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Crude protein levels in diets containing pelleted concentrate for lactating goats: intake, digestibility, milk production and composition

Níveis de proteína bruta em dietas contendo concentrados peletizados para cabras lactantes: consumo, digestibilidade, produção e composição do leite

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Abstract

This study aimed to evaluate the effects of crude protein (100, 130, 160 and 190 g kg^{-1} of dry matter) of diets composed of 200 g kg^{-1} of Tifton 85 grass hay and 800 g kg^{-1} of pelleted concentrate on intake, nutrient digestibility, production and composition of milk in lactating goats. Eight female Saanen goats with 42.7 ± 1.43 kg and 57.7 ± 7.37 days of lactation and milk production of 2 ± 0.22 kg at the beginning of the experiment were housed in individual 1.32 × 3.10 m stalls and distributed into two 4 × 4-balanced Latin squares. Intake of dry matter, organic matter, crude protein, neutral detergent fiber corrected for ash and protein, ether extract and total digestible nutrients showed a quadratic effect, with maximum intake of 2.030; 2.000; 305; 769; 55 and 1.574 g day^{-1} at the levels of 140.7; 140.8; 189.2; 140.9; 144.9 e 142.7 g kg^{-1} DM, respectively. Digestibility of dry matter, organic matter, crude protein, non-fibrous carbohydrates, ether extract and total digestible nutrient level varied linearly, with increases estimated at 0.54; 0.50, 2.02, 0.49, 0.80 and 0.63 g/100g for each percentage unit of protein added to the diet, respectively. Milk production was affected, with increase of 0.54 g for each 1% crude protein added to the diet. Milk lactose level decreased linearly, unlike the fat level, which increased linearly. Protein level showed a quadratic behavior, with a maximum of 36.7 g per kg of milk at the level of 160.5 g per kg of DM. It is recommended to use crude protein between 135 g and 150 g per kg of dry matter of diets consisting of 800 g of pelleted concentrate (composed of soybean meal replacing the alfalfa hay as protein source) per kg of DM for lactating goats producing 2 kg of milk per day.

Key words: Alfalfa hay, feedlot, mesquite pod meal, soybean meal, Tifton 85 grass

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Resumo

Objetivou-se avaliar os efeitos de proteína bruta (100; 130; 160 e 190 g kg^{-1} de matéria seca) de dietas compostas por 200 g kg^{-1} de feno de capim Tifton 85 e 800 g kg^{-1} de concentrado peletizado sobre o consumo, digestibilidade dos nutrientes, produção e composição do leite em cabras lactantes. Foram utilizadas oito fêmeas caprinas, da raça Saanen, com peso de 42,7 ± 1,43 kg e com 57,7 ± 7,37 dias de lactação e produção de leite de 2 ± 0,22 kg ao início do experimento. Os animais foram confinados em baias individuais com dimensões de 1,32 x 3,10 e distribuídos em um delineamento em quadrado latino 4 x 4. Cada período experimental teve duração de 20 dias, sendo 15 dias de adaptação a dieta e 5 dias de coleta de dados. Os consumos de matéria seca, matéria orgânica, proteína bruta, fibra em detergente neutro isenta de cinza e proteína, extrato etéreo e, nutrientes digestíveis totais, apresentaram respostas quadráticas, com consumos máximos de 2.030; 2.000; 305; 769; 55 e 1.574 g dia^{-1}, nos níveis de 140,7; 140,8; 189.2; 140,9; 144,9 e 142.7 g kg^{-1} de matéria seca, respectivamente. As digestibilidades da matéria seca, matéria orgânica, proteína bruta, carboidratos não fibrosos corrigidos para cinza e proteína, extrato etéreo e os teores de nutrientes digestíveis totais variaram linearmente estimando-se aumento de 0,54; 0,50; 2,02; 0,49; 0,80 e 0,63 g/100g, para cada unidade percentual de proteína adicionada à dieta, respectivamente. A produção de leite foi afetada, apresentando acréscimo de 0,54 g para cada 1% de proteína bruta adicionada à dieta. O teor de lactose do leite diminuiu linearmente diferentemente do teor de gordura que aumentou linearmente. O teor de proteína apresentou comportamento quadrático com máximo de 36,7 g por kg de leite no nível de 160,5 g de proteína por kg de MS na dieta. Recomenda-se a utilização de concentrações de proteína bruta de 135 g até 150 g por kg de matéria seca de dietas constituídas por 800 g de concentrados peletizados (compostos por farelo de soja em substituição ao feno de alfafa como fonte de proteína) por kg de MS para cabras lactantes produzindo 2 kg de leite por dia.

Palavras-chave: Capim Tifton 85, confinamento, farelo de algaroba, farelo de soja, feno de alfafa

Introduction

Supplementation with protein concentrates in feedlot systems has been used to improve production efficiency and maximize animal productivity. This requires knowledge of the animal protein metabolism as well as information about the nutritional value of the feed offered and rumen fermentation profile. Considering that these supplements are responsible for the high cost of feeding, they have to be used sparingly in order to reduce costs not only with production but also with regard to energy costs for the animal to excrete excess protein. Alfalfa is a highly palatable legume widely used in ruminant feed as a source of protein; it presents concentrations of 220 - 250 g kg^{-1} of crude protein per kg of DM, and its hay is a good source of highly digestible fiber (CHEEKE, 1987).

Alfalfa can be used as a component of the concentrate given the greater proportion of cell level in relation to cell wall components when compared with grasses and has a rumen-degradable protein level around 700 g kg^{-1}. Pelleting process of alfalfa hay solves some problems caused by the grinding, increases the density, facilitates handling and avoids problems caused by powder inhalation and reduces the possibility of selecting the diet (BOIN, 1993). Soybean meal is a co-product from soybean oil extraction traditionally used as a source of basic protein, it has optimal composition of amino acids, crude protein level around 480 g kg^{-1} and of this about 650 is degraded in the rumen (VALADARES FILHO et al., 2010). Assuming that there are few alternatives to replace it in concentrates, the combination with other protein sources can contribute to cost reduction. However, the use of alfalfa hay as the sole source of protein in concentrates is not feasible due to low crude protein level and the animal performance is lower in comparison with that achieved when using soybean meal.

Given the above, the objective of this experiment was to evaluate the effect of diets composed of 800 g kg^{-1} pelleted concentrate with crude protein level of 100; 130; 160 and 190 g kg^{-1} DM using soybean meal replacing alfalfa meal on the intake, nutrient digestibility, production and composition of milk in lactating goats.

Material and Methods

Location

The experiment was conducted at the Goat Sector of State University of Southwest Bahia (UESB), Campus Vitória da Conquista, from June to August 2009. Vitória da Conquista is a city in southwestern Bahia State, Brazil, located at 14º53' South latitude, 40°48' West longitude and 870 m altitude. The average annual rainfall is 733.9 mm. During the study months, the minimum and maximum temperatures averaged 9.7 and 31.3 ºC, respectively.

Experimental design, animal, housing, and diets

Eight Saanen goats with body score 2 and 57.7 ± 7.37 days in milk, producing daily 2 ± 0.22 kg were dewormed, housed in individual stalls with dimensions of 1.32 × 3.10 m. At the onset of the experiment, the body weight was 42.7 ± 1.43 kg; goats were weighed at the end of each experimental period. Animals were distributed into two 4 × 4-balanced Latin squares, repeated over time, consisting of four periods of 20 days (fifteen for adaptation and five for data collection).

Four diets with different protein levels were evaluated: 100, 130, 160 and 190 g kg^{-1} in the total dry matter of the diet, where the replacements of alfalfa hay by soybean meal in concentrate guaranteed increases in crude protein. The forage: concentrate ratio was 200:800 g kg^{-1} dry matter; the feed was composed of Tifton 85 grass hay chopped (5-8 cm) and pelleted concentrate. The diets were formulated according to NRC (2007) (Table 1).

Table 1. Composition of ingredients in concentrate as fed (g kg^{-1} of natural matter)

Ingredient	Níveis de proteína bruta (% MS)			
	100	130	160	190
Milled corn grain	294.3	294.0	293.8	293.5
Mesquite pod meal	495.7	495.3	494.9	494.5
Soy meal	-	6,32	12,64	18,94
Urea	2.2	2.2	2.2	2.2
Alfalfa hay	187.4	124.8	62.3	-
Common salt	3.3	3.3	3.3	3.3
Mineral salt*	16.8	16.8	16.7	16.7

*Composition: 24 g Ca kg^{-1}; 7.1 g P kg^{-1}; 2 g Mg kg^{-1}; 0.003 g Co kg^{-1}; 0.04 g Cu kg^{-1}; 0.004 g I kg^{-1}; 0.135 g Mn kg^{-1}; 2 g S kg^{-1}; 0.17 g Zn kg^{-1}.

Animals were fed daily at 07h30 and 15h00 *ad libitum*; diets were supplied to allow approximately 10% leftovers. The voluntary intake was calculated as the difference between the feed supplied and leftovers. From the 16th to the 20th day, leftovers were collected daily, weighed and sampled at 10% of their weight.

Sampling and measurements

Samples of leftovers of each animal for each trial were collected and stored at -20 ºC until laboratory analysis. At the end of the collection period, samples were thawed, homogenized, and then, following the procedures described by Silva and Queiroz (2002), the DM, ash, CP, NDIP, ADIP, EE, NDFap and ADF levels (Table 2) were analyzed.

Total carbohydrates were determined according to Sniffen et al. (1992): TC = 100 - (CP +EE + MM). Where: TC = total carbohydrates (g kg^{-1} of DM), CP = CP level (g kg^{-1} of DM), EE = EE level (g kg^{-1} of DM), MM = MM level (g kg^{-1} of DM).

Table 2. Chemical composition of Tifton 85 grass hay and of experimental diets.

Item		Crude protein levels (g kg^{-1} of DM)			
		100	130	160	190
	Tifton 85 grass hay	Chemical composition of the concentrates (g kg^{-1} of DM)			
DM	887.5	961.3	953.1	950.9	939.5
OM	981.8	989.9	990.1	990.0	988.0
CP	72.1	101.3	129.3	160.2	195.2
NDIP	13.1	19.5	23.3	24.3	35.4
ADIP	3.3	7.3	9.1	10.5	11.9
EE	15.5	27.1	32.2	30.5	27.6
CT	845.4	776.6	751.2	734.7	687.0
NDFap	838.4	333.8	326.0	323.7	250.0
FDA	484.5	197.4	187.0	165.9	154.4
NFCap	23.7	442.8	425.2	410.0	437.0
TDN	646.5	752.4	779.4.6	785.7	821.6

DM - dry matter; OM - organic matter; CP - crude protein; NDIP - neutral detergent insoluble protein; ADIP - acid detergent insoluble protein; EE - ether extract; TC - total carbohydrates; NDFap - neutral detergent fiber corrected for ash and protein; NFCap - non-fibrous carbohydrates corrected for ash and protein; TDN - total digestible nutrients.

Levels of non-fibrous carbohydrates corrected for ash and protein (NFC) were calculated according to Hall (2003), as follows: NFCap = 100 - (CP + EE + MM + NDFap). Where: NFC = estimated level of non-fibrous carbohydrates (g kg^{-1} of DM); CP = CP level (g kg^{-1} of DM); EE = EE level (g kg^{-1} of DM); MM = MM level (g kg^{-1} of DM); NDFap = NDF level corrected for ash and protein (g kg^{-1} of DM).

Total digestible nutrients (TDN) were calculated according to Weiss (1999), but using NDF and NFC free of ash and protein, with the following equation: TDN = 2.25 × DEE + DCP + DNFC + DNDFap. Where: DEE= digestible ether extract; DCP = digestible crude protein; DNFC = digestible non-fibrous carbohydrates; DNDFap = digestible neutral detergent fiber corrected for ash and protein.

Fecal samples were taken in four periods by the morning and afternoon on the 17th and the 18th days after milking, directly from the rectal ampulla. Indigestible acid detergent fiber (iADF) was used as internal marker to determine the digestibility of DM, OM, CP, EE, NDFap, and NFC. Samples of the feed supplied (hay, concentrate), leftovers and feces were pre-dried, crushed to 1.0 mm and incubated in the rumen of cattle per 264 hours in nylon nonwoven fabric bags - 100 g m^{2-1} (CASALI et al., 2008). They were then subjected to extraction with acid detergent to quantify the levels of iADF. The ratio between iADF intake and fecal iADF concentration was used to estimate the fecal excretion. Milk production was quantified from the 16th to the 20th experimental day and its composition was obtained based on a composite sample with 10% of the milk taken manually in the afternoon of the 15th day and in the morning of the 16th day of collection, in each experimental period. The milk of the afternoon milking remained stored under refrigeration (0-4°C) until the next morning, where composite samples were placed in plastic bottles with preservative (Bronopol®) to determine the concentration of total nitrogen and crude protein, lactose, fat, total solids and nonfat solids. Qualitative analyses of milk were performed at the Laboratory of Physiology of Lactation, Escola Superior Luiz de Queiroz (ESALQ), Piracicaba, São Paulo State, Brazil.

To correct the production of milk with 4.0% fat (FCM), the equation of NRC (2001) was used: FCM = 0.4(kg milk) + 15(kg of fat). Feed efficiency was obtained by considering the average milk produced (kg/day) divided by the amount of food consumed (kg/day), while the N utilization efficiency was calculated by dividing the amount of milk produced (kg/day) by the amount of N consumed (kg/day).

Statistical analysis

The effect of treatments was evaluated on intake, digestibility and milk production and composition and partitioned into linear, quadratic and cubic polynomial contrasts subjected to the procedure MIXED of SAS STATISTICAL ANALYSIS SYSTEM (1996) with the following model: $Y_{ijkl} = \mu + Q_i + C_j\ (i) + P_k + T_l + e_{ijkl}$. Where: μ = overall mean; Qi = squared effect (i = 1 to 4); Cj (i) = effect of goat within square (j = 1-8); P_k = effect of period (k = 1 to 4); T_l = effect of treatment (l = 100, 130, 160 and 190 g kg^{-1} of CP, on a DM basis); and e_{ijkl} = residual error.

Results and Discussion

A quadratic effect (P<0.01) was found according to the level of dietary protein for dry matter intake, with maximum intake of 2.030 g day^{-1} of DM estimated for a crude protein level of 140.7 g kg^{-1} of DM (Table 3).

For the intake of DM in g kg^{-1} BW, the same quadratic behavior (P<0.01) was observed, with an estimated peak of 49.34 g kg^{-1} BW at the level of 138 g of CP per kg of DM intake. These results were higher those reported by Fonseca et al. (2008), 1.53-1.74 kg day^{-1}, using diets for lactating goats with CP levels of 115-175 g kg^{-1} of DM, observing no effects on dry matter intake and organic matter despite the lower NDF level in the diet, which was 581.6 g kg^{-1} of DM. In the present study, the average was 669 g kg^{-1} of DM.

Paiva (2009) stated that increases in nutrient intake with the addition of dietary protein is justified by the increased availability of nitrogen in the rumen, providing greater growth of cellulolytic microorganisms, resulting in increased fiber degradation, passage rate and nutrient utilization.

Branco et al. (2011) claimed that the relationship between dry matter intake and neutral detergent fiber level in the diet has a quadratic nature, and that the inflection point is the balance between the physical and physiological control.

The fiber level in the diet at the inflection point indicates the approximate maximum amount of feed to maximize energy intake by the animal. In this study, the dry matter intake was affected by physiological control, considering that the NDF reduced with increasing crude protein in diets, due to the replacement of alfalfa hay by soybean meal.

In the same way of DM intake, there was also a quadratic effect (P<0.01) for organic matter intake, which was 2 kg day^{-1} at the crude protein level of 140.8 g kg^{-1}. When expressed in g kg^{-1} BW, the maximum intake (P<0.01) was 48.48 g kg^{-1} BW for 135.7 kg^{-1} CP in DM.

For crude protein intake in g day^{-1}, the quadratic model was fit (P<0.01) with a maximum intake of 290 g day^{-1} for the level of 189.2 g of CP kg^{-1} of DM.

This variation was a reflection of dry matter intake, although this estimate was very close to the highest level of CP tested. When CP intake was expressed as g kg^{-1} BW, we observed a linear effect (P<0.01) with the increase of 0.35 g in intake for every 10 g kg^{-1} increase in CP level in the diet.

Table 3. Average intake of nutrients by lactating goats fed diets containing levels of crude protein.

Item	Crude protein levels (g kg^{-1} of DM)				SDE	P-value	
	100	130	160	190		L	Q
(g day^{-1})							
DM	2050	2130	2190	1770	130	0.0001	0.0001[1]
OM	2010	2.10	2160	1740	130	0.0001	0.0001[2]
CP	180	250	310	300	20	0.0001	0.0001[3]
EE	40	60	60	40	10	0.0001	0.0001[4]
NDFap	780	770	790	520	60	0.0001	0.0001[5]
NFC	960	970	920	830	100	0.0001[6]	0.2779
TDN	1480	1600	1670	1390	180	0.0001	0.0001[7]
(g kg^{-1} of BW)							
DM	44.53	46.33	48.39	39.04	3.50	0.0135	0.0085[8]
OM	43.82	45.61	47.64	38.42	4.87	0.0143	0.0091[9]
CP	3.94	5.36	6.95	6.57	1.21	0.0001[10]	0.0642
EE	0.95	1.31	1.43	0.93	0.15	0.0002	0.0002[11]
NDFap	16.82	16.95	17.66	11.46	2.21	0.0003	0.0002[12]
NFC	21.06	20.94	20.35	18.28	1.90	0.0007[13]	0.2711
TDN	33.39	36.93	39.22	32.07	4.12	0.0001	0.0001[14]

SDE - standard error ; BW - body weight; DM - dry matter; OM - organic matter; CP - crude protein; EE - ether extract; NDFap - neutral detergent fiber corrected for ash and protein; NFC - non-fibrous carbohydrates ; TDN - total digestible nutrients.

[1] $\hat{Y} = -(574.3) + (370.8)X - (13.17)X^2$

[2] $\hat{Y} = -(518.1) + (357.8)X - (12.70)X^2$

[3] $\hat{Y} = -(330.0) + (67.04)X - (1.777)X^2$

[4] $\hat{Y} = -(112.6) + (23.18)X - (0.800)X^2$

[5] $\hat{Y} = -(1242.2) + (285.3)X - (10.12)X^2$

[6] $\hat{Y} = (1.1008) - (0.01684)X$

[7] $\hat{Y} = -(197.3) + (248.3)X - (8.700)X^2$

[8] $\hat{Y} = (1.6472) + (7.0358)X - (0.2595)X^2$

[9] $\hat{Y} = (1.9872) + (6.8502)X - (0.2523)X^2$

[10] $\hat{Y} = (0.9934) + (0.3481)X$

[11] $\hat{Y} = -(2.8732) + (0.5805)X - (0.01993)X^2$

[12] $\hat{Y} = -(23.7587) + (5.9895)X - (0.2139)X^2$

[13] $\hat{Y} = (26.8453) - (0.4363)X$

[14] $\hat{Y} = -(22.6116) + (8.8408)X - (0.3071)X^2$.

For lactating goats, Morand-Fehr and Sauvant (1980) suggested that the level of crude protein in the total diet should vary between 130 g and 160 g per kg of dry matter, depending on the quality of dietary protein, the production of milk and stage of lactation.

According to Silva Sobrinho et al. (1991), requirements for dietary CP were 49.77, 74.65 and 99.53 g day^{-1} for 1.0, 1.5 and 2.0 kg of milk with 4% fat, respectively.

The ether extract intake showed a quadratic effect (P<0.01), probably reflecting the variation in DM intake at the level of 144.9 g of CP per kg of DM, with the highest intake of 50 g of EE per day. When expressed in g kg^{-1} BW, the intake of EE was 1.35 for the maximum level of 145.6 g of crude protein per kg of DM in the diet.

The intake of neutral detergent fiber free of ash and protein showed a quadratic effect (P<0.01), with maximum intake of 770 g day^{-1} estimated for the level of 140.9 g of CP per kg of DM. Likewise, for the intake of NDFap in g kg^{-1} BW, a peak of 18.18 was observed at the level of 140 g crude protein per kg of DM in the diet. As previously discussed, these results confirm that there was no limiting of intake by rumen fill, considering that the level of NDFap in diets was reduced by replacing alfalfa hay meal by soybean meal. Thus, it is assumed that diet with crude protein above 140 g cause a reduction in intake of dry matter and other nutrients.

The intake of non-fiber carbohydrates (NFC) expressed in g/day and g kg^{-1} BW decreased (P<0.01) according to the replacement of alfalfa hay by soybean meal, due to the lower DM intake in the diet containing 190 g crude protein, given the similarity in NFC level between the diets.

It is worth mentioning that Malafaia et al. (1998) found about 302.5 g kg^{-1} DM of NFC in alfalfa hay, in which 480.9 g kg^{-1} of DM of TC were found in the fraction B2, while for soybean meal, Cabral et al. (2000) reported values of 278 g kg^{-1} DM of NFC, of which only 81 g kg^{-1} of DM of TC were in the fraction B2. Thus, it can be inferred that alfalfa hay, compared to soybean meal, has approximately 6 times more carbohydrates in the fraction B2, while soybean meal has on average 1.1 times more NFC, which has led to a progressive reduction in NFC in the diets with soybean meal replacing alfalfa hay.

The average intake of total digestible nutrients followed the same variation as the other nutrients, fitting to a quadratic model, with CP levels of 142.7 g kg^{-1} of DM and 143.9 g kg^{-1} of DM for their respective maximum intake, of 1.570 g day^{-1} and 41.01 g kg^{-1} BW. Although the diets were formulated to be isoenergetic (Table 2), the behavior of dry matter and organic matter intakes was similarly influenced.

The selective ability of goats was favored by the physical characteristic of diet, in which the pelleted concentrate intake can be adjusted in response to CP levels exceeding 140 g kg^{-1} DM. Excess CP intake increases ruminal deamination of amino acids with greater release of ammonia and formation of hepatic urea, which increases the demand for metabolic energy. Thus, the physiological control of intake was the key mechanism contributing to reduced dry matter intake, which, likewise, affected the intake of other nutrients.

The digestibility of dry matter and organic matter increased linearly (P<0.01), with an estimated increase of 54 and 50 g kg^{-1}, respectively for each 1% unit of protein added to the diet (Table 4), possibly because the larger share of soybean meal in the diets to achieve the desired level of protein has provided higher amount of digestible nutrients.

The digestibility of crude protein increased linearly (P<0.01) with the addition of 20.2 g kg^{-1} percentage units of protein to the diet, which is consistent with the increased caused by the addition of soybean meal.

The digestibility of ether extract also increased linearly (P<0.05), with an estimated increase of 8.0 g kg^{-1} for each percentage unit of protein added to the diet, due to the greater participation of soybean meal.

The values obtained for the total digestible nutrients were affected by the levels of dietary CP (P<0.01), with an estimated increase of 63 g kg^{-1} for each percentage unit of protein added to the diet, being a reflection of increased digestibility of most fractions of nutrients.

Table 4. Apparent nutrient digestibility coefficients of lactating goats fed diets containing levels of crude protein.

Digestibility	Crude protein levels (g kg^{-1} of DM) (%MS)				SDE	P-value	
	100	130	160	190		L	Q
Dry matter	777.0	805.0	821.0	839.0	1.52	0.0001[1]	0.6497
Organic matter	791.0	815.0	831.0	849.0	1.43	0.0001[2]	0.7933
Crude protein	610.0	731.0	778.0	841.0	2.71	0.0001[3]	0.1879
Ether extract	663.0	732.0	734.0	716.0	3.88	0.0247[4]	0.2719
NDFap	631.0	678.0	703.0	664.0	2.77	0.1115	0.0184[5]
NFC	880.0	884.0	886.0	886.0	1.25	0.0010[6]	0.2708
TDN	724.0	751.0	763.0	790.0	2.50	0.0001[7]	0.9951

SDE - standard errors; DM - dry matter; NDFap - neutral detergent fiber exempt of ashes and protein; NFC - non-fibrous carbohydrates; TDN - total digestible nutrients (g kg^{-1} DM).

[1] $\hat{Y}= (75.0249) + (0.5461)X$

[2] $\hat{Y}= (76.7539) + (0.5033)X$

[3] $\hat{Y}= (48.4235) + (2.0204)X$

[4] $\hat{Y}= (61.0010) + (0.8017)X$

[5] $\hat{Y}=70.16$

[6] $\hat{Y}= (81.7027) + (0.4943)X$

[7] $\hat{Y}= (67.0110) + (0.6314)X$.

Despite the quadratic effect ($P<0.05$) in CP levels for mean values of FDNcp digestibility, an equation model could not be fit to these data, indicating that this variable was not affected by protein levels in the diet but rather by FDNcp level of the experimental diets, which were reduced according to the replacement of alfalfa hay by soybean meal.

NFC digestibility was influenced linearly ($P<0.01$), with an estimated increase of 4.9 g kg^{-1} for each percentage unit of crude protein added to the diet. As the NFC intake was reduced, it can be observed that increased levels of CP favored the availability of rumen-degradable protein for better utilization of energy and carbon skeleton of carbohydrates for proper fermentation.

Alves (2009) argued that the difference in crude protein digestibility is related to the non-fiber carbohydrate source. This statement corroborates Casper and Schingoethe (1989), who reported that different sources and degradability of non-structural carbohydrates in the diet alter microbial protein synthesis and improve utilization efficiency of rumen-degradable protein. This occurs by increasing the synchronization between the availability of protein and energy, maximizing the fermentative capacity in the rumen, increasing microbial protein synthesis and production of volatile fatty acids and also by reducing losses of ruminal fermentation.

Milk production (MP) in kg day^{-1} was influenced ($P<0.01$) by levels of dietary crude protein presenting a linear increase, a result of increased dry matter intake (Table 5).

Thus, it is evidenced a positive relationship between increasing levels of dietary crude protein and supply of nutrients to the mammary gland. The 4.0% fat-corrected milk (FCM) was not affected ($P>0.05$) by the levels of crude protein in the diet. The fat concentration increased linearly ($P<0.01$) and no significant variation was found in the amounts produced for this component, although the absolute values ranged from 449.0 to 527.0 g day^{-1}. The best explanation for this is the dilution effect of the increased volume of milk produced, provided by the diets with higher levels of CP.

Table 5. Production and composition averages of lactating goats fed diets containing levels of crude protein.

Variables	Crude protein levels (g kg^{-1} of DM)				SDE	P-value	
	100	130	160	190		L	Q
	Milk production (kg day^{-1})						
MP	1.5	1.7	1.7	1.6	0.02	0.0001[1]	0.0642
FMC	1.3	1.4	1.4	1.4	0.20	0.0760[2]	0.2931
Composition							
Concentration (g kg^{-1} of milk)							
Fat	30.0	28.0	29.0	33.0	2.80	0.0001[3]	0.2467
Protein	31.0	32.0	35.0	34.0	1.30	0.0001	0.0001[4]
Lactose	44.0	43.0	43.0	43.0	0.90	0.0361[5]	0.6661
TS	113.0	112.0	116.0	117.0	4.10	0.1358[6]	0.5458
DDE	83.0	83.0	86.0	84.0	1.50	0.0001	0.0001[7]
Production (g day^{-1})							
Fat	449.0	480.0	494.0	526.0	49.90	0.1077[8]	0.9700
Protein	476.0	554.0	598.0	555.0	92.70	0.0109	0.0167[9]
Lactose	65.09	749.0	749.0	702.0	122.0	0.0368[10]	0.0376
TS	1704.7	1929.4	1985.8	1909.0	296.0	0.0014[11]	0.0557
DDE	1255.2	1450.5	1490.5	138.17	230.0	0.0201	0.0237[12]
Efficiency							
Dry matter*	7.30	8.20	7.90	9.10	10.0	0.0087	0.0048[13]
Nitrogen**	2.60	2.20	1.80	1.80	0.23	0.0001[14]	0.0529

*-Milk (kg day^{-1})/IDM **-N milk/livestock unit; MP. Milk production; FMC. 4.0% fat-corrected milk; TS. total solids; DDE. defatted dry extract.

[1]$\hat{Y}= (75.0249) + (0.5461)X$

[2]$\hat{Y}= 1.55$

[3]$\hat{Y}= (117.255) + (1.3322)X$

[4]$\hat{Y}= (10.475) + (3.183)X - (0.0966)X^2$

[5]$\hat{Y}= (46.331) - (0.01661)X$

[6]$\hat{Y}=115.3$

[7]$\hat{Y}= (52.855) + (4.221)X - (0.1361)X^2$

[8] $\hat{Y}= 51.62$

[9]$\hat{Y}= - (504.025) + (147.179)X - (4.717)X^2$

[10]$\hat{Y}= (55.9009) + (1.0730)X$

[11]$\hat{Y}= (144.07) + (3.83248)X$

[12]$\hat{Y}= - (708.069) + (316.934)X - (10.559)X^2$

[13]$\hat{Y}= (13.869) - (0.8458)X+ (0.03159)X^2$

[14]$\hat{Y}= (0.3322) - (0.00781)X$.

The evident positive effect of CP level of diet on milk fat concentration was possibly due to the increasing activity of fibrolytic bacteria, leading to variation in milk fat between 2.8% and 3.3%, similar to those obtained by other authors (ZAMBOM et al., 2005; FONSECA et al., 2006; RODRIGUES et al., 2007; QUEIROGA et al., 2007 reported values of 3.31%, 2.8%, 2.9 % and 3.4%, respectively. Although it is common that the low forage: concentrate ratio and the shortage of physically effective fiber provide a decrease in the concentration of fat in milk as a consequence of the reduced ruminal pH, increase in rate of passage and decreased use of fiber, it was not found in the present study.

The level and the quantity of protein in milk showed a quadratic effect, with maximum values of 36.7 g kg^{-1} milk and 64.41 g day^{-1} for the protein levels of 164.7 g kg^{-1} and 156.0 g kg^{-1} of DM, respectively. This behavior probably results from the reduction in energy intake with decreased dry matter intake, whereas the diet with 190 g of CP per kg of DM was with excess protein with limited energy caused by the replacement of alfalfa hay by soybean meal.

The protein level in milk increases with elevation of the flow of microbial protein and/or non-degradable fraction of dietary protein that has escaped from the digestion, because they are metabolizable protein sources required for the production of milk and its components by goats. With the increase of dietary crude protein, the milk protein level was expected to increase; however, this component is not very influenced by its increase in the diet, resulting in increased non-protein nitrogen in milk when more than the required is supplied to the animal.

The lactose level decreased linearly ($P<0.01$), with an estimated reduction of 0.1 g kg^{-1} for each percentage unit of CP added to the diet; it is influenced by the increase in milk production due to the dilution effect. On the other hand, lactose produced increased linearly ($P<0.05$) according to the CP level in the diet, which is because increased production of milk components is directly related to osmotic regulation, the higher the synthesis, the higher milk production.

Paiva (2009) affirmed that reduced intake of non-fibrous carbohydrates leads to a decrease in ruminal production of propionate, main precursor of glucose in the liver, which is the substrate used for composing galactose and lactose in the mammary gland. Furthermore, lactose is the milk component which suffers the least effect from the diet, compared with fat and protein. In case of this study, the reduction in NFC intake did not result in simultaneous reduction in lactose production.

Rota et al. (1993), cited by Queiroga et al. (2007), reported that levels of protein and fat are inversely related to milk production, reaching minimum values at greater of milk, which coincides with the second month of milk. However, this is not consistent with our results, showing that CP levels in the diet favored the synthesis of milk fat and protein, which contributed to the increase in milk production.

The maximum level for the defatted dry extract (DDE) was 85.6 g kg^{-1} of milk for the crude protein level of 155 g per kg of DM in the diet, which is consistent with the behavior of the protein level in milk, which was the factor that contributed most to the variation in DDE. Araújo et al. (2009) observed that the dry extract is directly related to the production of milk solids and thus follows the same pattern observed for these variables.

The total solids level was not affected by crude protein levels in the diet, but showed a linear variation ($P<0.01$) in the amount produced, since there was an increase in protein and fat of milk. The dry matter utilization efficiency was affected quadratically, presenting a maximum efficiency of 0.82 at the CP level of 133.8 g kg^{-1} DM. This result reflects the behavior of DM intake, which also varied quadratically, although milk production increased linearly.

Rodrigues et al. (2007) attributed the increase in milk production to increased DM intake and to improved efficiency of DM utilization.

The nitrogen use efficiency decreased linearly, probably because the higher the crude protein intake, the lower the nitrogen use efficiency for milk production, which agrees with the results obtained by Pereira et al. (2005), Fonseca et al. (2006) and Paiva (2009). Thus, the nitrogen fraction is not totally used for milk production, probably being directed to other routes of use and/or excretion.

Conclusions

The nutrient intake, as well as milk production and composition are influenced, mostly quadratically, by protein levels in the diets, with better results between 130 and 150 g of crude protein per kg of DM, although the digestibility of nutrients and total digestible nutrient levels increased with higher levels of crude protein. For diets containing 800 g of pelleted concentrate (composed of soybean meal and alfalfa hay as protein sources) per kg of DM for lactating goats producing 2 kg of milk per day, the best ratio between alfalfa hay and soybean meal as protein sources was 2:1, corresponding to the concentration of 150 and 135 g of crude protein per kg of dry matter.

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