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Impact of milk fat source and level on the productive performance of suckling goat kids

Abstract – The objective of this work was to evaluate the food intake, nutrient digestibility, and weight gain of female suckling goat kids fed with goat and cow milk with different levels of fat. Thirty-two crossbred goats in the suckling phase were distributed in a 2x2 factorial arrangement, in a completely randomized design. Two sources of fat (goat and cow milk) and two levels of fat addition to milk (3.5 and 7.0%) were evaluated for 97 days in eight replicates. Dry matter intake was affected by milk source and fat levels. The highest nutrient intake was observed with goat milk with 7.0% fat. Crude protein intake was affected only by fat source due to the greater presence of protein in goat milk, whereas crude fat intake was affected only by fat levels. The average daily gain was higher for goat kids that ingested milk with 7.0% fat. The source of fat did not affect nutrient digestibility, but the levels of fat influenced dry matter digestibility. The inclusion of 7.0% fat in milk increases the weight gain of suckling goat kids without affecting fat digestibility. Fat from goat milk increases weight at weaning possibly due to a higher energy intake.

Index terms: dairy goats, digestibility, food intake, lipids, weight gain.

Impacto de fonte e nível de gordura do leite no desempenho produtivo de cabritas lactentes

Resumo – O objetivo deste trabalho foi avaliar o consumo, a digestibilidade dos nutrientes e o ganho de peso de cabritas lactentes alimentadas com leite de cabra e de vaca com diferentes níveis de gordura. Trinta e duas cabras mestiças lactentes foram distribuídas em arranjo fatorial 2x2, em delineamento inteiramente casualizado. Foram avaliadas duas fontes de gordura (leite de cabra e vaca) e dois níveis de adição de gordura no leite (3,5 e 7,0%) durante 97 dias, em oito repetições. O consumo de matéria seca foi influenciado pela fonte e pelo teor de gordura do leite. A maior ingestão de nutrientes foi observada com leite de cabra com 7,0% de gordura. O consumo de proteína bruta foi afetado apenas pela fonte de gordura devido à maior presença de proteína no leite de cabra, enquanto o consumo de gordura bruta foi afetado apenas pelos níveis de gordura. O ganho de peso médio diário foi maior para as cabritas que ingeriram leite com 7,0% de gordura. A fonte de gordura não afetou a digestibilidade dos nutrientes, mas os níveis de gordura influenciaram a digestibilidade da matéria seca. A inclusão do nível de 7,0% de gordura no leite aumenta o ganho de peso das cabritas sem afetar a digestibilidade da gordura. A gordura de leite de cabra aumenta o peso ao desmame possivelmente devido à maior ingestão de calorias.

Termos para indexação: cabras leiteiras, digestibilidade, consumo, lipídios, ganho de peso.

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Introduction

In dairy goat systems, it is a usual practice to separate the female kids from their mothers right after the colostrum-intake phase in order to increase the availability of goat milk for sale (Berthelot et al., 2024). However, since the breeding phase is central in the goat production system, ensuring an adequate nutrition is essential to guarantee herd replacement (Alderman & Cottrill, 1993; Nasem, 2021).

Some feeding strategies have been used to obtain a high animal performance and low production costs. One strategy is the inclusion of fat sources in the diet for ruminants in order to increase dietary energy concentration, improving nutrient use and feed conversion efficiency for meat or milk production (Behan et al., 2019). This is important since energy deficiency slows animal growth, increases age at puberty, reduces fertility, and decreases weight gain and milk production (Strucken et al., 2015). When animals are young, they have a higher growth rate than in the subsequent phases (Owens et al., 1993), which demands a higher amount of energy that must be fully met so as not to irreversibly damage the animal's productive life (Slater et al., 2019). Excess fat in a diet can significantly affect digestibility and lead to metabolic issues like diarrhea (Argov et al., 2008). Therefore, balanced nutrition is necessary for optimal animal performance, health, and welfare (Conneely et al., 2014).

In goat milk production, feeding the kids with cow milk is a common practice due to its lower cost compared with that of goat milk. However, the actual impact of this substitution is not entirely known, although there are a few studies about the addition of fat and the use of different fatty acid (FA) profiles in the diet of suckling goat kids (Coutinho Neto et al., 2022).

The FA profile in ruminant milk varies among species. In goat and sheep milk, for example, there is a predominance of short- and medium-chain FAs, such as caprylic, caproic, capric, and myristic, while, in cattle and buffalo milk, long-chain FAs, as palmitic and stearic, predominate. Short-chain FAs are easier to absorb than long-chain FAs because they have a lower carbon number (<10 carbons), do not undergo re-esterification in intestinal cells (Singh et al., 2017), and can be absorbed directly and enter portal circulation (Silva et al., 2020). Considering these findings, the present study hypothesized that adding fat and using different FA profiles in the milk feed to goat kids would affect their productive performance.

The objective of this work was to evaluate the food intake, nutrient digestibility, and weight gain of female suckling goat kids fed with goat and cow milk with different levels of fat.

Materials and Methods

The ethics committee on animal use of the Animal Science Department of Universidade Federal de Viçosa (UFV) approved the experiment, under protocol number 114/2018.

The experiment was carried out in the municipality of Viçosa, in the state of Minas Gerais, Brazil (20°46'19"S, 42°51'12"W, at 707 m altitude). According to Köppen's classification, the climate is Cwa, tropical, high altitude, with rainy summers and dry winters. The annual average temperature is 18.5ºC, ranging from 8.2 to 28.5ºC, whereas the annual rainfall is 1,203 mm, and the average relative humidity is 80%.

Thirty-two crossbred female goat kids (Saanen x Alpine) from a single birth, in the suckling phase, were used from birth to weaning, at approximately 97 days. The animals were weighed and identified after birth, and colostrum was provided immediately. From birth until the third day, the kids remained with their mothers, and, then, they were taken to individual suspended cages, with 0.375 m^2 (0.50 x 0.75 m) and a plastic floor, where they stayed for 94 days.

The animals were distributed in a completely randomized design in a 2x2 factorial arrangement with eight replicates. Two sources of fat (goat and cow milk) and two levels of fat addition to milk (3.5 and 7.0%) were evaluated. The experimental unit was one female goat kid. The experimental period began on the seventeenth day of the animal's life, lasting until the ninety-seventh day, totaling 80 days for each animal in a treatment. During the experiment, the tested animals received only milk in order to avoid a confounding effect due to the inclusion of hay and concentrate. Skim goat milk was used as a baseline for the addition of fat to the diet. The liquid diet composed of 3.5% fat was considered as the control, based on the average fat content of goat milk. The diet with 7.0% fat exceeded the average fat content in whole goat milk, challenging the animals in terms of performance due to a higher energy intake. Goat and cow milk creams were used to reach the desired fat levels in the milk fed to the tested animals.

The goat and cow milk used in the study were obtained from UFV. The milk was taken to the Dairy School of UFV to obtain the creams, which were then stored in a cold room, heated to 45ºC in a water bath, added to skim milk, and properly homogenized to achieve a uniform emulsion, just like whole milk. The chemical composition of the goat and cow milk is presented in Table 1.

The kids received whole goat milk until the sixth day of life, after which they underwent an adaptation period until the seventeenth day of life. In the first day of the adaptation period, all groups were fed with milk with 3.5% fat. Then, every two days, the groups to be fed with milk containing 7.0% fat received an increment of 1.0% fat in their diets using either cow or goat milk cream (Table 2), depending on the treatment; the objective of this slow addition of fat was to avoid nutritional disorders, such as diarrhea. The fatty acid profile of the used milk cream is presented in Table 3.

The milk was offered in plastic baby bottles with a maximum capacity of 500 mL. From the fourth day of life to the twenty-fifth day, the kids received 1.0 L milk daily, whereas, from the twenty-fifth day to the ninety-seventh, they received 1.5 L milk per day. From the eighteenth day until weaning, the animals received milk four times daily at 8 a.m., 11 a.m., 2 p.m., and 5 p.m.

The samples of the diets fed to each animal were collected daily, stored in sterile bottles with 2-bromo-2-nitropropane-1,3-diol, and taken to the Animal Nutrition Laboratory of UFV. The contents of crude fat, crude protein, and lactose were determined using the 255A/B Minor Milko Scan infrared analyzer (Foss Electric, Hillerød, Denmark). Milk net energy was estimated according to the formula proposed by Nasem (2021), as follows:

$$NE=9.29 \times CF + 5.5 \times CP + 3.95 \times LA$$

where NE is milk energy net in Mcal kg^{-1}, CF is crude fat in kilograms, CP is crude protein in kilograms, and LA is lactose in kilograms.

Data on daily milk intake were recorded until kid weaning. The animals were individually weighed every three days in the morning and afternoon before the milk was supplied.

The observed nutrient intake was determined by the difference between the total milk offered and any possible orts, using the equation:

$$NI=TO - OR$$

where NI is nutrient intake in g kg^{-1}, TO is the total milk offered in g kg^{-1}, and OR is any possible orts in g kg^{-1}.

The digestibility trial started on the seventy-fifth experimental day. For this, metabolic cages were used to separate feces and urine. Total fecal collection was performed for five consecutive days, every 2 hours.

Table 1. Chemical composition of two milk sources (goat and cow) and two levels of added milk fat (3.5 and 7.0%).

Nutrient	Goat milk		Cow milk	
	3.5%	7.0%	3.5%	7.0%
Fat (g kg^{-1})	37	72	34	70
Protein (g kg^{-1})	28	30	16	27
Lactose (g kg^{-1})	45	43	38	33
Total solids (g kg^{-1})	121	163	109	126

Table 2. Chemical composition of the used milk cream from two sources.

Component	Goat milk	Cow milk
Fat (g kg^{-1})	444	473
Protein (g kg^{-1})	19	15
Lactose (g kg^{-1})	24	24
Total solid (g kg^{-1})	491	517

Table 3. Fatty acid profile of the used milk cream from two sources.

Compound (g 100 g^{-1} of fatty acid)	Goat milk	Cow milk
Butyric acid	3.5	4.8
Caproic acid	2.3	2.1
Caprylic acid	2.8	1.2
Capric acid	9.6	2.4
Lauric acid	3.0	4.6
Myristic acid	10.9	10.0
Palmitic acid	25.6	29.0
Stearic acid	12.7	9.6
Palmitoleic acid	2.3	2.0
Oleic acid	24.4	20.9
Linoleic acid	2.6	2.4
Linolenic acid	1.7	1.1
C 18:1 Trans	3.0	0.0
Σ short chain	9.2	19.4
Σ saturated	55.6	49.9
Σ monounsaturated	26.7	22.9
Σ polyunsaturated	4.3	3.5

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The fecal samples were stored in a freezer at -20°C, dried at 55°C in a forced-air oven for 72 hours, and ground in a Wiley mill with a 1.0 mm sieve for the chemical analysis.

The apparent nutrient digestibility was determined by the difference between nutrient intake and the nutrients present in the feces, using the following equation:

$$DI = NI - FE$$

where DI is apparent nutrient digestibility in g kg^{-1}, NI is nutrient intake in g kg^{-1}, and FE are the nutrients present in the feces in g kg^{-1}.

All samples were analyzed for total dry matter, crude fat, and crude protein (nitrogen × 6.38) using methods 967.03, 2,003.06, and 984.13, respectively, of Association of Official Analytical Chemists (AOAC) (Latimer Jr., 2019).

The following statistical model was used:

$$Y_{ijk} = \mu + \alpha_i + \tau_j + \alpha\tau_{ij} + \beta(X_{ijk} - \bar{X}) + e_{ijk}$$

where Y_{ijk} is the observed value for nutrient intake and digestibility of the k-th replicate of the i-th fat source in the j-th fat level; μ is the mean of all experimental units for the variable under study; α_i is the effect of fat sources with i=1, 2; τ_j is the effect of fat levels with i=1,2; $\alpha\tau_{ij}$ is the interaction between sources and levels of fat; β is the linear regression coefficient between the covariate (X=birth weight) and the response variable (Y), with $\beta \neq 0$; and e_{ijk} is the error associated with observation .

The data were subjected to the factorial analysis of variance, and means were compared by Tukey's test (α=0.05). The SAS MIXED package was used (SAS Institute Inc., Cary, NC, USA). Data normality and homoscedasticity were verified using Shapiro-Wilk's test through the PROC UNIVARIATE procedure and Bartlett's test, respectively. Outliers were checked using the methodology suggested by Draper & Smith (1998). Independence of errors was verified using Durbin-Watson's test. The assumptions were met, and no outliers were found.

Results and Discussion

There was no significant interaction (p>0.05) between the sources and levels of fat regarding the analyzed variables, according to the S x FL column in Tables 4, 5, and 6. However, dry matter intake was affected by fat source (p<0.001) and levels (p<0.001), meaning goat milk with 7.0% fat was the most ingested milk (Table 5).

Crude protein intake was only affected by fat source (p<0.001), showing an increase for animals that received goat milk due to its high crude protein content (Table 1). Based on the averages of the protein content of each source, the kids that received cow milk ingested 25.86% less protein than those that received goat milk. Based on the averages of the weights of each source, there was a 3.7 and 3.39% decrease in mean daily gain and weaning weight, respectively (Table 4). Similarly, Park (1994) found that goat milk may promote a better weight gain and growth in kids due to a greater bioavailability of nutrients (mainly protein) compared with cow milk. Proteins are essential for maintaining daily biological processes, such as enzymes, and are related to postnatal growth and development, including muscle deposition (Bartlett et al., 2006; Geiger et al., 2016).

Crude fat intake was influenced only by the levels of fat (p<0.001) (Table 5). However, the increase in fat intake initially caused diarrhea, which soon ceased during the diet adaptation period. For Park (1994), cow milk may be associated with a higher incidence of digestive problems, such as diarrhea, especially in goats that are sensitive to certain components of this milk.

Weaning weight was affected by the source (p=0.045) and levels (p=0.003) of fat (Table 4). In the high-fat diets (7.0%), the daily weight gain was higher than in the low-fat diets (p=0.003). The high-fat diets also presented a higher net energy intake (p<0.001), which may explain the higher daily weight gain observed (Table 5). According to Wicks et al. (2019), muscle deposition demands a large amount of energy (metabolism support) due to the growth rate of this tissue.

Lactose intake was affected by the source (p<0.001) and levels of fat (p<0.001). The highest intake was observed when using goat milk with 3.5% fat (Table 5), which is related to the higher lactose content in this milk compared with that of cow milk (Table 1). Lactose, the main carbohydrate in milk, is a readily available glucose source due to its high digestion rate (Forsgård, 2019).

Regarding digestibility, the fat source did not affect nutrient digestibility (p>0.05), whereas the fat levels only influenced dry matter digestibility (p=0.007) (Table 6). According to Chilliard et al. (2006), the FAs in goat milk cream are easier to digest and absorb, since they do not need to undergo re-esterification in the enterocyte due to the smaller size of their carbon chain when compared with that of the FAs in cow milk cream. However, this finding was not observed in the present study. Dry matter digestibility increased (p=0.007) when the animals received milk with 3.5% fat, which can be explained by the greater efficiency of rennin and αS1-casein. Rennin separates milk into liquid and solid fractions, increasing the time that milk remains in the body, which improves digestion efficiency and nutrient absorption (Aljammas et al., 2018). In addition to separating solid elements from water by agglutination, mainly fat, αS1-casein is easier to digest due to its lower concentration (Pazzola et al., 2019).

Table 4. Means and results of the analysis of variance for body weight at the beginning of the experiment (initial), weight at weaning (final), and daily gain of female Alpine x Saanen goat kids fed with different milk sources (goat and cow) and levels of added fat (3.5 and 7.0%)[(1)].

Body weight	Goat milk		Cow milk		SEM[(2)]	p-value		
	3.5%	7.0%	3.5%	7.0%		Source (S)	Fat level (FL)	S x FL
Initial weight (kg)	3.4	3.3	3.2	3.7	0.1	0.281	0.144	0.206
Final weight (kg)	18.0Ba	19.0Aa	17.0Bb	19.0Ab	0.2	0.045	0.003	0.439
Daily gain (kg)	0.13B	0.14A	0.12B	0.14A	0.00	0.095	0.003	0.655

[(1)]Means followed by the different letters, uppercase in the column and lowercase in the line, differ significantly between fat levels and between fat sources, respectively, using Tukey's test (α=0.05). [(2)]Standard error of the mean.

Table 5. Means and results of the analysis of variance of the daily intake of nutrients and energy of female Alpine x Saanen goat kids fed with different milk sources (goat and cow) and levels of added fat (3.5 and 7.0%)[(1)].

Intake[(2)]	Goat milk		Cow milk		SEM[(3)]	p-value		
	3.5%	7.0%	3.5%	7.0%		Source	Fat level (FL)	S x FL
DMI (g)	15.0Ba	19.0Aa	13.0Bb	18.0Ab	0.4	<0.001	<0.001	0.143
CPI (g)	4.0a	4.0a	3.0b	3.0b	0.1	<0.001	0.200	0.573
CFI (g)	4.0B	8.0A	4.0B	8.0A	0.3	0.140	<0.001	0.963
LacI (g)	5.0Aa	4.0Ba	3.0Ab	3.0Bb	0.2	<0.001	<0.001	0.465
NEI (Mcal)	1,038.2Ba	1,944.4Aa	840.1Bb	1,542.5Ab	201.1	<0.001	<0.001	0.072

[(1)]Means followed by different letters, uppercase in the column and lowercase in the line, differ significantly between fat levels and between fat sources, respectively, using Tukey's test (α=0.05). [(2)]DMI, dry matter intake; CPI, crude protein intake; CFI, crude fat intake; LacI, lactose intake; and NEI, net energy intake. [(3)]SEM, standard error of the mean.

Table 6. Means and results of the analysis of variance of the nutrient digestibility of female Alpine x Saanen goat kids fed with different milk sources (goat and cow) and levels of added fat (3.5 and 7.0%)[(1)].

Digestibility ($g\ kg^{-1}$ dry matter)	Goat milk		Cow milk		SEM[(2)]	p-value		
	3.5%	7.0%	3.5%	7.0%		Source (S)	Fat level (FL)	S x FL
Dry matter	984A	957B	977A	963B	2.773	0.945	0.007	0.277
Crude protein	987	986	983	981	1.118	0.113	0.315	0.684
Crude fat	908	880	954	948	8.769	0.158	0.673	0.770

[(1)]Means followed by different uppercase letters, in the column, differ significantly between fat levels, using Tukey's test (α=0.05). [(2)]Standard error of the mean.

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Conclusions

1. The addition of 7.0% fat to milk increases the weight gain of female suckling goat kids without affecting fat digestibility.

2. Goat milk as a fat source increases weight at weaning in goat kids possibly due to a higher energy intake.

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