13.12	14.07	14.40	14.06	0.48	0.93
Retained N	11.69	10.84	11.75	11.88	11.74	0.45	0.39
% of N intake							
Fecal N	29.19	28.90	27.34	26.94	26.37	0.41	0.05
Urine N	13.18	12.32	11.78	12.96	11.85	1.44	0.94
Absorbed N	70.81 ^{b}	71.10 ^{b}	72.66 ^{a}	73.06 ^{a}	73.63 ^{a}	0.40	<0.01
Retained N	57.63	58.78	60.88	60.10	61.79	1.48	0.35

FDP = untreated discarded durian peel; FDPM = treated discarded durian peel with molasses; FDPC = treated discarded durian peel with cellulase; FDPL = treated discarded durian peel with *L. casei* TH14; FDPML = treated discarded durian peel with molasses and *L. casei* TH14; SEM = Standard error of the mean. ^{a,b} Means in the same row with different letters differ ($p < 0.05$).

4. Discussion

Using untreated and treated discarded durian peel at the same amount in the diet mainly caused a change in fiber content such as NDF and ADF content. Using untreated discarded durian peel in the diet (FDP) had a higher NDF and ADF content compared with diets containing discarded durian peel treated with molasses (FDPM), discarded durian peel treated with cellulase (FDPC), discarded durian peel treated with *L. casei* TH14 (FDPL) and discarded durian peel treated with molasses and *L. casei* TH14 (FDPML). This was caused by the higher NDF and ADF content presented in untreated discarded durian peel than treated discarded durian peel. A lower NDF and ADF content in treated discarded durian peel is due to acid hydrolysis action during fermentation and cellulase activity. So et al. [7] used sugarcane bagasse treated with molasses in combination with cellulase or *L. casei* TH14 in TMR for dairy cows had a lower NDF content compared with the TMR diet containing untreated sugarcane bagasse. Oba and Allen [24] stated that fiber intake, ruminal fermentation, and production efficiency could be influenced by dietary NDF content and digestibility.

In this study, the intake of DM, expressed as either kg/d or %BW or g/kg $BW^{0.75}$, was not significant among treatments. Thus, using untreated or treated discarded durian peel with additives at 25% DM in the diet did not affect the daily DM intake of growing goats. Similarly, So et al. [7] found that 50% DM of untreated and treated sugarcane bagasse combined with additives in TMR diets did not affect the daily DM intake of dairy cows. This suggests that any roughage feeds treated with or without silage additives does not affect the DM intake in ruminants. Intake of ADF (g/d) was significantly different between the FDP and FDPML treatments. The reason for this effect is not clear, although DM, OM, and NDF intake were not different among these treatments. So et al. [7] found nutrient intake was unchanged in dairy cows fed TMR containing untreated and treated sugarcane bagasse with additives. Cherdthong et al. [13] fed untreated and treated rice straw with

molasses in combination with cellulase or *L. casei* TH14 to Thai Native beef cattle and found no effect on nutrient intake. Dietary treatments did not affect weight gain or BW change in growing goats. The effect of additives in combination on performance is small and unclear [25]. Addah et al. [26] compared untreated and treated whole-crop barley with inoculant combination (*L. buchneri*, *L. plantarum*, and *L. casei*) and found no change in weight gain in growing feedlot steers.

Using pretreatment roughage feeds with additives such as LAB, molasses, and fibrolytic enzymes in the diet has been reported to improve nutrient digestibility in the rumen [6,7,13,27]. Additives contribute two mechanisms during fermentation: (1) acid hydrolysis reaction and (2) direct effect of fibrolytic enzymes on polysaccharide structure, which increases feed digestion efficiency of ruminal microbes [10,28]. This study showed that FDPM, FDPC, FDPL, and FDPML were significantly better in terms of DM, OM, CP, NDF and ADF digestibility compared with FDP. This could be due to the pretreatment effect of molasses, cellulase, and *L. casei* TH14 during fermentation of carbohydrate structures, subsequently resulting in nutrient digestibility improvement. So et al. [7] reported that *L. casei* TH14, cellulase, and molasses in combination with treated sugarcane bagasse significantly increased OM, CP, NDF, and ADF digestibility in dairy cows fed TMR diets compared with untreated sugarcane bagasse. Zhao et al. [29] evaluated the in vitro degradability of untreated rice straw and rice straw treated with *L. plantarum* and molasses and found a significant improvement in DM and NDF degradability by *L. plantarum* and molasses in combination. FDPML significantly increased estimated ME intake expressed per kg DM intake compared with FDP. This could be due to a significantly higher OM digestibility found in FDPML than FDP. So et al. [7] similarly found that a combination of sugarcane bagasse treated with molasses and *L. casei* TH14 in TMR-fed dairy cows increased their estimated ME intake compared untreated sugarcane bagasse.

Ruminal pH significantly determines the normal function of microbes in the rumen [30–33]. The normal ruminal pH ranges from 5.5 to 7.0 [34]. This study showed that FDPML significantly decreased the mean ruminal pH by 0.27 compared with FDP; however, the pH was in a normal range (6.4 to 6.7). This could be due to the higher lactic acid and LAB population found in FDPML than FDP. In addition, a significantly higher propionate concentration in FDPML compared with FDP could contribute to a lower pH in FDPML compared with FDP. pHs ranging from 6.4 to 6.7 showed improved fiber digestibility (Table 3) as activity of cellulolytic bacteria slows down at a pH less than 6 [35]. Similarly, So et al. [7] showed that a combination of sugarcane bagasse treated with molasses and *L. casei* TH14 in TMR fed to dairy cows significantly decreased their ruminal pH by 0.07 after 4 h of feeding. Zhang et al. [36] revealed that whole-plant corn ensiled with complex inoculants (*L. plantarum* L28, *Enterococcus faecium* EF08, and *Lactobacillus buchneri* LBC136) significantly decreased ruminal pH by 0.21 compared with ensiled whole-plant corn without inoculants in growing-finishing cattle. Lower ruminal pH leads to lactic-acid-dependent acid production in the rumen and is achieved approximately 2 to 6 h after feeding [30]. Time after offering feed and lactic acid supply rate mainly determine the change in ruminal pH [2,37]. NH_3–N is a main nitrogen source for microbial synthesis in the rumen (5 mg/dL minimum and 30 mg/dL maximum requirement) [38]. Additive-treated discarded durian peel significantly decreased mean NH_3–N concentration. This could be due to the activity of LAB present in fermented discarded durian peel that affected deamination, resulting in less ruminal protein degradation and enhancing nitrogen utilization in the lower digestive tract. So et al. [7] similarly revealed that additives combined with treated sugarcane bagasse significantly decreased NH_3–N concentration from 22 to 20 mg/dL after 4 h of feeding compared with untreated sugarcane bagasse in dairy cows. FDPML significantly increased the propionate concentration, resulting in lowering the acetate-to-propionate ratio and acetate—butyrate-to-propionate ratio compared with other treatments. Increasing the propionate concentration could explain the high nutrient digestibility (Table 3) found in FDPML. In addition, a high lactic acid concentration in FDPML may contribute to an increase in the propionate concentration as lactic acid is

biologically converted into propionate by ruminal microbes in the rumen. Similarly, So et al. [7] showed that *L. casei* TH14 combined with cellulase- and molasses-treated sugarcane bagasse in TMR significantly increased the propionate concentration compared with untreated sugarcane bagasse in dairy cows. Zhang et al. [36] revealed that whole-corn plant treated with complex inoculants significantly increased the propionate concentration from 6.40 mmol/L to 8.98 mmol/L in growing-finishing cattle. Cherdthong et al. [13] similarly found that rice straw treated with *L. casei* TH14 and molasses fed to Thai Native beef cattle significantly increased their propionate concentration from 20.3 mol/100 mol to 23.2 mol/100 mol compared with untreated rice straw. Estimated CH_4 production was significantly lower in FDPML. The reason could be explained by the increase in propionate concentration found in FDPML as hydrogen was used for propionate synthesis, resulting in less hydrogen available in the methanogenesis pathway of methanogen bacteria to produce CH_4 as the main end-product [39]. Similarly, So et al. [7] showed that sugarcane bagasse treated with *L. casei* TH14 combined with cellulase and molasses in TMR fed to dairy cows significantly decreased CH_4 production by 4%. Monteiro et al. [40] tested *L. plantarum* as direct-fed microbial in high-producing cows and similarly found decreased in CH_4 production compared with no additive treatment.

Dietary treatments did not affect bacteria, fungal zoospore, total protozoa, *Holotrich* sp., or *Entodiniomorphs* sp. populations. Ruminal bacteria favor a pH around 7 for optimum growth [35]; this study found the pH ranged from 6.44 to 6.71, which may have contributed to the unchanged bacteria population. Similarly, Bureenok et al. [41] showed that ruzi grass ensiled with molasses or fermented juice of epiphytic lactic acid bacteria fed to cows separately or as a combination did not change ruminal bacteria. However, not all previous studies found unchanged ruminal bacteria when inoculants wer eused. Cherdthong et al. [13] found that rice straw treated with molasses and *L. casei* TH14 combined fed to Thai Native beef cattle significantly increased ruminal bacteria population; the changed in bacteria population may have been due to the optimum ruminal pH ranging from 7.0 to 7.1 for bacteria growth.

Blood metabolites including glucose, pack cell volume, blood urea nitrogen, total protein, albumin, globulin, the albumin-to-globulin ratio, red blood cell, hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin concentration, RBC distribution width, white blood cells, and lymphocytes were similar among dietary treatments. This suggests that the goats were in good health and had a normal metabolism status. Blood metabolites are usually used to evaluate the nutritious plane and health status in ruminants [42,43]. As well as blood metabolites, glucose, blood urea nitrogen, total protein, and albumin concentration were commonly used to evaluate protein and carbohydrate metabolism, where the higher mean value suggests a better nutrient metabolism when these metabolites changed within a normal range [44]. Liver is the main hub where glucose, albumin, and blood urea nitrogen are synthesized [45,46], and glucose and albumin concentrations were greater in goats fed FDPML. Mean glucose concentration ranged from 68.70 to 70.20 mg/dL, which varied in a normal range of 50 to 75 mg/dL [47]. Blood urea nitrogen is the product of NH_3–N recycling and is produced from protein degradation by ruminal microbes [48,49]. The lower blood urea nitrogen paralleled the lower NH_3–N concentration found in goats fed FDPML.

Dietary treatments did not influence nitrogen intake, fecal nitrogen, or apparent nitrogen retention, expressed as g/d or% of nitrogen intake in goats. Urine nitrogen was significantly lower, at 11%, in FDPC and FDPML when compared with FDP. The effect of cellulase or a combination of molasses and *L. casei* TH14 on urinary nitrogen reduction was unknown; it may possibly be inconsistent with retained nitrogen, as it was found to be the highest in FDPC and FDPML. Cherdthong et al. [13] showed that rice straw treated with cellulase or *L. casei* TH14 separately or as a combination fed to Thai Native beef cattle reduced nitrogen loss both in the urine and feces but failed to reach statistical significance.

5. Conclusions

This study showed that discarded durian peel fermented with a combination molasses and *L. casei* TH14 (FDPML) had significantly greater nutrient digestibility and propionate concentration, while estimated methane production, the acetate-to-propionate ratio and urinary nitrogen decreased when compared with untreated discarded durian peel (FDP). Therefore, a combination treated discarded durian peel with molasses and *L. casei* TH14 could add 25% of dry matter to the diet for growing goats without a negative impact. Further studies should evaluate the effect of fermented discarded durian peel with an additive content of higher than 25% in the diet on feed utilization, digestibility, rumen characteristics, blood metabolites, and nitrogen balance in ruminants.

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