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Nutritional value of feed used in diets for Saanen goats

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ABSTRACT. This study was performed to characterize feed used in diets for Saanen goats. The feedstuffs were: Tifton 85 hay (*Cynodon* spp.), soybean meal, ground corn, soybean hulls, ground ear corn and dried cassava residue. Contents were determined for dry matter, ash, crude protein, ether extract, neutral detergent fiber, acid detergent fiber, physically effective fiber and lignin, and organic matter, total carbohydrates and non-fiber carbohydrates were estimated. Carbohydrates were divided into fractions A + B1 (rapidly degradable), B2 (potentially degradable) and C (non-degradable); and the protein in fractions A (soluble), B1 (rapid ruminal degradation), B2 (intermediate degradation), B3 (slow degradation) and C (indigestible). To determine the gas production an automatic technique *in vitro* was used, modified by Ankom®. Significant differences were observed among feed for the parameters A, B, C, E and A + D of ruminal degradation kinetics, and feed with high non-fibrous carbohydrates content presented higher fraction A (rapid degradation), and the hay showed longer lag time (fraction C). The total gas production was higher for ground corn, ground ear corn and dried cassava residue.

Keywords: byproduct, fractioning, gas production, goats, ruminal degradation.

Valor nutricional de alimentos utilizados nas rações de cabras Saanen

RESUMO. Objetivou-se no presente trabalho caracterizar alimentos utilizados nas rações de cabras Saanen. Os alimentos avaliados foram: feno de Tifton 85 (*Cynodon* spp.), farelo de soja, milho moído, casca do grão de soja, milho desintegrado com palha e sabugo e resíduo seco de fecularia de mandioca. Foram determinados os teores de matéria seca, cinzas, proteína bruta, extrato etéreo, fibra em detergente neutro, fibra em detergente ácido, fibra fisicamente efetiva e lignina, e estimados a matéria orgânica, os carboidratos totais e os carboidratos não fibrosos. Os carboidratos foram divididos nas frações A + B1 (rapidamente degradáveis), B2 (potencialmente degradáveis) e C (não degradáveis); e a proteína, nas frações: A (solúvel), B1 (rápida degradação ruminal), B2 (degradação intermediária), B3 (lenta degradação) e C (indigestível). Para determinar a produção de gás foi utilizada a técnica automática *in vitro*, modificada pela Ankom®. Foram observadas diferenças entre os alimentos para os parâmetros A, B, C, E e A + D da cinética de degradação ruminal, sendo que os alimentos com alto teor de carboidratos não fibrosos apresentaram maior fração A (rápida degradação), e o feno apresentou maior tempo de colonização (fração C). A produção total de gás foi maior para o milho moído, milho desintegrado com palha e sabugo e resíduo seco de fecularia de mandioca.

Palavras chave: coprodutos, fracionamento, produção de gás, caprinos, degradação ruminal.

Introduction

The quality of the food supplied is critical to the success of animal production activity, because it directly influences the final product quality and animal health. However, spending on food represents the majority of production costs, which has led farmers and researchers to seek alternative foods with similar quality to the ingredients commonly used in feed, such as corn and soybean meal, but as they are not commodities, are sold at more competitive prices, making them an attractive alternative for use in ruminant feed.

Among these foods, co-products of agroindustry have represented one of the main fields of research in nutrition of ruminants, mainly in tropical countries (Morand-Fehr, 2005). The study of these alternative foods may be beneficial for the composition of ruminant diets, ensuring, in many cases, improved availability of food and increased production efficiency (Goncalves, Borge & Ferreira, 2009).

Agricultural co-products and crop residues have a very variable composition, and despite of the high availability, they present very different chemical characteristics each production (Gonçalves et al., 2009). Moreover, the lack of data on alternative feed composition, such as nutrient fractioning, indicates a lack of characterization, which allows a higher recommendation of these feed (Pereira et al., 2010).

The most common chemical analysis used includes dry matter, ash, ether extract, crude protein and fiber; and fiber is a nutritional term and its definition is linked to the analytical method used for its determination (Macedo Júnior, Zanine, Borges & Pérez, 2007). The last two groups of nutrients are very large and not all of its content can be available for animal organism, so that the feeds supplied for ruminants must be fractioned for its properly evaluation (Sniffen, O'Connor, Van Soest, Fox & Russell, 1992). Also, the chemical composition not always supply concrete information about the nutritive value of feeds, so that it must be considered the execution of physical analysis of the ingredients and its possible relationships with degradation of dry matter and passage rate through the digestive tract (Queiroz et al., 2010).

Regarding physical analysis of feed, the one which has been considered the most interesting is physically effective fiber (peFDN), which is related with the physical characteristics of the fiber (mainly particle size) that influence chewing activity and the biphasic nature of ruminal contents, besides being independent of animal related factors (Mertens, 1997).

In vivo analysis can demand more time and higher costs for its implementation, in this way, in vitro analysis has been more often used for feed evaluation, but it can have fails, mainly in the attempt to reproduce the ruminal environment. However, when the objective is to determine the intrinsic properties of the food, *in vitro* conditions can be controlled to prevent fluctuations in the physico-chemical environment, allowing to isolate the characteristic of interest of the food, so that be the limiting variable for the degradation study (Muniz et al., 2011).

Menke et al. (1979) described an *in vitro* system in which the gas produced by the fermentation of a substrate was used to estimate its digestibility and metabolizable energy (Mauricio et al., 1999). Studies and techniques that characterize ruminal metabolism of alternative foods, as *in vitro* technique of gas production, are necessary to identify feeds that can be effectively used in ruminant diets replacing traditional ingredients (Mizubuti et al., 2011).

It is possible to use agricultural by-products or another feedstuffs with high fiber content in diets for dairy goats, because among the species of ruminants, caprine animals show a higher capacity of adaptation to diets with high content of low quality fiber (Bava et al., 2001).

The objective of this study was to characterize alternative foods used in diets to Saanen goats in replacement to traditional foods, which allows to maintain milk production at lower costs.

Material and methods

The experiment was conducted in the goat sector of the Experimental Farm of Iguatemi (EFI) and in the Laboratory of Analysis of Food and Animal Nutrition, State University of Maringá. The feedstuffs were Tifton 85 hay (*Cynodon* spp.), soybean meal, ground corn, soybean hulls (SBH), ground ear corn (GEC) and dried cassava residue (DCR).

Feed samples were grounded in a Willey mill coupled to 1 mm sieve to determine the chemical composition. Dry matter (DM), ash, crude protein (CP), ether extract (EE), and lignin were determined according to techniques described by AOAC (2005). Organic matter (OM) was estimated from the difference between ash and dry matter. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined following the methodology of Van Soest, Robertson and Lewis (1991) and Goering & Van Soest (1970), respectively. Total carbohydrates (CT) were estimated according to equations described by Sniffen et al. (1992): $TC\ (g\ kg^{-1}) = 1000 - (CP + EE + ash)$.

Non-fiber carbohydrates (NFC) were estimated according to the equation proposed by Van Soest et al. (1991): $NFC\ (g\ kg^{-1}\ of\ DM) = 1000 - (NDF + CP + EE + ash)$.

Also, physically effective fiber (peFDN) was determined following the methodology proposed by Mertens (1997), which considers the %DM retained by 1.18 mm screen and NDF content of the feed.

The fractioning of carbohydrates and protein of the feeds was made according to methodologies proposed by Sniffen et al. (1992) and Licitra, Hernandez and Van Soest (1996), respectively; being the carbohydrates divided into: A and B1 fractions (non-fiber carbohydrates – rapidly degradable), B2 fraction (fiber carbohydrates – potentially degradable) and C fraction (fiber carbohydrates – non-degradable); while the protein was divided into the fractions: A (soluble), B1 (rapid ruminal degradation), B2 (intermediate degradation), B3 (cell wall associated protein – potentially available on the rumen) and C (indigestible).

For the determination of total gas production and kinetic parameters of ruminal fermentation, the automatic *in vitro* technique was used, as described by Theodorou, Lowman Davies, Cuddeford and Owen (1998); Pell, Pitt, Doane, and Schofield (1998) as modified by Ankom (ANKOM Tecnology Corporation, New York, USA) for Ankom® RF

Production System Gas appliance. Glass bottles were used, with 250 mL of capacity, in which were added 0.5 g of food sample in triplicate in 100 mL of buffer solution (artificial saliva described by McDougall (1948), comprising of KH_2PO_4 - 10.0 g L^{-1}; $MgSO_47H_2O$ - 0.5 g L^{-1}; NaCl - 0,5 g L^{-1}; $CoCl_22H_2O$ - 0.1 g L^{-1}; urea 0.5 g L^{-1} and Solution B: Na_2CO_3 - 15.0 g L^{-1}; Na_2S9H_2O - 1.0 g L^{-1}; in the ratio 5: 1), 25 mL of rumen inoculum and CO_2.

To obtain the rumen fluid, two non-pregnant and non-lactating goats cannulated in the rumen were used. The collection was performed in the morning before feeding the animals. Animals were fed a diet containing Tifton 85 hay and concentrate feed. For each incubation, two bottles were used as blank, containing only rumen inoculum and buffer solution, in order to adjust the pressure values.

The increased pressure produced inside the bottles during the incubation was measured in pounds per square inch (psi). Pressure data were collected every 5 min and transformed into mL gas 100 mg^{-1} of dry matter. The gas pressure inside the bottles was recorded by sensors located on the top of the modules, which transferred the information through a coordinating base unit connected to a computer during 48 hours of incubation.

Fermentation kinetic parameters of the gas obtained *in vitro* were analyzed on 100 mg of substrate according to the model $y = A / \{1 + \exp [2 + 4 * B * (C-t)] \} + D / \{1 + \exp [2 + 4 * E * (C-t)]\}$ where y = total gas volume at time T (lenght of degradation); A and D = volume of gas (mL) of rapid degradation fractions (soluble sugars and starch) and slow digestion (cellulose, hemicellulose), respectively; B and E = degradation rates of fractions of fast and slow digestion (per h), respectively; and C = bacteria colonization time.

To analyze the nonlinear model, the coefficient of determination (r^2) was used. This value represents how much the model is able to fit data of gas production (Y = mL gas g^{-1} incubated substrate) being obtained from the sum of squares error (SSE) and the total sum of squares (TSS) from the equation: $r = 1.0 - (SCE / TCS)$.

Results and discussion

Values for the chemical composition of foods are listed in Table 1. Values of dry matter of feed all close to 900 g kg^{-1} DM or above demonstrate ease management, as in relation to the homogeneity of the feed due to the proper mix of ingredients, as due to storage, which can be difficult when the food has a high moisture content.

The chemical composition observed for Tifton 85 hay differed from that observed by Muniz et al. (2011) as for protein (69.7 g CP kg^{-1} DM), NDF (656.4 g NDF kg^{-1} DM) and non-fiber carbohydrates (262.1 g NFC kg^{-1} DM), probably due to differences in the pasture cutting age.

As for energy sources, 170.4 g of CP kg^{-1} DM was recorded for SBH, which is due to the likely presence of soybean residue in its composition, especially when compared with values observed in literature: ranging from 121.0 to 147.2 g of CP kg^{-1} DM (Valadares Filho et al., 2010; Zambom et al., 2011).

The presence of straw and cob in GEC contributed to increase the NDF content of this feed in relation to corn, however the NFC content was lower due to lower proportion of grains in GEC. In general, the NDF content of used co-products (SBH and DCR) was high, common characteristic of co-products supplied to ruminants. The NFC content in DCR was similar to corn meal, which may be related to the starch present in cassava residue.

Table 1. Physical and chemical composition of ingredients used in ruminant feed.

Item (g kg^{-1} DM)	Ingredients					
	Tifton 85 Hay	Soybean meal	Ground corn	Soybean hulls	Ground ear corn	Dried cassava residue
Dry Matter[1]	913.54	904.29	887.09	907.80	902.00	887.11
Organic matter	930.11	938.26	988.87	958.69	983.50	989.04
Ash	69.89	61.74	11.13	41.31	16.50	10.96
Crude protein	114.09	519.22	85.02	170.43	82.45	12.57
Ether extract	8.89	20.49	35.02	54.95	19.83	0.34
Neutral detergent fiber	819.27	158.41	108.49	578.83	374.19	258.80
Acid detergent fiber	378.77	77.87	24.19	415.97	163.06	188.32
Indigestible acid detergent fiber	155.19	4.10	4.47	58.60	49.36	42.95
Physically effective fiber[2]	564.40	49.60	56.70	101.70	147.40	8.80
Non-fiber carbohydrate	60.38	376.26	789.25	202.85	534.54	733.47
Total carbohydrate	807.60	398.56	868.84	733.32	881.23	976.17
Lignin	64.54	16.60	6.96	38.60	29.89	50.54
INND[3]	526.01	113.35	85.68	201.44	160.95	580.51
INAD[4]	91.90	12.40	19.43	43.45	87.66	276.71

[1]g kg^{-1} natural matter; [2]g kg^{-1} natural matter, according to methodology described by Mertens (1997): % food retained in 1.18 mm sieve x % NDF of the food; [3]Insoluble nitrogen in neutral detergent (g kg^{-1} N); [4]Insoluble nitrogen in neutral detergent (g kg^{-1} N).

According to Lousada Junior, Costa, Neiva and Rodriguez (2006), changes in chemical, physical and nutritional values of agricultural co-products depend on the variety of products used, methods of processing and storage, among many factors.

The peNDF content varied among foods, but it should always be less than the NDF content of the food (Macedo Jr. et al., 2007). Physical characteristics of the food influence ruminal degradation parameters and passage rate, with more prominent effects on effectively degradable fraction. Thus, intrinsic physical characteristics of the food, such as solubility, water retention capacity, average particle size and density must be considered in research on ruminal degradation and kinetics of ingredients for ruminant diets (Queiroz et al., 2010).

According to Nussio, Campos and Lima (2011), concepts of effective fiber and physically effective fiber were not incorporated into the NRC (2001) due to the lack of a standard method for their determination and to the need for more research to identify chemical and physical factors of food which can influence the maintaining of rumen stability and animal health. However, only FDN is not sufficient to establish an adequate fiber supply in dairy animal feed when forage fiber sources are used in addition to forage as roughage, as it is the case of most of the co-products used in animal feed (Mertens, 1997). This is evidenced by the results obtained for DCR, whose NDF value observed was 258.8 g kg^{-1} DM, but the FDNfe observed was the lowest among all foods evaluated, 8.8 g kg^{-1} DM.

The values obtained for the carbohydrate fractions of foods were similar to those in the literature for hay, corn, soybean meal and soybean hulls (Malafaia et al., 1998; Gonçalves et al., 2003; Hashimoto et al., 2007) (Table 2).

Table 2. Carbohydrate fractions of the feeds in proportion of total carbohydrates.

	TC[1]	Fraction A+B1[2]	Fraction B2	Fraction C
Tifton 85 hay	807.60	8.48	72.28	19.37
Soybean meal	398.56	76.15	13.86	9.99
Ground corn	868.84	91.23	6.92	1.85
Soybean hulls	733.32	28.62	58.79	12.59
Ground ear corn	881.23	60.96	30.94	8.10
Dried cassava residue	976.17	75.28	12.36	12.36

[1](g kg^{-1}); [2](% total carbohydrates); TC = total carbohydrates; fractions A+B1 = rapidly degradable carbohydrates; fraction B2 = potentially degradable carbohydrates; and fraction C = non-degradable carbohydrates.

The percentages of carbohydrate fractions are different between the co-products used, which also occurs with the co-products evaluated by Pereira et al. (2010), which present the carbohydrate fractions quite variable.

The sum of fractions A and B1 to characterize the non-structural carbohydrates in addition to the convenience to adjust feed for ruminants is based on the analytical aspect, since the methods for determination of starch do not result in values corresponding to real values and do not allow good repeatability, due to the heterogeneous nature of plant tissues (Malafaia et al., 1998). The fractions A + B1 varied considerably between foods, being higher for corn and DCR in concentrate foods, which also showed the highest NFC values, which provides greater amount of starch in its compositions. But, although quantitatively similar in NFC, these ones differ in rumen degradation, because the dried cassava residue presented lower degradation than corn (Table 4). However, soybean meal showed a high value of fractions A + B1 and low amount of starch (1.2% DM, according to Hashimoto et al., 2007). This difference may be explained by the likely presence of oligosaccharides in its composition.

As bulky food, hay has a high value of B2 fraction, i.e., fiber carbohydrates. This is due to high levels of NDF in its composition, which leads to slower supply of energy in the rumen, which may affect the microbial efficiency and animal performance, beyond the fiber fractions present negative correlations with energy availability of foods (Pereira et al., 2010). As hay, soybean hulls have high values of B2 fraction and thus considered to be a bulky food, according to the classification of NRC (2007), but with different total rumen degradation, and considering that rumen degradation of SBH is closer to energy concentrates, such as GEC, followed by corn (Table 4).

The total carbohydrate content of corn and ground ear corn are similar, but the percentages of fractions A + B1 and B2 are different due to the presence of straw and cob in GEC, contributing to the increase in the fraction B2, which represents the fiber carbohydrates of food, and may influence the digestibility and energy value of food.

The high value of the fraction C in hay is related to the higher proportion of structural carbohydrates of cell wall in forages, whose content varies according to the age of the plant, and advancing in the growth stage of the grasses is associated with increased fiber fractions of stems and leaves, and reduced moisture content (Costa et al., 2007). Cultivars of *Cynodon* are characterized by high dry matter production and high nutritional value, although their quality is directly related to forage cutting age (Gonçalves et al., 2003).

Values of the fraction C observed for by-products increased compared to the corn, which can be attributed to the higher proportion of lignin in these foods, as can be seen in Table 1. The carbohydrate fraction C is unavailable and is related to the voluntary feed intake, the dietary energy availability and the greater or lesser digestibility of carbohydrates (Fernandes et al., 2003; Malafaia et al., 1998).

Values for the protein fractions (Table 3) obtained for corn, soybeans and SBH were similar to those reported by Hashimoto et al. (2007).

Apart from DCR, food presented values between 16 and 38% for fraction A, which corresponds to the soluble protein and non-protein nitrogen (NPN), mainly in forages, indicating the supply of non-protein nitrogen compounds to micro-organisms that ferment structural carbohydrates (Pereira et al., 2010).

Table 3. Protein fractions of the feeds in relation to crude protein.

	CP[1]	A[2]	B1	B2	B3	C
Tifton 85 hay	114.09	30.37	5.33	17.32	39.01	7.97
Soybean meal	519.22	16.64	11.82	61.78	8.69	1.07
Ground corn	85.02	18.85	17.66	56.25	5.60	1.64
Soybean hulls	170.43	38.70	6.91	36.97	13.85	3.56
Ground ear corn	82.45	16.35	16.10	53.72	6.29	7.53
Dried cassava residue	12.57	2.15	28.29	24.70	23.48	21.38

[1](g kg^{-1}); [2]%CP; CP = crude protein; A = soluble fraction; B1 = fraction of rapid degradation; B2 = intermediate degradation fraction; B3 = slow degradation fraction; and C = indigestible fraction.

The DCR had a higher proportion of fraction B1 compared to other foods, and the corn and GEC showed similar values for this nitrogen fraction. The observed values of fraction B1, which represents rapid degradation protein confirm Sniffen et al. (1992), who claimed that concentrates present fraction B1 twice higher than forages. According to Ribeiro et al. (2001), the higher the values of protein fractions A and B1, and thus their digestion rates, the greater the need for the supply of fast-digesting carbohydrates, so there is proper sink in ruminal fermentation of carbohydrates and proteins.

Concentrate foods have a higher proportion of fraction B2, true protein, compared to hay. The highest value observed was for soybean meal, since this is a protein food; between energy food this fraction is highly variable, being 47.82 g kg^{-1} DM in corn, 63.01 g kg^{-1} DM in SBH, 44.29 g kg^{-1} DM in GEC and 3.10 g kg^{-1} MS in DCR.

The highest value found for fraction B3 was for hay, followed by co-products DCR and SBH. According to Sniffen et al. (1992), co-products and forages have higher fraction B3 than protein foods, as seen in Table 3. Corn and GEC presented similar results, as well as for the crude protein and fractions A, B1 and B2.

As much of fraction B3 escapes from rumen degradation, this implies greater flow of amino acids into the intestine, available for enzymatic digestion. Thus, knowing the values of degradable and non-degradable protein in the rumen of different co-products is important for their use in formulation of diets for ruminants (Pereira et al., 2010).

The fraction C contains protein associated with lignin, complexes protein + tannins and products from the Maillard reaction, which are highly resistant to enzymes of animal and microbial organisms, and therefore are used to indicate the indigestible protein (Sniffen et al., 1992).

The highest proportion of fraction C is observed in DCR, which has very low protein content, and much of this has become unavailable. Among the energy foods, corn has the lowest fraction C (1.64% of CP), indicating high protein digestibility, unlike DCR, which showed 21.38% of fraction C.

Differences were verified ($p < 0.05$) for kinetic parameters of rumen degradation evaluated: fractions A, B, C, E, and A + D, as a result of the physical and chemical characteristics of food used (Table 4).

According to Mizubuti et al. (2011) that used the semiautomatic technique of *in vitro* gas production, the differences between the co-products are important because they result in higher or lower digestibility thereof.

Fraction A (rapid degradation) was greater in foods with a high content of non-fiber carbohydrates, which confer greater amount of rapidly fermentable carbohydrates to food and, as a consequence, higher production of gas in fractions of rapid degradation.

The degradation rate of fraction B presented similar behavior to that of fraction A, with the highest values observed for the degradation rate of non-fiber carbohydrates corresponding to foods that had higher gas production in the fraction A, except for the DCR. Whereas average retention time of food in the rumen is 48 hours, the greater the degradation in this time period, the better the quality of food fermentation (Mizubuti et al., 2011).

Table 4. Kinetic parameters of ruminal degradation of ingredients used in diets for Saanen goats.

Ingredients	Parameters[1]					
	A (mL gas^{-1})	B (/h)	C (hours)	D (mL gas^{-1})	E (/h)	A+D (mL gas^{-1})
Tifton 85 hay	5.98c	0.25c	4.16a	11.63	0.027d	17.61b
Soybean meal	6.27c	0.24c	2.04bc	12.45	0.045ab	18.72b
Ground corn	16.56a	0.56a	1.16c	10.35	0.042bc	26.91a
Soybean hulls	11.03b	0.48b	2.60b	7.75	0.051a	18.78b
Ground ear corn	13.22ab	0.51b	1.17c	9.47	0.023d	22.69ab
Dried cassava residue	14.45ab	0.17d	1.13c	7.18	0.036c	21.63ab
VC (%)	8.96	3.63	16.37	16.99	5.66	7.05

r^2 = 0.97 - adjustment of the bicompartmental logistic model to describe the fermentation for all experimental diets. [1]A and D= gas volume (mL) from the rapid digestion (soluble carbohydrates and starch) and slow digestion (cellulose and hemicellulose), respectively; B and E correspond to degradation rate of the rapid and slow degradation fractions (/h), respectively; C is *lag time* (h), bacterial colonization time.

Fraction C, which represents the time of colonization of food by bacterias in the rumen (*lag time*) is related to degradation of the fiber, and represents the time from the start of incubation until the microbial action on the food (Mertens & Loften 1980; Magalhães et al., 2010).

Hay was the food with the highest fraction C. This is due to forage composition, which has a high NDF and larger particle size compared to other foods used. Longer colonization results in lower gas production (fractions A + D), as can be seen in Table 4. The decrease in lag time is favored by the presence of readily fermentable substrates and by physical and chemical characteristics of the cell wall of food evaluated, which can facilitate microbial colonization (Magalhães et al., 2010).

Differences were not detected (p > 0.05) for the fraction D, which correspond to degradation of fiber carbohydrates. However, the degradation rate for this fraction (E) varied among foods, being higher for SBH. These results corroborate Zambom et al. (2008), who pointed out that, due to the pattern of rumen fermentation, SBH can be classified as a readily-fermentable fiber, and thus can be used both as source of energy and non forage fiber source, without decreasing the concentration of ruminal acetate and milk fat.

Nevertheless, the highest total gas production (fraction A + D) was obtained for corn, GEC and DCR.

Conclusion

Total gas production was higher in feeds with high content of non-fiber carbohydrates, which were: ground corn, ground ear corn and dried cassava residue, resulting from the higher fraction A, rapidly degradable, observed in these feeds.

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