INTAKE AND PERFORMANCE SIMULATION OF GOATS FED EXCLUSIVELY TIFTON 85, MULBERRY OR LEUCAENA

SIMULAÇÃO DO CONSUMO E DO DESEMPENHO DE CAPRINOS ALIMENTADOS EXCLUSIVAMENTE COM TIFTON 85, AMOREIRA E LEUCENA

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ABSTRACT: Intake and performance of goats fed exclusively forages Tifton 85, mulberry or leucaena were simulated to verify which nutrients limit performance. Simulations were performed using the nutritional model similar to Cornell Net Carbohydrate and Protein System (CNCPS) with modifications related to the kinetic attributes of digestion and feed passage. The animal category chosen to perform the simulations was female Saanen goats in growing phase between weaning and mating, with 20 kg of body weight and 150 g of daily gain. The intake of 0.870 kg/day of Tifton 85 was adopted for performance simulations because in this point caused rumen fill and also attended the energy requirement of the animal. For performance simulations of mulberry, the amount of dry matter intake of 0.580 kg/day was adopted based on average intake obtained from the study of Sabino Jr. (1996) and simulations for leucaena used the intake of 0.220 kg/day, corresponding to 30g/100g of dry matter intake that would supply the energy requirement of these female goats. The limiting factor of performance of Saanen female growing goats fed exclusively Tifton 85 or mulberry is the metabolizable protein and not the energy. The intake of leucaena exclusively would be able to supply the requirement of metabolizable protein to promote the target weight gain of 150 g/day. The forages do not present perfect synchronization between carbohydrates and proteins, demonstrated by the positive ammoniacal balance in rumen environment that indicates an excess of nitrogen compounds supplied by these feed.

KEYWORDS: Microbial mass. Model. Supplementation.

INTRODUCTION

Decisions about nutritional management, in production systems of goats, are highly important, because mistakes can bring unfavorable consequences to the whole system. Comparative studies between different feeding managements of goats should be performed based on animal performance, in order to provide a better support to producers in the decision making. However, such assessments are expensive and sometimes difficult to be conducted in practice. Therefore, due to the inability of direct quantification of performance of goats fed different forages, the use of mathematical models and simulations of different production systems emerge as important tools to assist the decision making.

Several simulation models have been developed in different countries and educational, research and development institutions, using different approaches and covering specific aspects of a given area of scientific-technological knowledge. In Brazil, simulation models have not been regularly used, despite of being powerful and low cost tools when compared to experiments (BARBOSA; ASSIS, 1999).

The system developed at Cornell University - CNCPS (Cornell Net Carbohydrate and Protein System) is a mathematical model to evaluate diets and cattle performance (FOX et al., 2004). The set of equations, many of which mechanistically based, helped to quantify the processes of degradation and escape in rumen of the carbohydrate and nitrogen compounds fractions, allowing the estimation of microbial growth with more accuracy than the preceding systems (RUSSELL et al., 1992; SNIFFEN et al., 1992). We chose to adopt this system in the present study by the fact getting through properly mechanistic models predict of effects of feed intake, ruminal fermentation, intestinal digestion, nutrient absorption, and subsequent animal performance.

Tifton 85, leucaena and mulberry are forages with potential use for goats production systems, because they present good nutritive value. The Tifton-85 when managed under light interception as criterion, has high proportion of leaves and low of stems and dead material (CARNEVALLI et al., 1999). Besides, leucaena and mulberry stands out by higher crude protein contents and lower fiber (BASAGLIA, 1993). Whereas goats are small ruminants, which have

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great flexibility feed, preferring to consume buds and leaves of trees and shrubs. The leucaena and mulberry constitutes excellent forage for these animals. Therefore, performance and intake of goats fed exclusively of forages Tifton 85, mulberry or leucaena were simulated through a nutritional model adapted for goats based on CNCPS, to verify which nutrients limit the maximum animal performance.

MATERIAL AND METHODS

A nutritional model similar to Cornell Net Carbohydrate and Protein System (CNCPS), proposed by Russell et al. (1992) and Sniffen et al. (1992) was used with some modifications related to the modeling of kinetic attributes of digestion and feed passage (FAVORETO et al., 2008; VIEIRA et al. 2008ab) in order to simulate the availability and rumen escape of protein and carbohydrates fractions, nitrogen balance, microbial growth, total digestible nutrients and performance of goats. Data of chemical composition, fractionation of carbohydrates and kinetic of degradation of Tifton 85, mulberry and leucaena are listed in Table 1 and 2.

Tifton 85 was harvested when plants intercepted 95% of sunlight, presenting average height of 20cm and 16 days old. Mulberry and leucaena leaves were collected when new shoots were 50 days old, and plants presented average height of 1.09 and 1.04 m respectively. The observations for mulberry and leucaena were made according to what goats consume and the material collected was composed only of leaves, which was what animals actually consumed.

Within the supposed Saanen goats production system, weaning would have occurred at 60 days and the animals would be 14kg. The objective was that the animals should reach 35kg of weight and seven months of age at puberty. Thus, the category of animals chosen to perform the simulations was the growing female Saanen goats with 20kg of body weight and daily weight gain of 150 g. Also, the animals should eat only the forages under study.

In order to perform the subsequent simulations for mulberry, the amount of dry matter intake of 0.580 kg/day was adopted based on average intake obtained from the study of Sabino Jr. (1996), whereas simulations for leucaena used the intake of 0.220 kg/day, corresponding to 30g/100g of dry matter intake that would supply the energy requirement of these female goats (0.732 kg/day).

The animal model adopted consisted of two sets of equations. The first concerned the description of feed about nutritional value as a function of intrinsic feed characteristics and physiological functions of the chosen animal category that would receive that feed (RUSSELL et al., 1992; SNIFFEN et al., 1992). The second set of equations from the animal model was referred to the daily nutritional requirements of growing goats, generated by the productive functions and the maintenance processes.

The equations proposed by Russell et al. (1992) e Sniffen et al. (1992) were used in order to calculate the fractions of nitrogen compounds and carbohydrates, rumen availability of nitrogen fractions, escape of nitrogen compounds in rumen-reticulum, rumen availability of carbohydrates, escape of carbohydrates from rumen-reticulum, microbial growth in rumen-reticulum, balance of ammoniacal nitrogen in rumen, intestinal absorption of nutrients, fecal losses, total digestible nutrients, metabolizable energy of diet, efficiency of utilization of metabolizable energy and intake of metabolizable protein. The efficiency of utilization of metabolizable energy was calculated according to Luo et al. (2004).

Energy values of forages were also estimated by the equations proposed by NRC (2001) considering the class of feed described as roughage. Total digestible nutrients (TDN), was calculated considering the feeding level (L) as equivalent to the maintenance level. Recommendations for energy and metabolizable protein for goats were considered according to NRC (2007).

The effect of rumen-reticulum fill with fiber is a function of kinetic properties of degradation and passage of fibrous material that allows estimating the mass of fiber that causes rumen fill using the following equation (VIEIRA et al., 2008b):

$$\sum_j \left\{ F_{fdn_j} \left[A_j \left\{ v \sum_{i=1}^{N_j} \left[\lambda_{rj}^{i-1} / (\lambda_{rj} + k_{dj})^i \right] + \lambda_{rj}^{Nj} / \left[(\lambda_{rj} + k_{dj})^{Nj} (k_{ej} + k_{dj}) \right] \right\} + U_j (N_j / \lambda_{rj} + 1/k_{ej}) \right] \right\} \leq CA \quad (1)$$

where, F_{fdnj} corresponds to the intake rate of NDF (g/day); *Aj* represents the potentially digestible fraction of NDF contained in rumen-reticulum (RR) to be digested by rumen microorganisms (g/g NDF); λ_r is the transfer rate of particles from non-escapable *pool* to the escapable *pool* (t^{-1}); k_d is equal to the degradation rate of NDF; *N* is the dependency-order of time to transfer particles from non-escapable *pool* to the escapable pool; k_e is the escape rate of particles of the escapable pool (t^{-1}); *U* corresponds to the undegradable fraction of NDF contained in RR (g/g FDN); the subscript *j* denotes the *j*-est feed; and *CA* represents the maximum animal capacity for fiber storage in rumen (g/kg/day).

The strategy of scaling the mass of fiber in rumen and the body mass was adopted to reduce the effect of animal size, allowing independent comparisons for body mass or animal size (VIEIRA et al., 2008b). According to Brody (1945) and Kleiber (1975), the power-law scaling function can be generally described as:

$$Y = \alpha X^{\beta} + e \qquad (2)$$

where, α is the constant of scale expressed as unit of dependent variable per unit of mass raised to the power b. The values of variables were replaced by Y, the scaled or adjusted values were obtained by the ratio Y/X^{β} . The error e is subjected to a common or universal presumption of normality and independence, with mean = 0 and variance σ^2.

Table 1. Chemical composition of tropical forages

Item	Forage		
	Tifton-85	Mulberry	Leucaena
DM[a] (g.kg-1)	187.4	224.2	255.4
OM[b] (g.kg-1)	868.2	876.8	925.5
EE[c] ($g.kg^{-1}$)	23.9	42.5	36.3
CP[d] ($g.kg^{-1}$)	229.0	261.1	283.9
CHOT[e] ($g.kg^{-1}$)	615.4	573.2	605.4
NFC[f] ($g.kg^{-1}$)	127.4	408.9	389.3
NDFap[i] ($g.kg^{-1}$)	488.3	164.2	216.1
ADF[j] ($g.kg^{-1}$)	281.0	125.3	155.9
NDIP[k] (g.kg-1)	112.3	69.0	93.7
ADIP[l] ($g.kg^{-1}$)	22.9	21.1	41.9
LDA[m] ($g.kg^{-1}$)	74.8	50.6	88.7
Sugars ($g.kg^{-1}$)	17.2	29.5	23.4
Starch ($g.kg^{-1}$)	1.9	1.9	00.7
NDSF[n] ($g.kg^{-1}$)	117.2	344.2	329.7

[a]dry matter, [b]organic matter, [c]ethereal extract; [d]crude protein, [e]total carbohydrate, [f]non-fibrous carbohydrates, [g]neutral detergent fiber; [h]NDF corrected for ash, [i]NDF corrected for ash and protein, [j]acid detergent fiber; [k]neutral detergent insoluble protein, [l]acid detergent insoluble fiber, [m]acid detergent lignin, [n]neutral detergent soluble fiber.

Table 2. Database used to performance simulations

	Protein Subfractions (g/100g CP)				Protein Kd (h^{-1})		Carbohydrate Subfractions (g/100g TC)				Carbohydrate Kd (h^{-1})		
	A	B_1	B_2	C	B_1	B_2	A	B_1	B_2	C	A	B_1	B_2
Tifton 85	31.12	20.50	38.47	9.90	0.2570	0.0798	2.80	17.87	54.08	25.25	0.78	0.41	0.084
Mulberry	13.89	59.66	18.34	8.10	0.3036	0.1076	5.17	66.12	20.87	7.84	0.35	0.07	0.275
Leucaena	24.89	42.07	18.26	14.78	0.1005	0.0631	3.90	60.40	25.69	10.03	0.1965*		0.1808

Kd: degradation rate; * Degradation rate A+B_1; CP: crude protein; TC: total carhydrate

RESULTS

The values of dry matter intake that caused ruminal fill of the studied forages are showed in Table 3. When the energy requirement is considered as intake regulator, the amounts of dry matter consumed by the animal are presented in Table 4.

The intake of 0.870 kg/day of Tifton 85 would be, concurrently, the maximum point to cause rumen fill and also attend the energy requirement of the animal. Then, this value of dry matter intake was considered in the simulations of the performance of goats fed Tifton 85. This matter intake would supply 8.94 MJ/d of metabolizable energy and 65 g/day of metabolizable protein for the animal.

The requirement of metabolizable energy for maintenance is 5.48 MJ/day (NRC, 2007) thus, 3.46 MJ/d would be left for gain, whereas of metabolizable protein for maintenance is 29 g/day (NRC, 2007), thus 36 g/day would be left to production. Considering the requirement of metabolizable energy for gain of 0.0231 MJ/g average daily gain (ADG), the energy available would be enough to promote the established performance of 150 g/day, whereas the requirement of metabolizable protein for gain of 0.290 g/g ADG would enable a performance of 124 g/day.

Table 3. Dry matter intake that causes rumen fill in the rumen-reticulum in growing goats

Forage	Amount	
	kg/day	g/kg BW[a]
Tifton 85	0.870	43.5
Mulberry	3.200	160.0
Leucaena	2.150	107.5

[a]g/kg in relation to body weight

Simulations with mulberry considered the daily intake per animal of 0.744 kg of dry matter that would supply the energy requirement of the animal (Table 3). This intake would yield 8.94 MJ/d of metabolic energy. When the same values of metabolizable energy requirements for maintenance and growth were used, 3.46 MJ/d (NRC, 2007) would be left for gain that would be enough metabolizable energy to promote the target performance of 150 g/day. However, this intake of mulberry would supply the requirement of metabolizable protein for maintenance (29 g/day) and only 22 g/day would be left for production that would allow 77 g/day of weight gain only.

Table 4. Dry matter intake limited by the energy requirements of growing goats

Forage	Amount	
	kg/day	g/kg BW[a]
Tifton 85	0.871	43.5
Mulberry	0.744	37.2
Leucaena	0.732	36.6

[a]g/kg in relation to body weight

Daily intake of 0.723kg of dry matter was considered to simulate the animals fed leucaena (Table 4), would supply 8.94 MJ/d of metabolizable energy. The requirement of metabolizable energy for maintenance is 5.48 MJ/d (NRC, 2007) then 3.46 MJ/d would be left for gain. Thus, the energy available would be enough to promote the performance of 150 g/day. However, this intake of Leucaena would supply 80.5 g of metabolizable protein. Considering the requirement of metabolizable protein of 29.03 g/day for maintenance, 51.47 g/day would be left for production, allowing 177 g/day of weight gain.

Goats fed exclusively with Tifton 85, mulberry or leucaena, aiming to meet energy requirements, BNAR values (balance of ammoniacal N in rumen) would be 8.6; 10 and 9.5 g/day. Production of microbial mass from feeding Tifton 85, mulberry and leucaena are presented in Table 5.

Table 5. Production of microbial mass estimated for growing goats fed different forages

Forage	BACTFC[a] (g/day)	BACTNFC[b] (g/day)	BACT[c] (g/day)
Tifton 85	64.11	40.86	104.97
Mulberry	29.00	52.51	81.51
Leucaena	33.69	84.60	118.29

[a]Biomass of microbial cells produced from the fibrous carbohydrates;[b]Biomass of microbial cells produced from non-fiber carbohydrates; [c]biomass of microbial cells produced daily from the total carbohydrate.

All simulations were above performed based on the amount of dry matter that would supply the energy requirements of the animal. However, mulberry and leucaena have chemical compounds for defense against herbivory that possibly would limit dry matter intake of these forages. Aiming to evaluate the intake of different varieties of mulberry in goats, Sabino Jr. (1996) found values of 564, 549 and 639 g/day, equivalent to 28.9, 27.2 and 29.9 g/kg of body weight for the varieties Sausage, FM 3/3 and FM Shima Miura, respectively. Thus, in order to perform the subsequent simulations for mulberry, the amount of dry matter intake of 0.580 kg/day was adopted based on average intake obtained from the study of Sabino Jr. (1996), whereas simulations for leucaena used the intake of 0.220 kg/day, corresponding to 30g/100g of dry matter intake. This value was adopted because leucaena has mimosine that is toxic principle which can cause problems in animals that ingested excess (Pupo, 1979). Based on studies with ruminant the leucaena on feeding should not exceed 30% of the total ingested by the animal / MS / day (Sá, 1997).

The intake of 0.580 kg/day of mulberry would supply 6.97 MJ/d of metabolizable energy and 40 g of metabolizable protein. The requirement of metabolizable energy for maintenance is 5.48 MJ/d (NRC, 2007) leaving 1.49 MJ/d for weight gain, whereas the requirement for metabolizable protein for maintenance is 29 g/day (NRC, 2007) leaving 11 g/day for production. Thus, considering the requirement of metabolizable energy for gain of 0.0231 MJ/g ADG and requirement of metabolizable protein for gain of 0.290 g/g ADG, the energy available would be enough to promote the performance of 64 g/day whereas the protein available would enable a performance of 38 g/day.

The intake of 0.220 kg/day of leucaena would provide 2.69 MJ/d of metabolizable energy and 24 g/day of metabolizable protein for the animal. Thus, the requirements for maintenance of metabolizable energy of 5.48 MJ/d and metabolizable protein of 29 g/day (NRC, 2007) would not be supplied.

DISCUSSION

Among several factors, dry matter intake can be influenced by the total requirement of metabolizable energy or the physiological limit due to rumen fill (MERTENS, 1994). When high quality diets are supplied the animals consume feed until the energy requirement is reached and the intake is limited by the genetic potential of the animal to use the absorbed energy. However, when low quality diets are supplied, the animal consumes feed until the reticulo-rumen capacity is at full (MERTENS, 1994). Therefore, the influence of these two factors on dry matter intake was considered in the simulations of performance.

The animals would not be able to intake such large amounts of mulberry and leucaena. Thus, intake would be limited by the energy requirement, i.e. by chemostatic regulation, because these forages present low concentration of fibrous compounds and fiber of good quality.

The factor that limited performance would be the protein and not the energy supplied by Tifton 85 and mulberry forage. Therefore, despite high levels of crude protein in Tifton 85 (22.9g/100g CP) and mulberry (26.1g/100g CP), most of nitrogen compounds are lost by the lack of synchronism between degradation of carbohydrates and protein. Approximately one to four hours after feeding, a peak of N-NH_3 production occurs, because the NPN and rapidly degradable protein present in the cellular contents are quickly solubilized and the protein degraded in rumen. However, that peak of N-NH_3 is important only if energy is simultaneously available for microbial synthesis.

Exclusive intake of mulberry or Tifton 85 would not allow these female goats to reach the established target of average daily gain. In this context, in order to optimize diets considering the target performance established for the animals, some supplementation strategies can be adopted such as the use of concentrates rich in non-degradable protein to supply the metabolizable protein requirement of the animal, or the addition of sources of carbohydrate of rapid digestion in the RR, so the nitrogen fractions of high degradation can be efficiently used.

Ingredients that can be used in the formulation of supplements as source of rapid degradation carbohydrates, due the high degradation rates of fraction A and B_1, are maize (3.0 and 0.35 h^{-1}) , citrus pulp (3.0 and 0.40 h^{-1}), wheat meal (3.0 and 0.70 h^{-1}) and soybean hulls (2.75 and 0.4 h^{-1}) (NRC, 2001).

Therefore, differently from Tifton 85 and mulberry, the factor that limits the performance of animals fed leucaena would be metabolizable energy and not protein. Possibly the fraction B_1 of protein that represents a large proportion in leucaena and has degradation rate of 0.1005 h^{-1}, provide good synchronization with the carbohydrate fractions A and B_1, with degradation rates of 0.1808 h^{-1}. Soluble protein together with available energy would be used for microbial protein synthesis, and along with the protein that escapes from degradation in rumen, would supply the requirement of metabolizable protein for maintenance and production of the animals. In fact, this argument can be confirmed by the higher production of microbial mass that would be derived from total carbohydrates of leucaena.

The BNAR values confirming the excess of NH_3-N in the rumen environment. In this case, the ammonia released in rumen would be absorbed by the rumen wall and, when the ability of recycling nitrogen as urea was surpassed, the exceeding N would be eliminated in urine, and four moles of ATP per mole of synthesized urea would be spent. BNAR values equal to zero are evidences of perfect synchronization between the degradation of both carbohydrates and protein, so that all available N in rumen would be used, without occurrence of losses.

Although mulberry and leucaena present high degradation rates of carbohydrates and proteins (Table 2), an excess of nitrogen in rumen can be observed with the BNAR values, even with the presence of rapidly available carbohydrates fibrous and non-fibrous. Thus, the energy supplied would not be enough to use all the available nitrogen in rumen, and then these forages would not have perfect synchronization between carbohydrates and proteins. However, leucaena would supply the requirement of metabolizable protein due to the better synchronism of degradation between nitrogen compounds and carbohydrates.

In the simulation where we used the average intake of previous studies with mulberry the limiting factor of performance would be the metabolizable protein and not energy. Anyway, the supply of nutrients would not allow the animals to reach the target weight gain. For leucaena, despite the low intake, the amount of protein available to the animal would be very high and only 4.84 g of metabolizable protein would be missing to fully supply the requirement for maintenance.

Nutrient deficiencies presented by mulberry and leucaena supplied in small amounts, can be perfectly adjusted by adding other feed, such as forages in larger proportions in diet and also concentrates.

CONCLUSIONS

The limiting factor of performance of female growing goats fed exclusively Tifton 85 or mulberry is the metabolizable protein and not the energy of forage.

The intake of leucaena exclusively would be able to supply the requirement of metabolizable protein to promote the target weight gain of 150 g/day established for this study.

The forages do not present perfect synchronization between carbohydrates and proteins contained in dry matter, demonstrated by the positive ammoniacal balance in rumen environment that indicates an excess of nitrogen compounds supplied by these feed.

RESUMO: Simulações de consumo e desempenho de caprinos alimentados exclusivamente com as forrageiras Tifton 85, amoreira e leucena foram realizadas para verificar quais nutrientes seriam limitantes para o desempenho. As simulações foram feitas utilizando o modelo similar ao Cornell Net Carbohydrate and Protein System (CNCPS) com algumas modificações em relação à cinética de digestão e passagem do alimento. A categoria animal escolhida foi a de cabritas Sannen em fase de crescimento entre o desmame e a puberdade, com 20 kg de peso corporal e ganho médio diário de 150 gramas por dia. Foi adotado o consumo de 0,870 kg/dia de Tifton 85 para realizar as simulações de desempenho, porque nesse ponto ocorreria repleção ruminal e ao mesmo tempo atenderia a demanda de energia do animal. Para simulações de desempenho da amoreira, foi adotada o consumo de matéria seca de 0,580 kg/dia obtido em estudo de Sabino Jr. (1996) e para as simulações com a leucena foi usado o consumo de matéria seca de 0,220 kg/dia, que corresponde à quantidade que iria suprir o requerimento de energia desses animais. O principal fator limitante do desempenho de fêmeas Saanen em crescimento alimentadas exclusivamente com Tifton 85 ou amoreira é a proteína metabolizável e não a energia. O consumo exclusivo de leucena seria capaz de suprir o requerimento de proteína metabolizável para promover ganho médio diário de 150 g/dia. As forrageiras não apresentaram perfeita sincronização entre carboidratos e proteína, verificado pelo balanço amoniacal positivo no rúmen, que indica excesso de nitrogênio desses alimentos.

PALAVRAS-CHAVE: Massa microbiana. Modelos. Suplementação

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