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Original

The feeding supplementation schedule modifies productive response of grazing dairy goats

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ABSTRACT

Objective. The objective of this study was to evaluate the effect of the complementation schedule with an integral food in the production and chemical composition of the milk of lactating goats under grazing conditions in northern Mexico. **Materials and methods.** Twelve adult Saanen goats were assigned equitably and randomly to three treatments: control, morning complementation and evening complementation. It was measured dry matter consumption (DM), live weight (LW), body condition (CC), milk production (PL), chemical composition and performance of milk (protein, lactose and fat). **Results.** The highest total DM consumption was obtained in goats supplemented in the afternoon (p=0.02), and they were also the ones that produced the highest milk quantity (p<0.0001). The concentrations of protein (p=0.07) and lactose (p=0.10) in milk were not modified due to treatments. In contrast, the fat content in milk of the goats of the control group was higher (p<0.05) than the supplementation treatments. **Conclusiones.** Complementation in the afternoon improved the productive response of lactating goats in grazing during the dry season in northern Mexico.

Keywords: Complementary feeding; milk; dry matter; arid lands (*Fuente: CAB*).

RESUMEN

Objetivo. Evaluar el efecto del horario de complementación con un alimento integral sobre la producción y composición química de la leche de cabras lactantes en condiciones de pastoreo en el norte de México. **Materiales y métodos.** Doce cabras Saanen adultas se asignaron en forma equitativa y aleatoria a tres tratamientos: testigo, complementación Mañana y complementación Tarde. Se midió consumo de materia seca (MS), peso vivo (PV), condición corporal (CC), producción de leche (PL), composición química y rendimiento de los componentes de la leche (proteína, lactosa y grasa). **Resultados.** El consumo mayor de MS total se obtuvo en las cabras complementadas por

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la tarde ($p=0.02$), y también fueron las que produjeron mayor cantidad de leche ($p<0.0001$). Las concentraciones de proteína ($p=0.07$) y lactosa ($p=0.10$) en leche no se modificaron por efecto de tratamientos. El contenido de grasa en leche de las cabras del grupo testigo fue mayor ($p<0.05$) que en los tratamientos con complementación. **Conclusiones.** La complementación por la tarde mejoró la respuesta productiva de cabras lactantes en pastoreo durante la época seca en el norte de México.

Palabras clave: Alimentación complementaria; leche; materia seca; zonas áridas (*Fuente: CAB*).

INTRODUCTION

Goat production in northern Mexico is carried out under extensive grazing, since the pasture is an inexpensive source of forage and its use reduces production costs (1, 2). However, the grazing routine includes long daytime walks with the goats and in the afternoon the animals are kept in stalls next to the producer's house. In this grazing system, the land used is communal, and the goats are protected from predators and theft, and they are prevented from causing damage to crop areas (3). This management scheme is not exclusive to Mexico, and is widely used in the world to feed sheep and goats, particularly in developing countries (4) and some areas of developed countries, such as the Mediterranean region of Italy (5).

Because goats graze for about 7 h per day during periods of high forage scarcity, this long grazing routine can result in low dry matter intake (6, 7). Likewise, this restriction in access to forage alters the natural circadian pattern of grazing activity, since the greatest feeding activity of ruminants is reached just before dawn and at dusk, even though ruminants have the capacity to self-regulate their consumption (8, 9). Due to the above, a low productive response is expected in goats under this system and, if the production objective includes increasing productivity, it is necessary to offer feed supplements to help the animals meet their nutritional requirements.

In this regard, Maldonado-Jáquez et al (7) included 1 kg of whole feed per goat per day in the diet of grazing dairy does, which increased milk production by 100%. However, a decrease in the consumption of forage consumed in the pasture was observed, which could be due to a substitution effect, since the feed was offered in the morning, just before the goats went out to pasture and after a prolonged fasting (up to 17 hours). In this sense, some studies conclude that an increase in the frequency of offering feed supplements to grazing ruminants has advantages with respect to a single offering, where, for example, stability in ruminal pH is promoted (10).

However, producers of extensive goat systems commonly reject the adoption of technologies that duplicate tasks and consequently increase the workload (3), since in addition to grazing, the producer must attend to other personal and labor priorities (1). In this sense, it is a priority to generate strategies that help the producer to make the production system efficient without increasing the amount of work and production costs (11), especially under extensive production schemes where herd size limits the development and adoption of improved management schemes (12). This has led to the hypothesis that offering the feed supplement at a certain schedule optimizes the productive response of the goats. Therefore, the objective of this study was to evaluate the effect of the supplementation schedule (morning or afternoon) with an integral feed on the production and compositional quality of milk of lactating goats under extensive grazing conditions during the dry season in northern Mexico.

MATERIALS AND METHODS

All methods used, as well as the handling of the animals used in this study are strictly adhered to the accepted guidelines for the ethical use, care and welfare of animals used in research according to the American Dairy Science Association (13), National Academy of Medicine (14) and Mexican Institutionally with the approval of the project "Development of feeding strategies to increase the production and nutritional quality of goat milk from the extensive system in the state of Nuevo Leon".

Experimental site and herd management. The study was conducted during the dry season in northern Mexico, in a private goat production unit in the ejido Los Medinas, Dr. Arroyo, Nuevo Leon, Mexico. This season coincides with the period of lower forage availability (15). The predominant climate is cold subhumid temperate Cb (w1) (i') w", with rainfall in summer, an average annual precipitation of 600 to 800 mm, and an average temperature of 12 to 18ºC (16). Goats were managed according to an extensive production scheme, where sanitary management is limited to the availability of economic resources of the producer, which includes only the control of internal and external parasites every six months. Feeding was through grazing with a routine of 7 h d^{-1} (11:00 to 18:00 hours) and in the afternoon, the goats returned to resting pens and had free access to water and mineral salts.

Goats and treatments. Twelve adult Saanen goats (2 and 3 parturitions) were randomly assigned to three experimental groups homogeneous in Body weight (BW), Body condition score (BC), number of parturitions and initial milk production (MP), in a randomized complete block design. Group 1) control (n=4; 33.9±9.5 kg BW; 1.6±0.1 (BC); 2.5±1.7 parturitions; initial MP 479.2±258.2 g goat d^{-1}; 142±19 d in lactation); Group 2-Morning) supplementation with whole feed in the morning (n=4; 34.1±9.3 kg BW; 1.3±0.1 BC; 2.0±0.8 parturitions; initial MP 483.7±152.4 g goat d^{-1}; 153± 21d in lactation); and Group 3-Evening) supplementation with whole feed in the afternoon (n=4; 33.2±6.9 kg BW; 1.5±0.2 BC; 2.4±1.2 parturitions; initial MP 487.5±251.2 g goat d^{-1}; 136±18 d in lactation).

The goats in the control group were fed only by grazing and did not receive any supplemental feed. The goats in the morning and afternoon groups received 1 kg goat d^{-1} of whole feed on a wet basis. The goats in morning group had access to supplementation from 6:00 to 8:00 am and the goats in evening group had access to supplementation from 7:00 to 9:00 pm. The experiment lasted 45 days. The goats were milked manually every week between 7:00 and 8:00 am. The whole food used as a supplement was sampled every 15 days in three repetitions. Similarly, the native plant species consumed by the goats were identified according to the methodology described by Toyes-Vargas et al (17). Species such as *Acacia* spp., *Atriplex* spp., *Senna* spp., *Dalea bicolor*, *Cirsium arvense*, *Parthenium incanum were* identified. The whole food samples were dried in a forced air oven at a temperature of 65°C to constant weight and then ground in a hammer mill with a 5 mm sieve and sent to the laboratory (AGROLAB, Gómez Palacio, Durango, Mexico) where a basic analysis was performed with near infrared spectroscopy (NIR) equipment (Table 1), which is based on chemometrics, associating the light absorbed in a feed sample with the chemical composition of the feed (18), the values of net maintenance energy (ENm) and net lactation energy (ENl) were calculated according to the equations proposed by the NRC (19).

Table 1. Ingredients and chemical composition of whole feed used as a dietary supplement in lactating goats grazing in northern Mexico at different schedules.

Ingredient	%	Chemical composition	%
Alfalfa hay	32.0	Dry matter	93.3
Corn stubble	8.0	Crude protein	20.1
Corn grain	17.1	Neutral detergent fiber	32.7
Sorghum grain	17.1	Acid detergent fiber	19.2
Wheat bran	9.0	NTD †	76.3
Soybean paste	9.0	ENm (Mcal ME kg^{-1} DM)	1.9
Urea	1.2	ENl (Mcal EM kg^{-1} DM)	1.7
Molasses	4.8		
Mineral premix§.	1.8		

†NTD: total digestible nutrients, ENm: net energy for maintenance, ENl: net energy for lactation. §Ovi3ways® mineral premix BIOTECAP Group.

Fodder consumption. To determine forage consumption in the pasture, chromium oxide (Cr_2O_3) was used as an external marker and acid insoluble ash as an internal marker (20,21). This was measured during the last fifteen days of the experimental period. The goats received 6 g of chromium sesquioxide (Cr_2O_3) through a capsule that was inserted directly into the mouth of each goat to ensure total consumption. Feces were obtained during five alternate days of the experimental period directly from the goat's rectum and were frozen for laboratory analysis. Chromium determination was performed on the fecal samples. Daily fecal production was calculated according to the following formula (20):

Fecal production ,MS (g d^{-1})= (Dose of Cr_2O_3 (g d^{-1})) / (Cr_2O_3 concentration in feces (g g^{-1} MS))

With the previous result, forage consumption in the pasture (g DM d^{-1}) was estimated according to the following formula (20):

DM Consumption at the pasture (g d^{-1}) = ([CIA_H x PTH] – [CIA_C x CTC]) / CIA_P

where, CIAH: acid insoluble ash (CIA) concentration in feces (g kg^{-1} DM), PTH: total feces production, using Cr_2O_3 as external marker (g d^{-1}), CIAC: CIA concentration of whole feed (g kg^{-1} DM), CTC: total consumption of whole feed (g), CIAP: CIA concentration in forage from the pasture (g g^{-1} DM). The substitution rate was estimated using a linear regression between forage intake and whole feed.

Whole feed offered and rejected was recorded each day during the experimental period, and the daily consumption of whole feed was determined by difference. Total DM consumption was determined by adding the amount of DM from pasture forage and whole feed consumed per goat per day.

Production test and milk quality analysis. The variables BW, BC, MP, fat, protein and lactose concentration in milk were measured once a week for six weeks. BW was measured with an electronic hanging scale (Rhino, Guadalajara, Mexico) with a capacity of 300 kg±100 g. BC was measured on a scale of 1 to 4, according to the methodology described by Rivas-Muñoz et al (22) which considers 1 as a wasted goat and 4 an obese goat. MP was measured in each goat once a week and was expressed in grams (g), using a commercial electronic hook scale (Metrology®, Nuevo León, Mexico) with a capacity of 45 kg ± 5 g. Milk quality was evaluated with a sample (50 ml) of the individual production, which was taken in the middle of the milking routine. The Milkoscope Expert Automatic® (Razgrad, Bulgaria) was used for its analysis, which was calibrated specifically for goat milk and the following variables were measured: fat, protein and lactose.

Statistical analysis. For the statistical analysis, a time-repeated measures model was used for the variables BW, BC, MP and chemical composition of the milk (fat, protein and lactose) using the MIXED procedure of the SAS statistical package (SAS, NY, USA). Likewise, the information criteria -2Log Likelihood, Bayesian of Schwartz and Akaike were obtained, with which the most appropriate covariance structure for each variable was determined. The least squares comparison of means was performed through the adjusted Tukey test. Dry matter and whole feed intake data were analyzed as a randomized complete block design, using the GLM procedure and the adjusted Tukey's test for comparison of means. The general structure of the model was:

$$Y_{ijkl}=\mu+R_{i(j)}+ T_j+ S_k+T_j*S_k+E_{ijkl}.$$

Where: Yijkl: dependent variable (BW, BC, MP, fat, protein or lactose); μ: constant characterizing the population; $R_{i(j)}$: random effect of the *i-th* animal nested in the j-th treatment (i=1,2,3,4), T_j: fixed effect of the *j-th* treatment (j=1,2,3); $S_{k:}$ fixed effect of the *k-th* week of treatment (k=1, 2...,6); T_j*S_k: treatment*week interaction effect; E_{ijkl}: random error. All random components were assumed normally distributed.

RESULTS

Dry matter consumption. A higher forage consumption in the pasture by the control group (p<0.05) was found (22.7%), compared to the groups that received feed supplementation. With respect to supplement consumption, the goats of the Afternoon group consumed 30% more whole feed than the goats of the Morning group (p<0.05). The highest total DM consumption (p<0.05) was found in the Afternoon group (Table 2). Independently of the supplementation schedule, a substitution effect of 21.5% (p≤0.05) was detected in the goats of the morning group and 24% (p 0.05) in the goats supplemented in the afternoon (p≤0.05).

Table 2. Dry matter intake in forage and supplemental feed in lactating goats supplemented in the morning and afternoon.

Variable	Control	Morning	Afternoon	SEM	P-Valor
Forage consumption (kg d^{-1})	1.31^a	0.89^b	0.87^b	0.04	0.0027
Whole food consumption (kg d^{-1})	0.00	0. 49^b	0.78^a	0.06	0.0014
Total dry matter consumption (kg d^{-1})	1.31^b	1.38^b	1.65^a	0.03	0.0216

SEM=Standard error of the mean; ^{abc}Different literals between columns indicate statistical difference (p<0.05).

Live weight, body condition and milk production. No differences were found in live weight between treatments (p>0.05). However, body condition decreased (p<0.05) in goats supplemented in the afternoon with respect to goats supplemented in the morning. Likewise, milk production was higher (p<0.0001) in the goats supplemented in the afternoon; and the lowest milk production was observed in the control group (Table 3).

Table 3. Productive performance of lactating goats supplemented in the morning or in the afternoon using a whole feed.

Variable	Control	Morning	Afternoon	P-Value		
				Trat	Time	Trat*T
BW (kg)	35.9	35.85	37.9	0.9121	<0.0001	0.0654
BC	1.6[ab]	1.7[a]	1.5[b]	0.0454	<0.0001	0.0756
MP(g d^{-1})	449.0[b]	632.5[ab]	833.9[a]	<0.0001	0.0004	0.0665

BW= live weight; BC= body condition; MP= milk production; Trat= treatment effect; Trat*T= treatment by time interaction effect; different [abc]Literals between columns indicate statistical difference (p<0.05).

Chemical composition and yield of milk components. Table 4 shows the results of chemical composition and yield of milk components (expressed in grams of fat, protein or lactose present in each kilogram of milk produced). Regarding milk composition, differences were observed only in milk fat concentration (p<0.0001); the control group presented the highest values and in the groups that received food supplementation there were no differences (p>0.05), independently of the time of day they received it. On the other hand, when analyzing the yield of the components present in the milk, treatment by time interaction effects and differences in fat, protein and lactose were found among the three groups (p<0.05); in this respect, the highest values were found in the Afternoon group and the lowest values were found in the control group.

Table 4. Composition and performance of milk components of goats supplemented in the morning or afternoon using a whole feed.

Variable	Control	Morning	Afternoon	P-Value		
				Trat	Time	Trat*T
			Milk composition (g kg^{-1})			
Fat	50.3[a]	40.3[b]	39.1[b]	<0.0001	0.6801	0.1422
Protein	33.0	32.8	32.0	0.0780	<0.0001	0.3500
Lactose	49.4	49.0	47.9	0.1066	<0.0001	0.3677
			Yield of milk constituents (g d^{-1})			
Fat	22.4c	25.5[b]	32.5[a]	<0.001	<0.001	<0.001
Protein	14.8c	20.1[b]	26.5[a]	<0.001	<0.001	<0.001
Lactose	22.2c	30.8[b]	39.8[a]	<0.001	<0.001	<0.001

Trat= Treatment effect; Trat*T= Treatment by time interaction effect; [abc]Literals different between columns indicate statistical difference (p<0.05).

DISCUSSION

The higher consumption of plant species in the pasture by goats of the control group compared to the supplemented goats was probably because grazing was the only feeding method for this group. Therefore, it is likely that their grazing activity was more intense compared to the goats that received dietary supplementation; however, it should be noted that when animals graze pastures with low forage quality or quantity for a longer time, the positive feeding effect is nullified in terms of productive response (5). On the other hand, despite consuming more forage in the pasture, total dry matter intake in the control group was lower than in the goats that consumed the supplement in the afternoon. In this regard, the percentage of total DM consumed in relation to the BW of the goats in the control group was 3.6%, in contrast to 4.3% consumed by the goats supplemented in the afternoon. In lactating goats, it has been documented that to optimize milk production and maintain a good condition for the next lactation, total DM intake should be around 4% of the BW of the goats (23, 24), a value that is similar to the consumption observed in goats supplemented in the afternoon.

The difference in supplement consumption between the Morning and Afternoon groups can be explained by an interaction between different physiological and ethological effects in the supplemented goats and where the substitution effect is the most accurate response. This is related to the high energy content of the supplement, since when lactating goats are supplemented with energy-dense ingredients such as cereal grains, molasses, fats or vegetable oils, nutrients from grazing are substituted (25). Also, these differences could be due to the production system itself, especially, the prolonged fasting periods (≈17 hours) to which goats are subjected (1). In this regard, restriction of time allocated to grazing (26) or access to feed in confined systems (27) is known to influence ingestion behavior in ruminants. In this regard, animals grazing under this management scheme compensate for access to grazing or little feed in the dry season through increased size and mouthful rate. Consequently, feeding activity and intake rate increase linearly as the time of access to grazing (5) or feed decreases (27). Based on the above, the fact that goats in the Morning group consumed less complement than goats in the Afternoon group could be due to the bite size and biting rate toward complement was higher in the latter group, because in some way, these animals identified that they would not have access to any feed for ≈ 17 hours. In contrast, goats offered supplementation in the morning went out to graze immediately.

On the other hand, it is known that when body condition is lost due to adipose tissue mobilization, BW loss may or may not be observed, since adipose tissue has high values of volume and energy density (28). This is supported by our results, since the goats that lost body condition (Afternoon group) were the ones that produced the greatest amount of milk. With this, adipose tissue is degraded to synthesize greater amounts of milk, and this may or may not be reflected in the loss of BW in the animals (28).

The higher milk production observed in the Afternoon group goats is explained by a higher total DM intake. This promotes a greater availability of nutrients for milk synthesis. In addition, because the afternoon supplemented goats did not consume any other feed after supplementation, it is likely that the rate of feed passage in the rumen was reduced, and this allowed the nutrients to remain in the rumen for a longer period of time making a more efficient use of feed, which implies a better utilization of nutrients in the gastrointestinal tract as pointed out by Lopez et al (29).

The response of dietary effect on milk composition is varied. In this regard, the increase in the yield of milk components because of the inclusion of a dietary supplement, independently of the supplementation schedule, is explained by an increase in milk production, although without changes in protein or lactose concentrations, which are generally not modified by the effect of the diet (30), similar to what was observed in this study.

On the other hand, the concentration of fat in milk is more easily manipulated because of the diet (31), which explains the fact that fat was the only milk component that was modified by the effect of the treatment. This can be explained by two main ways, in the first one, the goats of the control group presented the highest amount of fat, because they were only fed through grazing, with which, the rumen production of acetate and butyrate was probably higher and, being lipogenic precursors, caused a higher synthesis of fat in milk (32). The second hypothesis explains that the supplemented goats produced a higher concentration of conjugated linoleic acid (CLA) (due to the ingredients that make up the integral feed) (33), and as a consequence of the *trans-10*, *cis-12* isomer of CLA that inhibits the gene expression of lipogenic enzymes in the mammary gland, the concentration of fat in milk of the supplemented goats was reduced (34).

In conclusion, offering a feed supplement to lactating goats on pasture either in the morning or in the afternoon improves the productive response in terms of production and yield of milk quality components, however, the best results were observed in the evening supplementation with respect to the morning supplementation.

Therefore, under the extensive grazing conditions of northern Mexico, it is recommended to offer a complete feed as an afternoon supplement to lactating goats on pasture to increase production and yield of milk components during the dry season.

Conflict of interests

The authors of this study declare that there is no conflict of interest with the publication of this manuscript.

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