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Production and economic analysis of milk from goats fed with double-distilled glycerin

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Abstract

The objective of this research was to evaluate the production, milk quality, consumption and financial analysis of milk from goats consuming diets with different levels of double-distilled glycerin. Twelve multiparous Saanen goats, weighing 40 ± 6 kg and 30 ± 5 days of lactation, kept in a confinement system for 60 days were used. The goats were randomly distributed in a Latin square (4 x 4), according to the levels of double-distilled glycerin. The ingredients used were tifton hay, ground corn grain, soybean meal, vitamin/mineral supplement, urea, and double-distilled glycerin levels (0, 6, 12 and 18%) to replace corn in the diets. The milk fat of goats fed with double-distilled glycerin in the diet showed a decreasing linear regressive effect (P = 0.001). Dry matter intake showed a quadratic regressive effect (P = 0.033). Evaluating the total cost of each diet, it was observed that the level containing 0% glycerin was the diet with the lowest cost per kilogram. The use of double-distilled glycerin in the feeding of dairy goats can be recommended up to the level of 18% of corn replacement without harming milk production, however, it is necessary to verify the economic viability, considering that there will be losses in the quality of the milk produced.

Keywords: consumption of nutrientes; glycerol; milk fat; use of residues.

Practical Application: Glycerin can be used in the diet without harming the production and quality of milk and reduces diet expenses.

1 Introduction

The search for energy sources capable of mitigating impacts on the environment is growing, since most of the fuel used in the world is of fossil origin: oil, coal and natural gas. The damage to the environment and the possibility of depletion of natural resources are the main arguments used to justify the need to change the energy matrix in the world (Giotto et al., 2015).

The recent growth in the biofuel industries and the increase in the costs of grains traditionally used in animal feed, has encouraged studies aimed at the use of biodiesel co-products in order to create alternative foods and reduce environmental impacts in addition to increasing profitability. The high polluting potential of fossil fuels has opened space for the emergence of renewable energy sources, where biodiesel has gained prominence as a viable alternative (Lima et al., 2021). Glycerin is the main co-product of biodiesel production, obtained in the process of transesterification of triacylglycerols from vegetable oils or animal fats, usually using methanol and a catalyst (Chanjula et al., 2015).

The difficulty in using surplus glycerin production is exacerbated due to the peculiarity of its characteristics (Fávaro et al., 2014). Aiming at maximum efficiency in this activity, research and adaptation of new technologies has been intensified, including in nutrition, with the use of alternative food sources, which can replace premium foods without changing the composition and quality of goat milk and its derivatives (El-Shafei et al., 2020; Hadjimbei et al., 2020).

The researchers supplemented dairy cows' diets with glycerin in purified (Carvalho et al., 2011) and crude (Boyd et al., 2013) form. When crude glycerin (82.6% glycerol) was added up to 15.6% in diets for medium-yield cows, no changes was observed in milk production and quality (Harzia et al., 2013), evidencing no difference in results of studies using crude or purified glycerin, as reported by Omazic et al. (2013). These experiments indicate that purified or crude glycerin can be fed up to 15% of dietary dry matter to lactating cows without harmful effects.

Lima et al. (2021) replaced corn with double-distilled glycerin in the diet of dairy goats in proportions of 0, 6, 12 and 18% and observed that when inserted in the diet of dairy goats at increasing levels, it does not change milk production, protein and the lactose. Freire et al. (2022) replaced corn with double-distilled glycerin in the proportions of 0 and 15% in the feeding of dairy goats and observed that there was an increase in milk production, the amount of fat in milk and the size of milk fat

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globules also increased and saturated and polyunsaturated fatty acids did not change. In this way, glycerin appears as an option in the formulation of diets, which can replace corn (Lage et al., 2014). Its use in ruminant diets is not recent, however, this interest has been renewed due to its greater availability and price (Ezequiel et al., 2015).

In a production system aimed at dairy goats, the food item is one of the items that most raises production costs. When you don't have a well-designed plan to keep the herd well nourished and with desirable productions during periods of food shortage, maintaining this type of activity becomes more difficult. So properly nourishing a goat means providing the nutrients to meet its needs, this is fully possible since it is not difficult to find foods considered noble such as corn, soy and wheat for animal feed, however, in addition to being used in human food such ingredients have high cost.

In this way, the search for ingredients that allow good levels of productive performance with low cost is constant, without causing quantitative and qualitative losses in the performance and behavior of dairy goats. The objective of this research was to evaluate the productive performance, blood, hormonal and physiological variables of goats as well as the financial analysis of milk from goats consuming diets with different levels of double-distilled glycerin.

2 Material and methods

2.1 Experiment location and animals

This project was submitted to the Ethics Committee on Animal Use (CEUA) of the Federal University of Paraíba and approved according to protocol no. 052/2017.

The experiment was conducted at the Federal University of Paraíba, Campus at Bananeiras-Paraíba, Brazil (altitude 552 m, latitude 6° 41' 11", longitude 35° 37' 41"). The air temperature was 24.97 °C, and relative humidity was 76.48% in the stalls.

Twelve Saanen multiparous goats weighing 40 ± 6 kg and 30 ± 5 days of lactation were used. The animals were kept in a confinement system for 60 days, housed in a covered shed and kept in individual pens made of wood, provided with feeder and drinker.

2.2 Diets

The animals went through four periods of 15 days, twelve for adaptation to the diet, and three for data collection. During the adaptation and collection periods, daily offer and leftover food weighing were performed to calculate voluntary consumption and adjust the diet offered, in order to guarantee 10% leftovers based on a dry matter (DM). Water for animal consumption was offered on an ad libitum basis, and consumption was quantified daily during the data collection period. The animals were weighed at each period, at the beginning and after the collection period.

Diets were adjusted to meet the requirements of the National Research Council (2007) for lactating goats producing 2.0 kg milk/day and 4% fat, with a 55:45 forage: concentrate ratio. The experimental diet was offered ad libitum at 07:30 a.m. and 04:30 p.m. as a complete mixture. Tifton hay, ground corn grain, soybean meal, vitamin/mineral supplement, urea, and bidistilled glycerin levels (0, 6, 12, and 18%) were used to replace corn in the diets, as described in Table 1. The gross energy levels of corn and double-distilled glycerin used in the composition of the diets were 3.50 and 3.71 Mcal/kg, respectively.

2.3 Bromatological analysis of experimental diets

During each period, subsamples of diets, ingredients (Tifton hay, concentrates and double-distilled glycerin) and leftovers were collected, which were taken to a forced ventilation oven at 55-60º C for 72 h. Subsequently, they were ground in a Willey-type knife mill, passing through a 1.0 mm sieve, and then placed in polyethylene containers. At the end of the experimental period (60 days), a representative aliquot was removed from each

Table 1. Percentage and bromatological composition of experimental diets.

Ingredient (g kg $^{-1}$ of DM)	Levels of inclusion (%)			
	0	6	12	18
Glicerin	0	60	120	180
Ground corn	335	273	211	149
Soybean meal	95	95	95	95
Tifton hay	550	550	550	550
Urea	0	2	4	6
Mineral supplement[1]	15	15	15	15
Calciticlimestone	5	5	5	5
Determined nutrient composition (g kg^{-1} of DM)				
Dry matter, DM (g kg^{-1} as feed)	881	876	848	823
Crude protein	113	119	107	89
Ethereal extract	128	135	165	210
Neutral detergent fiber	901	784	709	638
Neutral detergente acid	282	270	254	238
Metabolizable energy (Mcal kg^{-1} of DM)	3.62	3.66	3.62	3.54

[1]Composition of mineral supplement per kg: P: 70 g; Ca: 140 g; Na: 148 g; S: 12 g; Mg: 1.320 mg; F: 700 mg; Zn: 4.700 mg; Mn: 3.690 mg; Fe: 2.200 mg; Co: 140 mg; I: 61 mg; Se: 15 mg; Monensinasódica: 100 mg.

subsample, being homogenized to form a composite sample that was later analyzed in the laboratory.

The experimental diets, ingredients and leftovers were analyzed for dry matter (DM) and ether extract (EE) contents, with the crude protein (CP) content obtained by the product of the nitrogen content (N) by the factor 6.25 (Association of Analytical Chemists, 2010). To determine neutral detergent fiber (NDF) and acid detergent fiber (ADF), the methodology proposed by Van Soest et al. (1991).

2.4 Milk production and physicochemical analysis of milk

Milking was performed manually, throughout the experiment, occurring twice a day at the times of (6:00 a.m. and 3:00 p.m.), including adaptation periods and data collection, and the dairy control was performed by weighing. Milk (kg/day) during the three days of collection of each period (all experimental period). Before milking, the goats' udders were washed with chlorinated water and dried with paper towels and then tested for mastitis (black bottom mug test). After each milking was done post-dipping, the goats' roofs were dipped in a 2% iodine solution.

Milk samples from each animal were collected twice a day, at regular times, during the three days of data collection of each period respecting the proportion of milk milked (morning/afternoon).

Vials and glassware were sanitized at 105 °C for one h, to avoid contamination by milk residues from the previous milking. The samples of the morning production were conditioned in a refrigerated environment (4 °C) to be later mixed to the milk samples of the afternoon, forming a sample composed of goat per day. From the whole milk milked per animal (kg day-1), an aliquot of 200 mL was taken (with the participation of the samples proportional to the morning and afternoon milking), for analysis of the physicochemical characteristics. After being placed in identified plastic bottles, the samples were slowly pasteurized at 65 °C for 30 min (Brasil, 2001) and finally frozen at -4 °C (in a freezer) for further analysis.

Physicochemical requirements for fat (%) and lactose (%) were evaluated according to the Master Complete® Milk Analyzer (AKSO®, São Leopoldo, Rio Grande do Sul, Brasil), under specific technical conditions.

2.5 Financial analysis

The financial analysis was based on the local costs of the ingredients in the diets, the values consumed by the animals, the feed efficiency and milk production per treatment. The values of ingredients per kilogram were consulted, and for the composition of one kilogram of each experimental diet. The values were determined according to the formulation percentage (Table 1). The following values were considered: typhton hay (kg) = R$ 0.80; corn (kg) = R$ 1.20; soybean meal (kg) = R$ 1.48; double-distilled glycerin (kg) = R$ 3.20; urea (kg) = R$ 5.00; mineral supplement (kg) = R$ 1.60 and limestone (kg) = R$ 3.00. The sale value of a liter of goat milk was R$ 2.50.

2.6 Statistical analysis

The design adopted for this experiment was the Latin square (4 x 4), triple, with (4 treatments and 4 periods), in a rotating experiment.

The data were submitted to analysis of variance (ANOVA) and the degrees of freedom were split from polynomial regression for double-distilled glycerin levels, considering the probability of 5%, using the "Statistical Analysis System" software (SAS Institute, 2001).

3 Results

The milk fat of goats fed with double-distilled glycerin in the diet showed a decreasing linear regressive effect (P = 0.001) (Table 2), the milk fat reduced by 21.50% with the inclusion of glycerin in the diet. The production of milk and lactose showed no regressive effect.

The dry matter (CM) consumption presented a quadratic regressive effect (P = 0.033), with the maximum point of 5% starting at 6% of inclusion, there was a decrease in CM. Glycerin also showed a quadratic regressive effect (P = 0.009), with the maximum point being at 26.25% glycerin inclusion. Energy consumption showed a quadratic regressive effect (P = 0.014), with the maximum point of 5% being the same as the CM, from 6% onwards, energy consumption begins to decrease (Table 2).

Evaluating the total cost of each diet, it was observed that the level containing 0% glycerin was the diet with the lowest cost per kilogram. However, the diets had their values increased

Table 2. Production and composition of milk and consumption of dairy goats submitted to a diet with different levels of double-distilled glycerin.

Variable	Levels of inclusion (%)				SEM	P value	
	0	6	12	18		Linear	Quadr.
Milk production (kg day^{-1})	2.02	2.05	2.09	1.97	0.43	0.785	0.491
Fat (%)	2.51	2.17	2.04	1.94	0.40	0.001[1]	0.315
Lactose (%)	4.59	4.45	4.40	4.59	0.33	0.925	0.102
Intake							
Dry matter (kg day^{-1})	1.74	1.73	1.69	1.37	0.45	0.001	0.033[2]
Glycerin (kg day^{-1})	0.00	0.10	0.20	0.24	0.02	< 0.001	0.009[3]
Water (kg day^{-1})	5.66	5.18	5.08	4.59	1.41	0.066	0.981
Metabolizable energy (Mcal day)	6.29	6.36	6.13	4.87	1.29	0.004	0.014[4]

Quadr. = Quadratic; SEM = standard error means. [1]$Y = 2.443 - 0.030x$ ($R^2 = 0.91$); [2]$Y = 1.728 + 0.021x - 0.0022x^2$ ($R^2 = 0.97$); [3]$Y = -0.002 + 0.021x - 0.0004x^2$ ($R^2 = 0.99$); [4]$Y = 6.26 + 0.090x - 0.009x^2$ ($R^2 = 0.98$).

according to the increasing levels of corn replacement by glycerin. This was due to the value of glycerin being approximately 167% higher than that of corn. For the same reason, a lower cost per liter of milk was also observed in the treatment containing 0% double-distilled glycerin, even with lower feed efficiency (Table 3).

4 Discussion

According to the National Research Council (2007), the ideal dry matter (DM) intake for lactating goats weighing approximately 40 kg should be 1.6 kg/day. The data obtained are presented in accordance with the precepts, with an average consumption of around 1.64 kg/day.

According to Dias et al. (2016) the inclusion up to 15% of glycerin in the diet of kid goats Boer crossbred, although does not affect feed conversion and performance, compromises the intake and carcass weight. This same trend was observed by Santos et al. (2015) who, when evaluating the productive performance of kids fed with crude glycerin, found that diets containing increasing levels of 0; 4; 8; and 12% of glycerin replacing corn also did not significantly influence ($P > 0.05$) the dry matter intake.

Diets containing higher levels of double-distilled glycerin led to a higher consumption of glycerol. This was already expected in view of the concentrations of double-distilled glycerin in the diets. On the other hand, evaluating energy consumption (Mcal/kg.day-1) there was an inverse and significant effect ($P < 0.01$) to that observed in glycerol consumption. This fact must have occurred due to lower DM intakes in diets containing higher levels of double-distilled glycerin.

Feed efficiency data were presented in kilogram of milk per kilogram of diet. For this parameter, there was an increasing linear regression effect ($P < 0.05$), which indicates that more milk was produced per kilogram of the diet in the treatment containing 18% of double-distilled glycerin. Possibly this is because part of the glycerol has a rapid absorption in the rumen wall to be metabolized in the liver to glucose and another part is fermented to propionate, which will also be converted into glucose. Fávaro et al. (2014) found that 43% of the glycerol that reaches the rumen disappears by absorption by the rumen wall and 44% by fermentation, the main product of fermentation being propionate, which is a precursor of volatile fatty acids and metabolic glucose in ruminants.

The lower milk fat contents are probably due to the decrease in dry matter intake (Table 2), which led to a lower fiber intake.

When studying the influence of herd management on the chemical composition of milk from saanen goats, Queiroga et al. (2007) reported that the fat content of goat milk is susceptible to fluctuations caused by factors such as breed, milking shift and lactation period. Some breeds are characterized by low production of high-fat milk, such as the Anglo-Nubian breed, or by a high amount of low-fat milk, such as the Saanen breed. Other factors, such as the availability of certain foods and seasonality, also affect the amount of fat in goat's milk. According to Zigo et al. (2021) who analyzed milk composition and diagnosis of mastitis in goats, the fat content of milk can vary greatly according to the time of year, geographic region and management, but, undoubtedly, the factor that most contributes to this variation is the diet of the herd. In cattle, diets low in fiber can result in a 50% reduction in milk fat content.

Normative Instruction No. 37 of November 8, 2000 of the Ministry of Agriculture establishes minimum values of 2.9% and 4.3% for fat and lactose, respectively. It was observed that the lactose levels are within the required standards, however the fat levels are below the minimum value established by the legislation in all treatments.

Table 3. Cost of experimental diets and recipe as a function of milk production of goats fed different levels of double-distilled glycerin.

Ingredients	Levels of inclusion (%)			
	0	6	12	18
Grand corn (kg)	0.40	0.33	0.25	0.18
Soybean meal (kg)	0.14	0.14	0.14	0.14
Tífton hay (kg)	0.44	0.44	0.44	0.44
Glicerin (L)	0.00	0.19	0.38	0.58
Urea (kg)	0.00	0.01	0.02	0.05
Mineral supplement (kg)	0.02	0.02	0.02	0.02
Calciticlimestone (kg)	0.02	0.02	0.02	0.02
Total cost of diet (R$/kg)	1.02	1.15	1.28	1.40
Financial analysis				
Feed efficiency	1.16	1.19	1.26	1.49
Cost per liter of milk (R$/kg)	0.88	0.96	1.01	0.94
Value of goat's milk (R$/kg)	2.50	2.50	2.50	2.50
Day milk production (kg/goat)	2.03	2.06	2.09	1.97
Monthly milk production (kg/goat)	60.84	61.65	62.76	59.19
Gross margin per kg milk (R$/kg)	1.62	154	1.49	1.56
Gross margin per goat day (R$)	3.29	3.15	3.11	3.07
Price received/month production (R$)	152.10	154.12	156.91	147.97
Gross margin per goat month (R$)	98.61	94.64	93.35	92.19

Studying the effect of glycerin on the ruminal microbiota of cattle Fávaro et al. (2014) reported that the economic viability of using glycerin in animal feed depends on the price relationship between ingredients, especially corn and soybean oil or other energy source. Lage et al. (2014) recommended that glycerin emerges as an option in the formulation of diets, being able to replace corn, when the price represents up to 70% of the price of corn.

For daily milk production and monthly milk production, it was found that the treatment containing 12% of double-distilled glycerin obtained the best production values, however in financial terms the treatment with 0% presented a better gross margin per goat, precisely due to the lower cost per kilogram of milk. It is observed that it is possible to obtain a better gross margin per goat when the value of double-distilled glycerin is higher than that of corn by up to 83%, since the feed efficiency of the animals was improved with the replacement of corn by double-distilled glycerin.

5 Conclusion

There was a reduction in the consumption of dry matter and energy, however, the feed efficiency increased linearly with the increase in the levels of double-distilled glycerin. No influence on milk production and hormonal parameters was observed. There was an effect on the production of volatile fatty acids which led to changes in milk composition leading to a reduction in fat content.

The use of double-distilled glycerin in the feeding of dairy goats can be recommended up to the level of 18% of corn replacement without harming milk production, however, it is necessary to verify the economic viability, considering that there will be losses in the quality of the milk produced.

References

Association of Analytical Chemists – AOAC International.(2010). *Official methods of analysis of AOAC International* (19th ed.). Washington: AOAC International.

Boyd, J., Bernard, J. K., & West, J. W. (2013). Effects of feeding different amounts of supplemental glycerol on ruminal environment and digestibility of lactating dairy cows. *Journal of Dairy Science*, 96(1), 470-476. http://dx.doi.org/10.3168/jds.2012-5760. PMid:23182356.

Brasil, Ministério da Saúde, Agência Nacional de Vigilância Sanitária – ANVISA. (2001, January 10). Resolução de Diretoria Colegiada-RDC nº 12, de 02 de janeiro de 2001. *Diário Oficial da República Federativa do Brasil*, seção 1.

Carvalho, E. R., Schmelz-Roberts, N. S., White, H. M., Doane, P. H., & Donkin, S. S. (2011). Replacing corn with glycerol in diets for transition dairy cows. *Journal of Dairy Science*, 94(2), 908-916. http://dx.doi.org/10.3168/jds.2010-3581. PMid:21257059.

Chanjula, P., Pakdeechanuan, P., & Wattanasit, S. (2015). Effects of feeding crude glycerin on feedlot performance and carcass characteristics in finishing goats. *Small Ruminant Research*, 123(1), 95-102. http://dx.doi.org/10.1016/j.smallrumres.2014.11.011.

Dias, J. C., Silveira, A. L. F., Lançanova, J. A. C., Hill, J. A. G., & Moletta, J. L. (2016). Crude glycerin in meat goat diets: intake, performance and carcass traits. *Ciência Rural*, 46(4), 719-724. http://dx.doi.org/10.1590/0103-8478cr20141489.

El-Shafei, S. M. S., Sakr, S. S., & Abou-Soliman, N. H. I. (2020). The impact of supplementing goats' milk with quinoa extract on some properties of yoghurt. *International Journal of Dairy Technology*, 73(1), 126-133. http://dx.doi.org/10.1111/1471-0307.12628.

Ezequiel, J. M. B., Sancanari, J. B. D., Machado, O. R. No., Silva, Z. F., Almeida, M. T. C., Silva, D. A. V., van Cleef, F. O. S., & van Cleef, E. H. C. B. (2015). Effects of high concentrations of dietary crude glycerin on dairy cow productivity and milk quality. *Journal of Dairy Science*, 98(11), 8009-8017. http://dx.doi.org/10.3168/jds.2015-9448. PMid:26298757.

Fávaro, V. R., Ezequiel, J. M. B., D'Aurea, A. P., Sancanari, J. B. D., Homem, A. C. Jr., van Cleef, E. H. C. B., & Santos, V. C. (2014). A utilização de glicerina em dietas para bovinos altera a microbiota ruminal. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 66(5), 1504-1512. http://dx.doi.org/10.1590/1678-6654.

Freire, L. F. S., Cruz, G. R. B. C., Costa, R. G., Ribeiro, N. L., Guerra, R. R., Sousa, S., Lima, A. M., Silva, G. F., Sant'ana, A. M. S., & Nascimento, G. V. (2022). Glycerin diet affects the size of the far globule and the fatty acid profile of goat's milk. *Food Science and Technology*, 42, e85821. http://dx.doi.org/10.1590/fst.85821.

Giotto, F. M., Osmari, M. P., Salab, B. L., Matos, L. F., & Diaz, T. G. (2015). Subproduto do biodiesel na alimentação de ruminantes: o caso da glicerina. *Arquivos de Ciências Veterinárias e Zoologia da Unipar*, 18(4), 253-257.

Hadjimbei, E., Botsaris, E., Goulas, V., Alexandri, E., Gekas, V., & Gerothanassis, I. P. (2020). Functional stability of goats' milk yoghurt supplemented with Pistacia atalntica resin extracts and Saccharo myces boulardii. *International Journal of Dairy Technology*, 73(1), 134-143. http://dx.doi.org/10.1111/1471-0307.12629.

Harzia, H., Kilk, K., Ariko, T., Kass, M., Soomets, U., Joudu, I., Kaart, T., Arney, D., Kart, O., & Ots, M. (2013). Crude glycerol as glycogenic precursor in feed: effects on milk coagulation properties and metabolic profiles of dairy cows. *The Journal of Dairy Research*, 80(2), 190-196. http://dx.doi.org/10.1017/S0022029913000101. PMid:23473443.

Lage, J. F., Paulino, P. V. R., Pereira, L. G. R., Duarte, M. S., Valadares, S. C. Fo., Oliveira, A. S., Souza, N. K. P., & Lima, J. C. M. (2014). Carcass characteristics of feedlot lambs fed crude glycerin contaminated with high concentrations of crude fat. *Meat Science*, 96(1), 108-113. http://dx.doi.org/10.1016/j.meatsci.2013.06.020. PMid:23896144.

Lima, A. M., Cruz, G. R. B., Costa, R. G., Ribeiro, N. L., Beltrão, E. M. Fo., Sousa, S., Justino, E. S., & Santos, D. G. (2021). Physicalchemical and microbiological quality of milk and cheese of goats fed with bidestilated glycerin. *Food Science and Technology*, 41(1), 25-33. http://dx.doi.org/10.1590/fst.27119.

National Research Council – NRC. (2007). *Nutrient requirements of small ruminants*. Washington: National Academy of Sciences.

Omazic, A. W., Traven, M., Bertilsson, J., & Holtenius, K. (2013). High- and low-purity glycerine supplementation to dairy cows in early lactation: effects on silage intake, milk production and metabolism. *Animal*, 7(9), 1479-1485. http://dx.doi.org/10.1017/S1751731113001110. PMid:23800400.

Queiroga, R. C. R. E., Costa, R. G., Biscontini, T. M. B., Medeiros, A. N., Madruga, M. S., & Schuler, A. R. P. (2007). Influência do manejo do rebanho, das condições higiênicas da ordenha e da fase de lactação na composição química do leite de cabras Saanen. *Revista Brasileira de Zootecnia*, 36(2), 430-437. http://dx.doi.org/10.1590/S1516-35982007000200021.

Santos, D. A., Parente, H. N., Parente, M. O. M., Rocha, K. S., Ferreira, E. M., & Alves, A. A. (2015). Desempenho produtivo de cabritos alimentados com glicerina bruta. *Ciência Rural*, 45(4), 690-696. http://dx.doi.org/10.1590/0103-8478cr20140536.

SAS Institute. (2001). *SAS/STAT user's guide: statistics. Version 9* (2nd ed.). Cary: SAS Institute Inc.

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, 74(10), 3583-3597. http://dx.doi.org/10.3168/jds.S0022-0302(91)78551-2. PMid:1660498.

Zigo, F., Vasil, M., Ondrašovičová, S., Výrostková, J., Bujok, J., & Pecka-Kielb, E. (2021). Maintaining optimal mammary gland health and prevention of mastitis. *Frontiers in Veterinary Science*, 8, 607311. http://dx.doi.org/10.3389/fvets.2021.607311. PMid:33681324.