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# Digestibility and performance in crossbred ½ Boer x ½ Saanen goat kids fed diets containing protected fat

# Digestibidade e desempenho produtivo em cabritos mestiços ½ Boer x ½ Saanen alimentados com dietas contendo gordura protegida

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## Abstract

The objective of this study was to evaluate the intake, performance parameters, digestibility of dry matter, and nutrients in diets with increasing levels of metabolizable energy containing protected fat, as well as the economic analysis of the diets of ½ Boer x ½ Saanen goat kids finished in a feedlot. Twenty-eight uncastrated male goat kids with an initial weight of 19.02 ± 2.20 kg and an age of 88 ± 5.77 days were used and assigned to a completely randomized design in four diets: a control with 2.5 Mcal ME/kg DM and the others with 2.6, 2.7, and 2.8 Mcal ME/kg DM with protected fat (Lactoplus®). The animals were kept on experiment until they reached approximately 32 kg of weight. In order to estimate digestibility, we used ADFi as an internal marker. There were treatment effects on the intake of dry matter, organic matter, ether extract, and non-fiber carbohydrates. We observed a quadratic effect of diets on daily weight gain and feed conversion. The diets had no effect on the digestibility of dry matter, organic matter, neutral detergent fiber, or gross energy. The digestibility of non-fiber carbohydrates and total carbohydrates showed a linear decrease, and crude protein increased linearly. We observed a quadratic behavior in ether extract digestibility resulting from the inclusion of protected fat in the diets. The serum cholesterol level was influenced by the diets and showed a linear increase. The economic evaluation was favorable, with a larger net revenue value for the diet with 2.5 Mcal ME/kg DM. The increase of energy density of diet for ½ Boer x ½ Saanen goat kid through the inclusion of protected fat influences negatively the intake of dry matter and the digestibility of non-fiber carbohydrates and total carbohydrates without improving the growth performance of the animals.
**Key words:** Digestion, goats, internal marker, Lactoplus®, metabolizable energy, weight gain

## Resumo

Objetivou-se com este trabalho, avaliar a ingestão, os parâmetros de desempenho produtivo, a digestibilidade da matéria seca e dos nutrientes de dietas com concentrações crescentes de energia metabolizável contendo gordura protegida, e a análise econômica das dietas para cabritos mestiços ½ Boer x ½ Saanen terminados em confinamento. Foram utilizados 28 cabritos, machos não castrados com peso inicial de 19,02 ± 2,20 kg e idade de 88 ± 5,77 dias, distribuídos em delineamento inteiramente

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casualizado Com quatro dietas: controle com 2,5 Mcal de EM/kg MS e os demais com 2,6; 2,7 e 2,8 Mcal de EM/kg de MS, onde se utilizou a gordura protegida (Lactoplus®) como suplemento energético. Os animais foram mantidos no experimento até atingirem peso aproximado de 32 kg. Para as estimativas de digestibilidade foi utilizado o FDAi como indicador interno. Houve efeito das dietas sobre as ingestões de matéria seca, matéria orgânica, extrato etéreo e carboidratos não fibrosos. Foi observado efeito quadrático das dietas sobre os parâmetros de ganho de peso diário e conversão alimentar. Não houve efeito das dietas sobre as digestibilidades da matéria seca, matéria orgânica, fibra em detergente neutro e da energia bruta. A digestibilidade dos carboidratos não fibrosos e dos carboidratos totais apresentou decréscimo linear e da proteína bruta apresentou aumento linear. Observou-se comportamento quadrático da digestibilidade do extrato etéreo, resultante da inclusão de gordura protegida nas dietas. O nível sérico de colesterol aumentou linearmente de acordo com as dietas. A avaliação econômica se mostrou favorável, com maior valor de renda líquida para a dieta com 2,5 Mcal de EM/kg de MS. A elevação da densidade energética da dieta de cabritos mestiços ½ Boer x ½ Saanen, por meio da inclusão de gordura protegida afeta negativamente a ingestão de matéria seca, e a digestibilidade dos carboidratos não fibrosos e dos carboidratos totais, sem proporcionar melhoria do desempenho produtivo dos animais.

**Palavras-chave:** Digestão, caprinos, energia metabolizável, ganho de peso, indicador interno, Lactoplus®

## Introduction

In dairy goat farming, the amount of kids born is a possibility of revenues generation for the producer through the commercialization of meat. In general, dairy breeds have carcass traits inferior to those of meat breeds (YÁÑEZ et al., 2006), and the utilization of cross-breeding with specialized breeds, such as Boer, seeking a complementarity between breeds allows for more precocious animals with a greater yield of the carcass and better meat quality capable of supplying the needs of the consumer market (CAÑIZARES et al., 2012).

The input of nutrients in the diet has a significant influence in animal production. The addition of sources of lipids can offer benefits, mainly due to elevated energy density, when utilized in situations of high energy demand, allowing the decrease of the quantity of concentrate supplied and avoiding changes in the ruminal fermentation (NRC, 2007; MÜLLER et al., 2008). However, when fat is added to the diet of ruminants with contents over 5% of the dry matter (DM), we usually observe a reduction in the digestibility of the cell wall and in the consumption of food (PALMQUIST; MATTOS, 2011).

Lipidic supplements, called “protected fats”, have been developed with the goal of increasing the energy concentration of the diets with a minimal interference in the ruminal fermentation. The methods of fat protection include encapsulation by a protein treated with formaldehyde, hydrogenation of fats, and the production of calcium soaps (JENKINS; PALMQUIST, 1984).

In the exploitation of livestock breeding, especially goat breeding, determination of the costs and economic return of the activity becomes indispensable. In this context, the evaluation of the animal response to the kind of diet offered is of greater importance, since feeding, being the main component of the production cost, is a limiting factor to goat meat production (RAMOS et al., 2010).

The objective of this study was to evaluate the intake, parameters of productive performance, digestibility of the nutrients from diets with growing contents of metabolizable energy containing protected fat, and the economic analysis of diets of ½ Boer x ½ Saanen kids finished in a feedlot.

## Materials and Methods

The experiment was carried out in the goat farming sector at Iguatemi Experimental Farm (FEI), located in the Iguatemi district in Maringá, State of Paraná, Brazil, and in the Animal Food and Nutrition Analyses Lab (LANA) at the State University of Maringá.

We used 28 uncastrated male ½ Boer x ½ Saanen kids with initial weight of 19.02 ± 2.20 kg and mean age of 88 ± 5.77 days, that were distributed in a completely randomized design with four diets: a control with 2.5 megacalories of metabolizable energy for kilogram of dry matter (Mcal ME/kg DM) and the others with 2.6, 2.7, and 2.8 Mcal ME/kg DM, where we used protected fat (Lactoplus®) to increase the energy density of the diets.

The diets consisted of feeds containing oat hay, ground corn, soy bran, inactivated sugar cane dry yeast (*Saccharomyces cerevisiae*), mineral supplement, ammonium chloride and protected fat - calcium soaps of long-chain fatty acids − Lactoplus® containing 10% of calcium, 82% of lipids and 175% of total digestible nutrients (TDN). The diets were adjusted according to the needs of the growing kids, with an estimated gain of 150 g/day, according to the NRC (2007).

The feeds were formulated with a roughage:concentrate ratio of 50:50 and supplied as a pelleted total diet to avoid selection and waste by the animals.

The samples of the feeds supplied were ground in a sieve with a mesh size of 1 mm for determination of the contents of DM, crude protein (CP), ether extract (EE), ashes, and gross energy (GE), according to the methods described by Silva and Queiroz (2006), and neutral detergent fiber (NDF), according to Van Soest, Robertson and Lewis (1991) (Tables 1 and 2).

**Table 1.** Chemical composition of the food used in the formulation of the diets in g kg$^{-1}$ dry matter.

| Nutrients (g kg$^{-1}$) | Foods | | | |
|---|---|---|---|---|
| | Oat hay | Corn | Soybean meal | Dry yeast |
| Dry matter (g kg$^{-1}$ as feed) | 924.00 | 878.20 | 882.24 | 918.87 |
| Organic matter | 931.00 | 987.00 | 934.00 | 967.10 |
| Ashes | 69.00 | 13.00 | 66.00 | 32.90 |
| Crude protein | 76.71 | 87.83 | 514.09 | 354.91 |
| Ether extract | 15.50 | 31.00 | 20.90 | 0.60 |
| Neutral detergent fiber | 681.80 | 138.70 | 155.00 | - |

**Source**: Elaboration of the authors.

The values of total carbohydrates (TC) and TDN were estimated according to the equations described by Sniffen et al. (1992): *TC (g/kg DM) = 1000 − (crude protein + ether extract + ashes); TDN (g/kg DM) = DCP + 2.25 x DEE + DTC*. Where: DCP = digestible crude protein, DEE = digestible ether extract, and DTC = digestible total carbohydrates.

The values of non-fiber carbohydrates (NFC) were estimated using the equation proposed by Van Soest, Robertson and Lewis (1991): *NFC (g/kg DM) = 1000 − (NDF + CP + EE + ashes)*.

Before the beginning of the experiment, the animals received anti-parasite drugs and the application of an ADE vitamin complex. Then they were housed in individual stalls in an indoor and suspended facility with a slatted floor and access to an automatic drinking fountain and an individual feeder.

The animals were weighed at first to adjust the quantity of food offered, and then every two weeks for diet adjustment. The diets were supplied once a day in the morning (8 a.m.) in order to provide a waste of approximately 10%. The quantities supplied were weighed daily and adjusted according to animal intake, thus guaranteeing an *ad libitum* feeding. Before the daily supply of feed, the waste was weighed to control the DM intake. We determined the daily DM and nutrient intakes, as well as daily and total weight and feed conversion.

**Table 2.** Composition in dry matter (g kg$^{-1}$) and chemistry of the diets (g kg$^{-1}$ DM).

| Item | Diets (Mcal ME kg$^{-1}$ DM) | | | |
|---|---|---|---|---|
| | 2.5 | 2.6 | 2.7 | 2.8 |
| Oat hay | 500.00 | 500.00 | 500.00 | 500.00 |
| Soybean meal | 100.00 | 100.00 | 100.00 | 100.00 |
| Inactivated dry yeast | 94.55 | 98.38 | 108.00 | 117.63 |
| Ground corn | 266.86 | 252.48 | 216.29 | 180.10 |
| Lactoplus®[1] | - | 19.15 | 45.71 | 72.27 |
| Calcitic limestone | 8.59 | - | - | - |
| Mineral supplement[2] | 20.00 | 20.00 | 20.00 | 20.00 |
| Ammonium chloride | 10.00 | 10.00 | 10.00 | 10.00 |
| Dry matter (g kg$^{-1}$) | 908.19 | 905.74 | 908.86 | 911.16 |
| Organic matter | 933.22 | 935.56 | 929.23 | 925.38 |
| Ashes | 66.78 | 64.44 | 70.77 | 74.62 |
| Crude protein | 159.24 | 160.39 | 159.61 | 164.52 |
| Ether extract[3] | 17.91 | 17.73 | 16.61 | 15.49 |
| Supplementary fat[4] | - | 15.61 | 37.61 | 59.60 |
| Neutral detergent fiber | 397.43 | 402.93 | 395.88 | 396.07 |
| Non-fiber carbohydrates | 358.64 | 338.90 | 319.54 | 289.69 |
| Total carbohydrates | 756.07 | 741.83 | 715.41 | 685.76 |
| Gross energy (Mcal/kg DM) | 4.44 | 4.80 | 4.91 | 5.01 |

[1]Protected fat (100 g Calcium/kg). [2]Commercial product. Composition: Calcium 240 g/kg, Phosphorus 71 g/kg, Potassium 28.2 g/kg, Sulfur 20 g/kg, Magnesium 20 g/kg, Copper 400 mg/kg, Cobalt 30 mg/kg, Chromium 10 mg/kg, Iron 250 mg/kg, Iodine 40 mg/kg, Manganese 1,350 mg/kg, Selenium 15 mg/kg, Zinc 1,700 mg/kg, Fluorine (max.) 710 mg/kg. [3]Obtained through analysis of oat hay, ground corn, soybean meal, and dry yeast. [4]Estimated through the Lactoplus® manufacturer's manual (Dalquim Indústria Química Ltda).
**Source**: Elaboration of the authors.

To determine the digestibility of the diets, when the animals had an average weight of 26.4 ± 3.9 kg, between the 40$^{th}$ and the 46$^{th}$ day of the experiment, we carried out feces sampling (± 15 g/sample) during six consecutive days straight from the animals' rectal ampule at 8 a.m., 10 a.m., noon, 2 p.m., 16 p.m., and 18 p.m., and subsequently joined in composed samples by animal.

The feces samples were pre-dried in a greenhouse with forced air ventilation at 55ºC for 72 hours. Subsequently, they were ground in a mill with a 1 mm mesh sieve to determine the contents of DM, CP, EE, ashes, and GE according to methodologies described by Silva and Queiroz (2006), as well as NDF according to Van Soest, Robertson and Lewis (1991).

The estimates of fecal excretions were carried out though the utilization of the indigestible neutral detergent fiber (NDFi) as an internal indicator obtained after 240 hours of *in situ* incubation

(CLIPES et al., 2006) of the feeds and feces of goats cannulated at the rumen. After incubation, we performed an analysis of fiber in acid detergent according to the technique described by Ankom® (DETMANN et al., 2001). The fecal flow was calculated according to the following equation (VAN SOEST, 1994): Flow (kg/day) = indicator intake (kg)/(concentration of the indicator in the feces).

A day before slaughter, we collected a blood sample from the animals through a puncture of the jugular vein. After collection, the samples were centrifuged at 3000 rpm to obtain the serum, which was packaged in Eppendorf tubes, identified, and stored in a freezer for subsequent analyses of cholesterol, triacylglycerols, and serum urea using commercial kits by Gold Analyzes Diagnóstica Ltda®.

When they reached the body weight of 31.95 ± 1.13 kg, the animals were submitted to a fasting from solids for 16 hours, electrically stunned, and slaughtered.

The data for DM and nutrient intake, daily weight gain (DWG), and total weight gain were submitted for variance and regression analysis (P<0.05) using the SAEG software (UFV, 2005), defining the metabolizable energy in the diets (2.5, 2.6, 2.7, and 2.8 Mcal ME/kg DM) as an independent variable according to the following model:

$$Y_{ij} = \mu + T_i + b_1(PI_{ij} - PI) + b_2(PI_{ij} - PI) + e_{ij}$$

Where: Yij = observation of the variable studied in the animal j receiving the diet i; μ= general constant; $T_i$ = concentration of metabolizable energy (2.5, 2.6, 2.7, and 2.8 Mcal ME/kg DM); b1 = coefficient of linear regression as a function of the variable studied as a function of the initial weight; b2 = quadratic regression coefficient as a function of the initial weight; PI = starting weight used as a co-variable; and *eij* = random error associated to each observation.

The data of feed conversion and blood parameters were also submitted for variance and regression analysis (P<0.05) without using the starting weight as a co-variable.

In the economic evaluation, the structure of the cost of production adopted was the budgets approach recommended by Olson (2004). The expenses were calculated considering the costs of the diet ingredients. The revenue achieved corresponded to the market price paid for a kilogram of goat carcass charged at the Maringá region (R$ 12.50/kg) multiplied by the weight of the carcass obtained in each diet. The feed costs were quoted at the Maringá region in December 2012 (Table 3).

**Table 3.** Price per unit of food and diets, quoted in the region of Maringá, State of Paraná, Brazil, in December 2012

| Foods | R$/kg | Diets (R$/100 kg feed)[1] | | | |
|---|---|---|---|---|---|
| | | 2.5 | 2.6 | 2.7 | 2.8 |
| Oat hay | 0.50 | 25.00 | 25.00 | 25.00 | 25.00 |
| Soybean meal | 1.14 | 11.40 | 11.40 | 11.40 | 11.40 |
| Inactivated dry yeast | 0.75 | 7.09 | 7.38 | 8.10 | 8.82 |
| Ground corn | 0.50 | 13.34 | 12.62 | 10.81 | 9.01 |
| Lactoplus® | 3.00 | - | 5.75 | 13.71 | 21.68 |
| Calcitic limestone | 0.26 | 0.22 | - | - | - |
| Mineral supplement[2] | 1.68 | 3.36 | 3.36 | 3.36 | 3.36 |
| Ammonium chloride | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Total | | 62.42 | 67.51 | 74.39 | 81.27 |

[1]Mcal ME/kg DM; [2]Commercial product.
**Source**: Elaboration of the authors.

For purposes of simplification of the economic evaluation procedures, the revenues and costs were calculated only regarding the diet consumed and the value obtained for the carcasses of the animals, respectively.

## Results and Discussion

The intakes of DM and organic matter (OM) varied between 0.816 kg and 0.888 kg DM/day and 0.759 kg and 0.828 kg OM/day (Table 4), respectively, and presented a quadratic effect as a function of the diets ($P<0.05$), with minimal values estimated at 2.66 and 2.67 Mcal ME/kg DM, respectively.

**Table 4.** Intake of dry matter and nutrients and productive performance of ½ Boer x ½ Saanen kids as a function of energy concentrations in the diet.

| Parameters | Diets (Mcal ME/kg DM) | | | | Regression equation; $R^2$ | CV (%) |
|---|---|---|---|---|---|---|
| | 2.5 | 2.6 | 2.7 | 2.8 | | |
| Initial weight | 19.07 | 19.29 | 19.01 | 19.60 | | |
| Final weight | 32.64 | 31.94 | 31.16 | 32.07 | | |
| | Intake (kg/day) | | | | | |
| DM[2] | 0.888 | 0.828 | 0.816 | 0.866 | $\hat{Y}$=20,21-14,56X+2,73X²; 0.14 | 8.24 |
| DM (%LW)[3] | 3.440 | 3.243 | 3.262 | 3.356 | $\hat{Y}$=3,224; NS[1] | 7.83 |
| OM[4] | 0.829 | 0.775 | 0.759 | 0.801 | $\hat{Y}$=17,95-12,88X+2,41X²; 0.14 | 9.04 |
| CP [5] | 0.157 | 0.164 | 0.174 | 0.158 | $\hat{Y}$=0,164; NS | 12.50 |
| EE[6] | 0.018 | 0.034 | 0.063 | 0.072 | $\hat{Y}$= -0,47+0,19X; 0.87 | 53.36 |
| NDF[7] | 0.323 | 0.341 | 0.354 | 0.314 | $\hat{Y}$=0,334; NS | 11.19 |
| NFC[8] | 0.354 | 0.348 | 0.342 | 0.279 | $\hat{Y}$=0,84-0,19X; 0.11 | 18.18 |
| TC[9] | 0.746 | 0.761 | 0.773 | 0.660 | $\hat{Y}$=0,740; NS | 17.57 |
| TDN[10] | 0.626 | 0.676 | 0.718 | 0.694 | $\hat{Y}$=0,678; NS | 16.74 |
| | Productive performance | | | | | |
| DWG (kg)[11] | 0.185 | 0.149 | 0.156 | 0.173 | $\hat{Y}$=9,58-7,09X+1,33X²; 0.18 | 16.97 |
| TWG (kg)[12] | 13.571 | 12.657 | 12.143 | 12.467 | $\hat{Y}$=12,718; NS | 21.91 |
| FC[13] | 4.8 | 5.6 | 5.3 | 5.1 | $\hat{Y}$=181,55+141,01X- 26,57X²; 0.15 | 10.50 |

[1]NS: Not significant ($P>0.05$), [2]Dry matter, [3]Dry Matter in %PV, [4]Organic matter, [5]Crude protein, [6]Ether extract, [7]Neutral detergent fiber, [8]Non-fiber carbohydrate, [9]Total carbohydrate, [10]Total digestible nutrients, [11]Daily weight gain, [12]Total weight gain, [13]Feed conversion.
**Source**: Elaboration of the authors.

The DM and OM intake values (Table 4) were higher than those obtained by Possamai et al. (2015), who, using diets varying from 2.5 to 2.8 Mcal ME/kg DM with the inclusion of protected fat for Saanen kids slaughtered at 28 ± 2.54 kg, observed a daily intake of 0.77 kg of DM and 0.72 kg of OM. According to Hashimoto et al. (2007), studies with Saanen kids or ½ Boer x ½ Saanen kids with similar weights and diets containing 2.63 Mcal ME/kg DM presented daily intake values varying between 0.70 and 0.90 kg of MS and 0.73 to 0.96 kg of OM. The higher intake and genetic potential for meat deposition presented by mixed race Boer kids contribute to higher weight gain in those animals when compared with dairy breed goat kids (CAÑIZARES et al., 2012).

The intake of DM in percentage of live weight was not influenced by the diets, presenting an average value of 3.224% of DM in relation to live weight (Table 4), which is similar to values observed in the literature (varying between 3.1% and 3.7%). In this way, we observe that the inclusion of protected fat in the diet did not limit the ingestion of DM by the animals due to the pelletization of the feeds, which lowered the selection of feed ingredients by the animals.

The intake of EE plus protected fat presented an increasing linear effect with the addition of protected fat in the diets, resulting from the larger input of this nutrient in the diets supplemented with protected fat, increasing 19 g for each 0.1 Mcal ME/kg DM (Table 4). However, there was no increase ($P>0.05$) in the TDN intake, which was a consequence of the higher energy intake of the diet.

We observed a decreasing linear effect of the intake of NFC as a function of the diets (Table 4). According to Silva et al. (2007), this reduction can be attributed to the substitution of the NFC by the supplementary EE from lipidic sources. The intakes of CP, DF, and TC were not influenced by the diets.

There was a quadratic effect ($P<0.05$) of the diets on the parameters of DWG and food conversion (Table 4). For the DWG, we observed values varying between 0.149 and 0.185 kg/day, with a minimal gain estimated for a diet with 2.66 Mcal ME/kg DM. These results may be related to the lower intake of DM and worse feed conversion observed in diets containing protected fat, since the intake can be considered the most important measure to draw inferences on the food and the animal response (FORBES, 1995).

By comparing the DWG observed in the animals in this study, we observed results superior to those obtained by Possamai et al. (2015), who, using Saanen kids with a weight between 19.54 and 29.25 kg and diets between 2.5 Mcal ME/kg DM and 2.8 Mcal ME/kg DM with protected fat (Lactoplus®), observed weight gains between 0.092 and 0.158 kg/day. This fact can be related to the higher performance of mixed breed Boer kids in relation to other goat genotypes (DHANDA et al., 1999; CAMERON et al., 2001; RODRIGUES et al., 2010).

In the experimental conditions presented, the inclusion of protected fat did not improve feed conversion, with the best value (4.8) for the control diet 2.5 Mcal ME/kg DM and with a maximum point estimated for 2.65 Mcal ME/kg DM (Table 4). These results can be explained by the replacement of corn with protected fat in the diets, providing a different nutrient pool for the animals with possible changes in the fermentable metabolizable energy/CP ration of the diets, which may have caused changes in the ruminal environment and a synthesis of microbial protein. Homem Júnior et al. (2010), when comparing diets with and without the inclusion of protected fat, for lambs with approximately 30 kg, observed an increase in the concentration of ruminal ammonia in animals fed diets containing protected fat, showing the possibility of interference in the metabolism of the protein in the rumen.

The values obtained for feed conversion were similar to those observed by Saqhir et al. (2012), who obtained results varying from 4.78 to 5.19 in Black Goat kids ingesting feeds supplemented with different oils. Alcalde et al. (2011), working with ¾ Boer + ¼ Saanen kids fed diets containing on average 2.65 Mcal/Kg DM and 3.6% EE formulated with oil seeds, related a food conversion of 6.58. Lima et al. (2011) stated that the feed conversion can vary within the same genetic group, depending on the age of the animals and the diets supplied.

The diets did not affect the digestibility of DM, OM, or NDF (Table 5). According to Sanz Sampelayo et al. (2002), the absence of influence of the diets on fiber digestibility allows one to infer a high degree of fat protection in relation to ruminal metabolism. Jenkins and Palmquist (1984) reported that calcium soaps of long-chain fatty acids do not alter the ruminal fermentation due to fat insolubility.

Otaru et al. (2011), when supplying diets containing up to 8.2% of palm oil in DM for Red Sokoto goats (33.14± 1.75 kg), observed that there was a reduction in DM intake in diets containing more than 6.3% of oil. This result, according to the researchers, occurred due to the inhibition of the ruminal microbial activity, promoting the decrease of fiber digestion and stressing the importance of the use of protected fat sources in diets with a high content of EE.

**Table 5.** Digestibility of the nutrients of the diets of ½ Boer x ½ Saanen kids as a function of the energy concentrations in the diet.

| Parameters (kg/kg) | Diets (Mcal ME/kg DM) | | | | Regression equation; $R^2$ | CV (%) |
|---|---|---|---|---|---|---|
| | 2.5 | 2.6 | 2.7 | 2.8 | | |
| DM[2] | 0.658 | 0.660 | 0.654 | 0.640 | $\hat{Y}$= 0,653; NS[1] | 3.63 |
| OM[3] | 0.666 | 0.668 | 0.662 | 0.667 | $\hat{Y}$= 0,665; NS | 3.38 |
| CP[4] | 0.760 | 0.769 | 0.769 | 0.781 | $\hat{Y}$=0,599 + 0,064X; 0,11 | 2.79 |
| EE[5] | 0.734 | 0.842 | 0.904 | 0.933 | $\hat{Y}$= -14,775 + 11,156X - 1,980X$^2$; 0.96 | 9.37 |
| NDF[6] | 0.453 | 0.454 | 0.452 | 0.406 | $\hat{Y}$= 0,442; NS | 11.19 |
| NFC[7] | 0.804 | 0.780 | 0.752 | 0.712 | $\hat{Y}$= 1,564 - 0,30X; 0.70 | 5.31 |
| TC[8] | 0.644 | 0.638 | 0.619 | 0.592 | $\hat{Y}$= 1,087 - 0,175X; 0.35 | 5.16 |

[1]NS: Not significant (P>0.05), [2]Dry matter, [3]Organic matter, [4]Crude protein, [5]Ether extract, [6]Neutral detergent fiber, [7]Non-fiber carbohydrate, [8]Total carbohydrate.
**Source**: Elaboration of the authors.

The digestibility of NFC and TC presented a linear decrease as a result of the inclusion of protected fat in the diets, decreasing 3.0% and 1.7%, respectively, for each 0.1 Mcal of ME (Table 5). Possamai et al. (2015), observing kids fed with diets containing protected fat, also obtained a reduction in the digestibility of NFC and TC and linked this reduction to the lower intake of these nutrients due to the composition of the feeds. Silva et al. (2007) did not observe a reduction in the digestibility of the NFC in lactating goats receiving a diet with protected fat; however, the metabolizable fermentable energy of the diets was constant.

The digestibility of the CP presented a linear increase ($P<0.05$) of 0.064 kg/kg for every 0.1 Mcal ME added to the diet (Table 5). The increase in the digestibility of the CP can be related to the decrease in the quantity of fermentable substrate available for ruminal microorganisms, resulting from the reduction in the intake of NFC and TC with the inclusion of protected fat in the diets. According to Ribeiro et al. (2001), the microbial growth is dependent on the supply of fermentable carbohydrates. When the fermentation of carbohydrates is available for generation of cell energy, the amino acids can be incorporated in microbial protein.

The digestibility of the EE was influenced positively by the diets, presenting a quadratic behavior, with a maximum value estimated at 2.81 Mcal ME/kg DM (Table 5). According to Kadzere and Jingura (1993), the addition of calcium salts of fatty acids may increase the digestibility of the EE; however, this effect seems to depend on the quantity and type of fat supplemented. Sanz Sampelayo et al. (2002) suggested that the increase of the digestibility of the EE can be a result of the increase of availability of the fat supplemented, which is more easily digested when compared with the fat present in particles or biological membranes. Furthermore, the addition of lipids decreases the importance of endogenous secretion of lipids, resulting in an increase of the accuracy of the digestibility estimate.

The protected fat (Lactoplus®) had a large percentage of unsaturated lipids (23.3%) and polyunsaturated lipids (60%) in its composition (LIMA et al., 2006). According to Palmquist and Mattos (2011), the unsaturated fatty acids present better digestibility than saturated fatty acids due to their property of forming more soluble fatty micelles in the intestine, which favors the transposition of the inert water layer associated with the intestinal microvilli. This increases the absorption of these fatty acids and contributes to the digestibility of the EE.

The digestibility of the GE was not influenced by the diets (Table 6), remaining at values of 0.673 kg/kg DM. The digestible energy calculated (DEc) and metabolizable energy calculated (MEc) of the diets presented linear increases as a function of the diets, confirming the increment of the energy concentration of the diets. There was a linear increase ($P<0.05$) of TDN due to the diets, presenting an increase of 1.79% for every 0.1 Mcal ME added (Table 6). This shows the larger energy density of the diets supplemented with protected fat, however without an improvement of goat productive parameters.

**Table 6**. Energy value of the experimental diets.

| Parameters | Diets (Mcal ME $kg^{-1}$ DM) | | | | Regression equation; $R^2$ | CV (%) |
|---|---|---|---|---|---|---|
| | 2.5 | 2.6 | 2.7 | 2.8 | | |
| GE[1] (Mcal $kg^{-1}$ DM) | 4.44 | 4.80 | 4.91 | 5.01 | | |
| GED[2] (kg $kg^{-1}$ ) | 0.676 | 0.670 | 0.671 | 0.675 | $\hat{Y}$= 0,673; NS[6] | 3.45 |
| DEc[3] (Mcal $kg^{-1}$ DM) | 3.00 | 3.22 | 3.31 | 3.36 | $\hat{Y}$=0,0112+0,0012X; 0.91 | 4.63 |
| MEc[4] (Mcal $kg^{-1}$ DM) | 2.46 | 2.64 | 2.72 | 2.76 | $\hat{Y}$=0,0423+0,00098X; 0.91 | 4.63 |
| TDN[5] (kg $kg^{-1}$) | 0.658 | 0.660 | 0.676 | 0.692 | $\hat{Y}$= 0,191 + 0,179X; 0.46 | 4.39 |

[1]Gross energy; [2]Gross energy digestibility; [3]Digestible energy calculated (GE*GED); [4]Metabolizable energy calculated (DEc*0.82); [5]Total digestible nutrients.[6]NS: Not significant ($P>0.05$).
**Source**: Elaboration of the authors.

The urea and serum triacylglycerols were not influenced as a function of the energy concentration of the diets. Serum cholesterol presented a linear increase of 6.4 mg/dl for each 0.1 Mcal ME added to the feed as a consequence of the increase of lipid concentration in the diets (Table 7).

**Table 7.** Blood parameters of ½ Boer x ½ Saanen kids as a function of energy concentrations in the diet.

| Parameters mg/dl | Diets (Mcal ME $kg^{-1}$ DM) | | | | Regression equation; $R^2$ | CV (%) |
|---|---|---|---|---|---|---|
| | 2.5 | 2.6 | 2.7 | 2.8 | | |
| Urea | 54.18 | 52.32 | 53.13 | 58.47 | $\hat{Y}$=54,379; NS[1] | 12.08 |
| Triacylglycerols | 29.49 | 30.26 | 29.54 | 33.27 | $\hat{Y}$=30,544; NS | 22.69 |
| Cholesterol | 70.69 | 80.31 | 83.32 | 91.07 | $\hat{Y}$=-88,48+64,08X; 14.39 | 23.38 |

[1]NS: Not significant ($P>0.05$).
**Source**: Elaboration of the authors.

The concentration of plasmatic cholesterol is an adequate indicator of the total lipids in the plasma, because it corresponds to approximately 30% of the total (GONZÁLEZ, 2000). In addition, it is a constituent of the lipoproteins synthesized in the liver and small intestine and has a role in lipid transportation in the body (BRUSS, 2008). Possamai et al. (2015), when assessing Saanen kids supplemented with protected fat, observed an increase of 7.1 mg/dl of cholesterol for each 0.1 Mcal ME added to the diet. However, Adibmoradi et al. (2012), when observing kids supplemented with soy oil or palm oil (2% of DM), did not obtain differences in blood parameters.

According to Fernandes et al. (2012), variations in the serum/plasma concentration of cholesterol are related to the nutritional state of the animals. Cholesterol is a reliable indicator of the energy metabolism in the liver, in particular the exportation of lipids in the form of very low density lipoproteins. The serum concentrations of urea and cholesterol considered normal for kids are 21 to 42 mg/dl and 80 to 130 mg/dl, respectively (PUGH, 2004).

According to Ribeiro (1997), the cost of food in goat farming (roughage + concentrate) amounts to 50 to 60% of the production cost and may even reach 80%, depending on the context. From this total, approximately 2/3 is represented by the concentrated feed.

In line with the best results of productive performance, weight gain, and feed conversion in the control diet (without inclusion of protected fat), the economic evaluation was found to be favorable (Table 8), with a higher net revenue value for the diet with 2.5 Mcal ME/kg DM. The increase of ME in the diets through the inclusion of protected fat caused an increase in their cost without a significant increase in animal performance. These results differ from those obtained by Possamai et al. (2015), who obtained a better economic evaluation in Saanen kids receiving a diet with 2.7 Mcal ME/kg DM.

**Table 8.** Economic analysis of the productive performance of ½ Boer x ½ Saanen kids as a function of energy concentrations in the diet.

| Parameters | Diets (Mcal ME/kg DM) | | | |
|---|---|---|---|---|
| | 2.5 | 2.6 | 2.7 | 2.8 |
| | Expenses | | | |
| Food (kg/animal/day) | 1.09 | 1.13 | 1.17 | 1.10 |
| Feeding cost (R$/animal/day)[1] | 0.68 | 0.76 | 0.87 | 0.89 |
| DC (days)[2] | 75.71 | 88.00 | 80.57 | 74.17 |
| Total cost of feeding (R$/animal)[3] | 51.34 | 67.06 | 70.39 | 66.58 |
| Total expenses (R$)[4] | 359.40 | 469.43 | 492.74 | 466.04 |
| | Revenues | | | |
| Weight of the carcasses (kg/animal) | 14.48 | 14.31 | 14.10 | 14.32 |
| Total revenue (R$ 12.50/kg carcass)[5] | 1,267.00 | 1,252.12 | 1,233.75 | 1,253.00 |
| Net income (R$)[6] | 907.60 | 782.69 | 741.01 | 786.96 |

[1]Feeding cost = cost of the individual kid feeding, [2]Days in confinement, [3]Total cost of feeding = cost of food * days in confinement, [4]Total expenses = total cost of animal feeding * days in confinement * 7 animals for each treatment, [5]Total revenue = Weight of the carcasses * R$ 12.50/kg carcass * 7 animals, [6]Net income = total revenue − total expenses.
**Source**: Elaboration of the authors.

The results of the economic evaluation (Table 8) allow us to infer that goat farming may be a profitable activity for producers, considering that the cost components in goat farming related to feeding represent approximately 75% of the total (GONÇALVES et al., 2008), and that even the diet with the lowest economic return had a positive net income.

## Conclusions

The increase of the energy density of ½ Boer x ½ Saanen kids above 2.5 Mcal ME/kg DM through the inclusion of protected fat negatively affects the ingestion of dry matter and the digestibility of non-fiber carbohydrate and total carbohydrate without improving the productive performance of the animals.

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