Tropical Animal Health and Production (2021) 53:495
https://doi.org/10.1007/s11250-021-02946-2

REGULAR ARTICLES

Impact of varied time of feeding on the lactation and growth performance of West African Dwarf goat

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Received: 22 January 2021 / Accepted: 23 September 2021
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Abstract

This study was conducted to evaluate the effect of time of feeding on production performance of West African Dwarf (WAD) goats. Two experiments involving twenty-seven goats (15 bucks and 12 gravid does) were conducted. In Experiment I, the bucks were randomly allocated into three treatments of five replicates and fed for 115 days. In experiment II, pregnant goat-does were randomly allocated into three experimental treatments of four replicates per treatment 1 month to kidding. Goats were either fed in the morning (06:00 h), afternoon (12:00 h), or evening (18:00 h) respectively under natural light cycles. In experiment I, dry matter intake, weight gain, carcass characteristic, and meat chemical composition were not affected ($P > 0.05$) by time of feeding. In experiment II, data collection on feed intake, feed efficiency (FE), and milk yield spanned 6 weeks and were analyzed. From the results, milk yield in morning-fed goat-does was higher than evening-fed does while afternoon-fed does have the lowest yield at $P < 0.001$. Energy corrected milk in evening-fed does was higher ($P = 0.006$) than other treatments. Feed efficiency for milk yield and energy corrected milk yield ($P < 0.001$) in evening-fed does were higher than morning and afternoon-fed does. Milk component yield (g/day) for lactose ($P = 0.002$) was the highest in morning-fed does; evening-fed does had the highest ($P = 0.001$) crude fat while afternoon-fed does had the lowest yield for all milk component parameters. Conclusively, feeding in the morning and evening is recommended for milk production and component yield per day. However, for improved energy corrected milk yield and feed efficiency in lactating goats, feeding in the evening is recommended. It is recommended that further studies should be conducted on improving milk productivity in evening-fed goats due to the advantage it had over other feeding regimes. Thus, altering time of feeding could be a suitable alternative feeding strategy in a changing climate with a potential to improve production efficiency, especially in the tropics.

Keywords Adaptation strategy · Feed efficiency · Feeding regime · Goat milk · Growth performance

Introduction

Ruminant production is essential for milk and meat supply locally and globally. Goat products are highly nutritious and are one of the sources of high-quality protein and mineral supply. This ensures their contribution to food security and micronutrients lacking among rural dwellers in developing nations. Increasing milk production and growth rate was the focus of ruminant production. However, in recent times, the focus has shifted from only production to efficiency and sustainable milk and meat production (Hernández-Castellano et al. 2019). To improve production yield and efficiency, new strategies must be researched.

Altering time of feeding could be a novel strategy used for improving production efficiency in ruminants (Niu and Harvatine 2018). There is evidence that altering the time of feeding affected feed intake, nutrient digestibility, and weight gain in steers (Small et al. 2004; Aharoni et al. 2005; Furedi et al. 2006). Furthermore, several studies have shown that altering the time of feeding affected feed intake, milk yield and composition, and energy yield in dairy cows (Nikkhah et al. 2006; Niu and Harvatine 2018). Dairy cows fed once daily in the evening (21:00 h) improved milk yield and composition, increased milk fat, energy yield, milk energy

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output, and increased energy corrected milk than morning-fed cows (09:00 h) (Nikkhah et al. 2008, 2011). These studies suggest that altering time of feeding could be adopted as a management strategy in improving animal productivity. However, no study has reported the impact of altered time of feeding on the performance of goats, and how such strategy could be incorporated into ruminant feed management in the tropics. Thus, this study aims to evaluate the impact of altered time of feeding on the performance, carcass characteristics, and efficiency of West African Dwarf goats in the tropics.

Materials and methods

Experimental facilities and animal care

The experiment was carried out at the goat unit, Teaching and Research Farm of the Federal University of Technology, Akure (FUTA). The study area is located in the Southwest of Nigeria on latitude 7.3043° N and longitude 5.1370° E. Goats were managed in accordance with the guide for the care and use of agricultural animals in agricultural research and teaching (National Institute of Animal Science, Abuja) Nigeria.

Experiment I

Feeding and experimental design

The experiment lasted for 115 days with fifteen West African Dwarf bucks randomly allocated into three treatments of five replicates each, in a completely randomized design. The bucks weighed 7.4 ± 0.1 kg. The bucks were housed individually in pens and had free access to feed and water *ad libitum*. The bucks were offered guinea grass (*Panicum maximum*) and concentrate at a 50:50 dry matter (DM) ratio. The bucks were fed once daily in the morning, afternoon, or evening at 06:00 h, 12:00 h, or 18:00 h respectively under the natural light–dark cycle.

Performance record

Bucks were weighed weekly during the feeding trial period. Data for forage intake, and concentrate intake were taken daily. The feed offered was subtracted from feed leftover to calculate the feed intake. From the above parameters, weight gain, daily forage intake, daily concentrate intake, total forage, total concentrate intake, and feed conversion ratio were calculated. The daily intakes were calculated by finding the average intake throughout the experimental period. The dry matter intake was calculated using the DM of concentrate (86.96%) and the DM obtained from fresh grass (27.91%) individually and then summed together as total intake.The feed conversion ratio was calculated by dividing the feed intake by the weight gain. The feeding trial of the bucks was conducted between January and April 2020.

Carcass characteristics

Three bucks per treatment were randomly selected and slaughtered. Carcass measurement was done according to Aduku and Olukosi (2000). All bucks were weighed before slaughtering. The bucks were deskinned, the visceral (except kidney), tails, and head were removed, and the weight was recorded as carcass weight. Afterwards, the carcasses were cut into forelimbs, hind limbs, head, neck, loins, flank/belly, skin, foot, tail, stomach, heart, liver, kidney, spleen, and testis. The forelimbs were measured as the combination of the right and left forearm, including the shoulders but without the foot. The hind limbs were measured as the left and right hindlimbs without the foot. The ribs weight was the carcass weight between the 5th and 12th ribs. The loin weight was the muscle that attaches to 1–5 lumbar bones after the ribs. The neck weight was determined by the seven cervical bones from the occipital condyle toward the proximal end of the thoracic bone. The foot weight was the combination of both front and back feet. The skin weight was taken as the skin of the whole body without the head skin and foot skin. The lung weight was a combination of the lungs and trachea. The weights are represented in (g/100 g BW). Afterwards, the *longissimus* muscles of each animal from the ribs and loin area were collected, and the meat chemical composition was determined for moisture, dry matter, crude protein, ether extract, and ash according to AOAC (1997).

Experiment II

Management of goat-does, feeding, and experimental design

Twelve pregnant West African Dwarf goats were randomly allocated into three treatments of four replicates per treatment, 1 month to kidding with a weight of 20.02 ± 0.56 kg. Treatment involves feeding the does once daily in the morning, afternoon, or evening at 06:00 h, 12:00 h, or 18:00 h, respectively. All the does were on their first parity. Furthermore, the dams were housed individually in pen (2×1 m/goat), and had free access to feed and water. They were offered an experimental diet of grass (*Panicum maximum*) and concentrate (Table 1) 50:50 DM ratio. The chemical composition of the grass and concentrate diet is shown in

Table 1 Ingredient composition of the concentrate diet

Ingredient	g/100 g DM
Cassava peel	40
Palm kernel cake	26
Wheat offals	14
Brewer dried grains	15
Bone meal	2
Urea	1
Premix[a]	1
Salt	1
Chemical composition (g/100 g)	
Crude protein	10.52
Ether extract	3.11
Organic matter	87.35
Acid detergent lignin	16.74
Acid detergent fiber	24.57
Neutral detergent fiber	74.06
Hemicellulose	49.48
Cellulose	7.84

[a]Vitamin A 8,000,000 IU, vitamin D3 17,000,000 IU, vitamin E 5000 mg, vitamin K3 1500 mg, folic acid 200 mg, niacin 1500 mg, vitamin B2 3000 mg, vitamin B12 5 mg, vitamin B1 1000 mg, vitamin B6 1000 mg, iron 25,000 mg, manganese 45,000 mg, copper 3000 mg, zinc 35,000 mg, choline chloride 100,000 mg

Table 1. Data collection spanned 6 weeks. The experiment on the does occurred between May and July 2020.

Feed intake record

The feed intake of the does was taken throughout the lactation period. The feed offered was subtracted from feed leftover to calculate the feed intake. The does were fed *ad libitum*. The dam feed intake record was from the day of birth till the sixth week of lactation.

Milk yield record

The milk yield was measured by an indirect method using the weigh-suckle-weigh method (Williams et al. 1979). All kids were allowed to stay 1 week with their mother post-partum to build intimacy with their dam and to allow enough time for colostrum intake. The milk yield records were taken three times in a week (Monday, Wednesday, and Friday) and five times per day at (06:05, 09:00 h, 12:05 h, 15:00 h, and 18:05 h). Prior to the day milk yield records would be taken, the kids of all dams were withdrawn at 18:00 h the previous day irrespective of the feeding regime of their dam. The kids suckled their mother five times a day at 06:05 h, 09:00 h, 12:05 h, 15:00 h, and 18:05 h and were withdrawn 15 min later for weighing. Dams that do not allow their kids to suckle were restricted to permit the kids to suckle. After suckling at the last period of the day (18:00 h), the dams were hand-milked to remove the last residues of milk from the udder, and milk was weighed and added to the total milk produced per day. This milk yield data was collected for 5 weeks starting from the 2nd, 3rd, 4th, 5th, and 6th week post-partum.

Milk component

The milk samples for analysis were collected for 4 weeks at the 2nd, 3rd, 4th, and 5th week post-partum. The milk samples were collected three times per day in the morning, afternoon, and evening at 06:00–06:30 h, 12:00–12:30 h, and 15:30–16:00 h and mixed for all animals. The chemical analysis of the milk was done. The milk fat (method ID 920.39) was analyzed with AOAC (1997) while the solid not-fat (SNF) and total solids (TS) were calculated according to Tona et al. (2017). Milk lactose was determined by colorimetric method (NagiWahba 2013). The milk protein was determined by Lowry's method (Lowry et al. 1951).

Feed efficiency (FE) of milk yield was calculated as FE = milk yield (kg)/dry matter intake (kg); FE of ECM yield was calculated as FE = ECM yield (kg)/dry matter intake (kg); yields (g/day) of each milk component were calculated for individual goats by multiplying milk yield (g/day) by the component content (g/kg) of milk divided by 1000. The gross energy content of milk was calculated according to Tyrrell and Reid (1965) as: milk energy content (MJ/kg) = 4.184 × 2.204 × [41.63 × fat (g/100 g) + 24.13 × protein (g/100 g) + 21.60 × lactose (g/100 g) − 11.72)/1000]. Milk energy output (MJ/day) was calculated as milk energy (MJ/kg) × milk yield (kg/day). Energy corrected milk (ECM) was calculated according to Sjaunja et al. (1991) as: ECM (kg/day) = milk (kg/day) × [38.3 × fat (g/kg) + 24.2 × protein (g/kg) + 16.54 × lactose (g/kg) + 20.7]/3140.

Chemical analysis

The proximate of feed and meat samples was analyzed for DM (method ID 930.15), ash (method ID 942.05), nitrogen by Kjeldahl method (method ID 954.01), and ether extract (method ID 920.39) according to AOAC (1997). The neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed according to Van Soest et al. (1991). Hemicelluloses were calculated as NDF-ADF while cellulose was calculated as ADF-ADL.

Statistical analysis

Data collected from the bucks and does were analyzed as a completely randomized design. All data collected were subjected to analysis of variance using SPSS version 23.0

(SPSS 2015). The differences between treatment means were examined by Duncan's multiple range test of the same package. The significance level of $P < 0.05$ was adopted.

Results

Experiment I

Performance, carcass, and chemical composition of bucks meat

Feeding regimes did not significantly (P > 0.05) affect the dry matter feed intake, final weight, average daily gain, weight gain, and feed conversion ratio of bucks fed at varied times of the day. Also, the carcass characteristics and meat chemical analysis of the bucks were not affected (Tables 2, 3, 4).

Experiment II

Overall milk yield and feed efficiency of does under different feeding regimes

Time of feeding significantly ($P < 0.05$) influenced milk yield of does. Milk yield of morning-fed does was higher ($P < 0.001$) than evening-fed does, while afternoon-fed does have the lowest value (Table 5). Dry matter intake of evening-fed lactating does was lower ($P < 0.001$) than morning and afternoon-fed does which were similar. However, FE ($P < 0.001$) of evening-fed lactating does was the highest while afternoon-fed does had the lowest value.

Milk yield and component of does under different feeding regimes

The milk yields here were the values for the 2nd, 3rd, 4th, and 5th weeks. Milk yield, ECM yield, and FE milk yield of morning- and evening-fed lactating does were similar, but higher ($P = 0.005$) than afternoon-fed does (Table 6). Feed intake of afternoon-fed lactating does was higher ($P < 0.001$) than morning and evening-fed Does. Feed efficiency and ECM yield of evening-fed Does were higher ($P < 0.001$) than of those in morning-fed does while afternoon-fed Does had the least.

Lactose yield (g/day) in the milk produced by morning-fed does was higher ($P = 0.002$) than afternoon and evening-fed does which were similar. Evening-fed Does had the highest milk fat yield ($P = 0.001$) while afternoon-fed Does had the lowest. Morning and evening feeding improved ($P = 0.033$) TS compared to afternoon-fed does. Evening-fed Does had the highest ($P = 0.045$) fat/SNF ratio while afternoon-fed Does had the lowest. However, the time of feeding did not significantly affect milk components such as milk fat, lactose, protein, SNF, TS yield, and protein/fat ratio.

Discussion

Performance, carcass, and meat chemical composition

Performance record of bucks showed that feeding time did not significantly impact the growth response and feed intake. However, it was observed that there were numerical increases in the weight gain and feed intake and decrease in the feed conversion ratio of afternoon- and evening-fed bucks compared to morning-fed bucks. This result is similar

Table 2 Performance of West African Dwarf bucks under different feeding regimes

	Time of feeding				
	06:00 h	12:00 h	18:00 h		
Parameters	Morning	Afternoon	Evening	SEM	*P*-value
Initial weight (kg)	7.40	7.50	7.50	0.35	0.993
Final weight (kg)	10.80	11.76	11.96	0.60	0.732
Average daily gain (g/day)	29.28	36.72	38.45	3.06	0.463
Total weight gain (kg)	3.40	4.26	4.46	0.36	0.463
Forage intake (g DM/day)	103.19	109.45	95.40	6.69	0.723
Concentrate intake (g DM/day)	197.46	210.7	226.15	14.24	0.743
Total intake (g DM/day)	300.65	320.15	321.55	14.96	0.828
Feed conversion ratio	10.67	9.25	8.86	0.57	0.419
Forage: concentrate	34.3: 65.7	34.2: 65.8	29.7: 70.3		
Number of animals	5	5	5		

Table 3 Carcass characteristics of West African Dwarf bucks under different feeding regimes

	Time of feeding				
	06:00 h	12:00 h	18:00 h		
Parameters	Morning	Afternoon	Evening	SEM	*P*-value
Live weight (kg)	10.69	10.02	10.93	0.871	0.929
Exsanguinated weight (kg)	10.18	9.62	10.49	0.826	0.930
Carcass weight (kg)	4.70	4.40	4.89	0.422	0.917
Carcass yield	43.71	43.74	44.54	0.534	0.819
Carcass parts (g/100 g BW)					
Fore limb	8.53	8.58	8.32	0.18	0.850
Hind limb	13.02	12.56	13.83	0.35	0.368
Head	8.09	8.18	8.25	0.28	0.980
Neck	4.44	4.45	4.39	0.19	0.994
Ribs	9.26	9.22	9.42	0.21	0.938
Loin	3.46	3.29	2.95	0.2	0.633
Flank/belly	2.07	2.41	2.14	0.18	0.775
Skin	7.43	8.33	7.96	0.29	0.522
Foot	3.16	3.06	2.33	0.23	0.311
Tail	0.18	0.19	0.14	0.01	0.460
Organ weight (g/100 g BW)					
Stomach	3.98	3.93	3.33	0.19	0.345
Heart	0.56	0.53	0.53	0.02	0.718
Liver	1.8	1.98	1.84	0.09	0.769
Spleen	0.18	0.16	0.18	0.01	0.571
Testes	0.61	0.73	0.63	0.05	0.589
Lung	1.11	1	1.25	0.04	0.071
Kidneys	0.35	0.41	0.39	0.03	0.772
Number of animals	3	3	3		

Table 4 Chemical composition (%) of meat of West African Dwarf bucks under different feeding regimes

	Time of feeding				
	06:00 h	12:00 h	18:00 h		
Parameters	Morning	Afternoon	Evening	SEM	*P*-value
Dry matter	38.12	40.46	37.69	1.051	0.574
Crude protein	30.24	31.24	29.92	0.862	0.848
Ash	1.41	1.56	1.72	0.061	0.114
Ether extract	6.83	7.73	6.23	0.432	0.399
Number of animals	3	3	3		

Table 5 Overall performance parameters of lactating West African Dwarf does

	Time of feeding				
	06:00 h	12:00 h	18:00 h		
Parameters	Morning	Afternoon	Evening	SEM	*P*-value
Milk yield (kg/d)	0.41^a	0.31^c	0.36^b	0.007	< 0.001
Dry matter intake (kg/d)	0.74^a	0.74^a	0.60^b	0.011	< 0.001
Feed efficiency	0.56^a	0.44^b	0.60^a	0.011	< 0.001
Number of animals	4	4	4		

Means with different superscripts in the same row are significant ($P < 0.05$)

to the study of Reinhardt and Brandt (1994), Pritchard and Knutsen (1995), Schwartzkopf-Genswein et al. (2004), and Small et al. (2004) who reported improved weight gain and feed intake in steers fed in the evening. The numerical increase in weight could be caused by increased feed digestion and reduced energy expenditure in animals fed at night (Coomans et al. 2013). Nonetheless, the daily intake, weight gain, and feed conversion ratio were within the range reported by Saka et al. (2019), Adebayo et al. (2019), and Omotoso et al. (2019). The dressing percentage and other carcass parameters were not affected by the feeding regime. However, the dressing percentage was similar to the bucks slaughtered in Anya and Ozung (2018). The meat chemical composition of the bucks in

Table 6 Milk yield and component in West African Dwarf does under different feeding regimes

Production (g/d)	Time of feeding 06:00 h Morning	12:00 h Afternoon	18:00 h Evening	SEM	*P*-value
Milk	406.64[a]	339.92[b]	383.58[a]	8.476	0.005
ECM	790.00[a]	640.00[b]	840.00[a]	26.00	0.006
Feed intake	700.22[b]	777.84[a]	640.98[b]	13.52	< 0.001
Total solid	96.16[a]	81.37[b]	94.08[a]	2.437	0.033
Solid non-fat	63.17	56.70	55.91	1.422	0.059
Protein	28.16	28.28	29.63	0.895	0.757
Crude fat	32.99[a]	24.67[b]	38.17[a]	1.549	0.001
Lactose	31.16[a]	24.24[b]	26.64[b]	0.982	0.002
Milk energy output (MJ/d)	2.47	2.01	2.61	0.135	0.212
Milk component (g/kg)					
Total solids	234.14	238.99	246.67	5.254	0.615
Solid not-fat	157.89	167.33	148.76	5.019	0.200
Protein	70.76	82.47	77.01	3.080	0.394
Crude fat	76.25	71.67	97.92	4.641	0.075
Lactose	78.38	70.68	68.67	3.284	0.394
Ash	19.90[a]	10.80[b]	10.60[b]	1.54	0.017
Milk energy content (MJ/kg)	5.95	5.59	6.73	0.193	0.172
Protein/fat	1.06	1.36	0.87	0.096	0.171
Fat/solid not-fat	0.52[ab]	0.44[b]	0.72[a]	0.047	0.045
Feed efficiency					
FE milk yield	0.59[a]	0.46[b]	0.61[a]	0.015	< 0.001
FE ECM	1.14[b]	0.88[c]	1.34[a]	0.044	< 0.001
Number of animals	4	4	4		

Means with different superscripts in the same row are significantly different ($P < 0.05$) with different ECM: energy corrected milk; *FE* feed efficiency; *FE ECM* feed efficiency energy corrected milk; *FE ECM* feed efficiency energy corrected milk

this study was higher than those reported by Eneji et al. (2015) and Rodriguez et al. (2014) which were in a range of 29.77–30%, 4.67–6.67%, and 2–4.03% for DM, ether extract, and ash respectively. The difference in this result may be due to the quantity and quality of macronutrients available to the bucks in these experiments (Joost et al. 2007).

Circadian system co-ordinates and regulates dam's physiological changes needed to initiate and maintain lactation and this affects milk yield and composition (Plaut and Casey 2011). The numerically higher milk yield in morning-fed lactating does may be associated with the higher feed intake compared to evening-fed does. It could also be due to increased level of insulin-driven cellular nutrient uptake like glucose which occurred in morning-fed does due to increasing nutrient availability for mammary tissue use resulting in more milk synthesis and yield (Bickerstaffe et al. 1974). However, given that afternoon-fed lactating Does consumed the same feed as morning-fed does, the decrease in milk yield may be due to other factors like heat stress which affected the milk yield. It is reported that thermal tolerance affects milk yield negatively because the lactating animals are sensitive to metabolic heat load produced during digestion and milk synthesis (Bernabucci et al. 2014; Nasr and El-Tarabany 2017). The reduction in milk yield in afternoon-fed does may be because the animals adjusted its feed intake in the afternoon to produce less bodily heat due to high heat load in the afternoon, affecting the ability of mammary epithelial cells to utilize blood-derived milk precursors contributing to lower milk production (Sammad et al. 2020).

Improved feed intake and milk yield have been reported in dairy cows fed in the evening or night compared to morning-fed dairy cows (Aharoni et al. 2005; Nikkhah et al. 2008, 2011). However, the lower milk yield in this study contradicts the result of Nikkhah et al. (2006, 2008) who reported an increase in milk yield in evening-fed dairy cows. It is plausible that the reduction in feed intake is associated with lower milk yield in evening-fed does. Furthermore, this variation may be caused by the different protocols between the study of Nikkhah et al. (2008) and this study. Nikkhah et al.'s (2008) study provided lights for 3 h post-feeding in dairy cows fed at 21:00 h. This study was conducted under the natural light–dark cycle. Thus, the darkness (associated with increased melatonin) could cause the variation. Plasma melatonin concentration is associated with plasma prolactin decrease (Plaut and Casey 2011). Auldist et al. (2007) reported on the potential of melatonin to decrease plasma prolactin decrease, which reduced milk yield by 23%. It could be inferred that evening feeding coincides with increased melatonin secretion (favored because of darkness) which affected milk yield compared to morning-fed lactating does.

There is increasing pressure being placed on the dairy industry to improve the efficiency and sustainability of dairy production (Richardson et al. 2021). This necessitates the need to modify management system to improve feed and production efficiency. The higher feed efficiency in evening-fed Does showed that, despite lower feed intake, evening-fed lactating does were more efficient. This may be associated with dry matter digestibility, resulting in increased milk efficiency (Socha et al. 2007; Linn et al. 2009). Also, feeding at night reduces energy expenditure in diurnal mammals by reducing nutrient use by peripheral tissues, which are redirected to mammary tissues in favor of milk production (Nikkhah et al. 2008; Adamovich et al. 2014; Yasumoto et al. 2016). The milk yield in this study is higher than the range of 116–298 g/day in early lactation (Odoemelam et al. 2012; Tona et al. 2015, 2017). The milk efficiency in this study is lower than the range of 0.74–1.44 in Oliveira et al. (2014), but higher than the FE of 0.42 in Does milked three times per day (Williams et al. 2012). The variation may be due to the frequency of milk yield measurement. In this study, does were suckle-milked five times per day between 06:00 h and 18:15 h. This shows the impact of milking frequency because milking more than 2–3 times per day improved milk yield and milk efficiency than once-a-day milking (Akpa et al. 2003; Williams et al. 2012). This is associated with the prevention of the secretion of feedback inhibitor of lactation (FIL) that would have inhibited milk synthesis due to accumulation of milk in the udder (Akpa et al. 2003;Wilde et al. 1995).

Milk yield and component of does under different feeding regimes

The milk yield here was the milk produced in the weeks milk samples were collected for analysis. ECM determines the amount of energy in the milk based on milk fat, protein, and lactose. Milk yield and ECM yield were 19.63 and 23.44% in morning-fed and 12.84 and 31.25% evening-fed does higher than afternoon-fed does. This suggests that ECM yield from evening-fed does contained higher energy than milk from the other two treatments. Evaluating ECM yield is important because milk fat production has actual energy cost and permits accurate measurement of feed efficiency (Linn 2006). Aharoni et al. (2005), Nikkhah et al. (2008), and Nikkhah et al. (2011) reported that feed delivery in the evening improved energy efficiency milk fat and milk energy output, and led to increased energy corrected milk compared to morning-fed cows. Alteration in the rhythm of peripheral tissues could also affect the derivatives or metabolites controlled by the peripheral tissues such as milk yield and milk composition. Time of peak milk and component yield were shifted by feeding time (Salfer and Harvatine 2020). Higher milk fat in milk produced by evening-fed does may be due to higher post-prandial peak of peripheral blood metabolites such as lactate and beta-hydroxybutyrate resulting in increased and efficient uptake by mammary tissues (Nikkhah 2011). In addition, the greater insulin resistance in many tissues causes higher availability of precursors for milk fat synthesis because insulin insensitivity of adipose tissue results in an increased lipolysis, thereby increasing the availability of fatty acids for milk fat synthesis (Corl et al. 2006). However, for the milk ash, the reason for the variation at present is not known. Higher milk component yield is associated with milk yield and milk chemical composition. The milk component yield in this study was higher than 119–190 g/kg TS, 61.10–130.24 g/kg SNF, 32–53.00 g/kg protein, 30.20–83.00 g/kg fat, 43.8–56.6 g/kg lactose, and 6.4–9.10 g/kg ash reported (Tona et al. 2015, 2017; Anya et al. 2019). The variation in the report of the current study may be due to the method of milk collection and the quantity of feed consumed. In these studies, milk samples were collected once in the morning, but, in this experiment, milk samples were collected three different times a day (i.e., morning, afternoon, and evening samples and pooled). For the lactose (g/day), the higher yield in morning-fed does may be associated with the glucose uptake from the blood. Zhao (2013) reported that glucose is a major precursor of lactose which is synthesized in the Golgi vesicle of the mammary secreting alveolar epithelial cells during lactation. The glucose uptake is facilitated by glucose transporters which drive glucose movement across the plasma membrane. Thus, due to the insulin sensitivity in the morning in diurnal animals, the increased absorption of glucose at that period favored increased lactose concentration in the milk of the morning-fed does. However, due to the decrease in the insulin sensitivity in muscle tissues from dawn to dusk, there is also a decrease in lactose concentration in milk of other feeding time.

Conclusions

Time of feeding did not affect the growth performance and carcass bucks. Afternoon-fed Does had the lowest milk yield while morning-fed Does had the highest followed by evening-fed does. However, evening-fed Does had the lowest feeding intake, but had the highest FE of milk yield, highest ECM yield, and highest FE of ECM yield. Morning feeding increased lactose yield (g/day) while milk fat yield (g/day) was higher in evening-fed does, and afternoon-fed Does had the lowest value of all. For improved ECM yield and FE in lactating goats, feeding in the evening is recommended. It is recommended that further studies should be conducted on how to improve milk productivity in evening-fed goats due to the advantage of higher feed efficiency, highest FE of milk yield, highest ECM yield, and highest FE of ECM yield.

Author contribution MJ, SO, and AN conceived and designed the experiment; MJ, TC, and AA conducted the experiment; SC, AN, and OB performed supervision; MJ, OB, MMYE, and AZM prepared the manuscript. All authors approved of the manuscript.

Availability of data and material Not applicable.

Declarations

Statement of animal rights Animal studies have been approved by the ethical committee. The research was performed in accordance with the ethical standard laid down in the 1996 declaration of Helsinki and its later amendments.

Conflict of interest The authors declare no competing interests.

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