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Use of high moisture corn silage replacing dry corn on intake, apparent digestibility, production and composition of milk of dairy goats[1]

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ABSTRACT - Twenty primiparous and multiparous Alpine breed goats at approximately 80 days of lactation were used in this experiment. The animals were housed individually in metal cages and distributed according to milk production in five 4 × 4 Latin squares. The experimental diets used in the experiment presented concentrate:forage ratio of 65:35. The treatments were characterized by increasing levels of 0, 33, 67 and 100% of high moisture corn silage (HMCS) replacing corn dry grain (CDG). Average intake of DM (1.62 kg/day, 3.90 % BW), CP (0.22 kg/day), NFC (0.76 kg/day) and TDN (1.29 kg/day) were not influenced by levels of HMCS. However, intake of NDF (0.53 kg/day) was significant for the different level of HMCS. Daily milk production and production of milk correct at 3.5% of fat, feed efficiency (MP/DMI), fat percentage, protein, lactose, total solids and milk urea nitrogen, with means of 1.86; 1.69; 1.11; 2.96; 2.85; 4.36; 10.96 and 17.1, respectively, were not influenced by the levels of HMCS. Percentage of non fat solids (8.00%) was affected by replacing levels of HMCS. The use of high moisture corn silage in the diet does not change milk production and it can be applied in total or partial substitution to dry corn grain in the feeding of milk goats.

Key Words: dairy goats, dry matter intake, processed corn

Utilização da silagem de grãos úmidos de milho em substituição ao milho seco no consumo, digestibilidade aparente, produção e composição do leite de cabras leiteiras

RESUMO - Foram utilizadas 20 cabras da raça Alpina, primíparas e multíparas, com aproximadamente 80 dias em lactação, alojadas individualmente em gaiolas metálicas e distribuídas, de acordo com a produção de leite, em cinco quadrados latinos 4 × 4. As dietas experimentais utilizadas apresentaram relação concentrado:volumoso 65:35. Os tratamentos foram caracterizados por níveis crescentes 0, 33, 67 e 100% de silagem de grãos úmidos de milho (SGUM) em substituição ao grão seco de milho (GSM). As médias de consumo de MS (1,62 kg/dia, 3,90 %PV), proteína bruta (0,22 kg/dia), carboidratos não fibrosos (0,76 kg/dia) e nutrientes digestíveis totais (1,29 kg/dia) não foram influenciadas pelos níveis de SGUM. Entretanto, o consumo de FDN (0,53 kg/dia) foi significativo para os diferentes níveis de SGUM. A produção diária de leite e produção de leite corrigida a 3,5% de gordura (kg/dia), eficiência alimentar (PL/CMS), porcentagens de gordura, proteína, lactose, sólidos totais e nitrogênio ureico do leite, com médias de 1,86; 1,69; 1,11; 2,96; 2,85; 4,36; 10,96 e 17,1, respectivamente, não foram influenciados pelos níveis de SGUM. A porcentagem de extrato seco desengordurado (8.00%) foi afetada pelos níveis de substituição da SGUM. A utilização de silagem de grãos úmidos de milho na dieta não altera a produção de leite e pode aplicada em substituição parcial ou total ao grão seco de milho na alimentação de cabras leiteiras.

Palavras-chave: cabras leiteiras, consumo de matéria seca, milho processado

Introduction

Cereal grains used in animal feeding have high content of starch. For example, corn and sorghum have in average 72% of starch whereas barley, oat and wheat have 57, 58 and 77% of it, respectively (Huntington, 1997). Of those cereal grains, corn is used as the principal source of energy and it is essential in the nutrition management of

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high milk production animals, which require high levels of energy.

High moisture corn silage is defined as a product of corn grain conservation in anaerobic environment, destined to animal nutrition and based on the preservation of its nutritive value, avoiding degradation processes by undesirable attack by microorganisms such as fungus. Ensilage process consists of grain harvesting right after physiological maturity when moisture content is between 28% and 33% (Mader & Erickson, 2006). Physiological maturity is characterized by the moment that the translocation of nutrients from the plant to the grain ceases and it is determined by the occurrence of a black layer in the basis of the corn grain. The ensilage process of high moisture corn silage follows the same principles of roughage ensilage (Costa, 2001).

Wilkerson et al. (1997) evaluated the inclusion of high moisture corn silage (HMCS) or dry-ground corn (DGC) in dairy cows diets and observed that the digestibility of dry matter (DM), organic matter (OM), crude protein (CP) and non fibrous carbohydrates (NFC) were higher in cows fed HMCS than in those fed DCG. In the same study, milk production was 2.0 kg/d higher in cows fed HMCS when compared with cows fed diets with DCG, suggesting that the higher milk production in HMCS diets could be related to a greater utilization of starch and energy from the diet. However, no differences in percentages of protein and fat in milk were observed among treatments.

San Emeterio et al. (2000) observed no differences in intake and digestibility of dry matter, neutral detergent fiber (NDF) and acid detergent fiber (ADF) in dairy cows fed once daily with different forms of high moisture corn grain (shelled or ear) or dry corn grain (finely or coarsely ground). Moreover, it was not observed differences in milk production and 4% fat-corrected milk.

In Brazil, high moisture corn silage has been included mainly in diets for feedlot cattle and high production dairy cows and in diets for swine and poultry as well. There is no information regarding its use in production systems of dairy goats. The objective of this study was to evaluate the effects of levels of replacement of dry-ground corn grain by high moisture corn silage on intake, total tract apparent digestibility of nutrients, milk production and composition in diets for dairy goats.

Material and Methods

Twenty primiparous and multiparous Alpine goats with an average body weight of 39.1 ± 6.1 kg were distributed in five 4 × 4 Latin squares balanced according to milk production. Each experimental period lasted 14 days (9 days for adaptation and 5 days for sample collection), totaling 56 days of experiment. Animals were individually placed in metal cages with slatted floor and adapted for total feces collection. They were also equipped with feed bunks and drinkers.

Table 1 - Ingredients and chemical composition of the experimental diets

Item	High moisture corn silage (%)			
	0	33	67	100
Ingredient composition (%DM)				
Oat hay	35.00	35.00	35.00	35.00
High moisture corn silage	-	16.50	33.50	50.00
Ground corn	50.00	33.50	16.50	-
Soybean meal	11.00	11.00	11.00	11.00
Limestone	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.00	1.00	1.00	1.00
Trace mineralized salt	2.00	2.00	2.00	2.00
Chemical composition				
Dry matter (%)	83.94	80.17	76.28	72.51
Crude protein (%DM)	13.16	13.20	13.25	13.29
Ether extract (%DM)	1.72	1.84	1.96	2.08
Neutral detergent fiber (%DM)	34.67	34.75	34.84	34.93
Acid detergent fiber (%DM)	17.05	16.34	15.60	14.89
Total carbohydrate[a] (%DM)	78.76	78.80	78.40	78.02
Non fibrous carbohydrate[b] (%DM)	44.51	44.04	43.56	43.09
Net energy[c] (Mcal/kg DM)	1.71	1.72	1.73	1.74
Total digestive nutrient[b] (%DM)	74.60	74.97	75.35	75.71
Calcium (%DM)	1.48	1.38	1.17	1.17
Phosphorus (%DM)	0.81	0.73	0.68	0.72

[a] Calculated based on Sniffen et al. (1992).
[b] Calculated based on NRC (2001).
[c] Calculated based on Van Soest et al. (1991).

Increasing levels of HMCS of 0, 33, 67 and 100% replacing DGC characterized the experimental treatments. Diets had a roughage:concentrate ratio of 35:65 and they were formulated to be isoproteic (13.0% CP) and isoenergetic (72% TDN) according to nutrients requirements for lactating goats (NRC, 1981) (Table 1). In order to estimate the quantity of dry matter to be offered (DMI), it was considered a goat with 40 kg of body weight, producing 3 kg/day of milk with 3.5% of fat, determined by the formula: *DMI = 0.062MBW + 0.305MP*, where MBW = metabolic body weight and MP = milk production with 3.5% fat, according to AFRC (1998).

For high moisture corn silage confection, corn grain was harvested during physiological maturity phase with moisture content around 28 to 30% (Mader & Erickson, 2006) and right after ground in order to start the ensilage process at the same experimental unit. Corn grains were harvested and mechanically ground and this material was placed in 200-L plastic buckets, manually compacted to remove the excess of air favoring the process of anaerobic fermentation. The evaluation of silage quality was done after 30 days of ensiling.

High moisture corn silage was mixed with diets previously formulated and offered *ad libitum* once a day (8:00 a.m.), adjusting the offer according to observed feed refusal (10% of the quantity offered).

To evaluate the effect of treatments, a compound sample of diets, feed refusal and feces was formed per goat in each period, sealed in plastic bags and frozen for posterior analysis. For bromatological analysis, all samples were dried at 55 °C for 48 h in an oven with air forced circulation and ground in a knife mill through a 1-mm screen and stored in plastic recipients.

For nutrient intake determination, composite samples per goat were used to determine dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF) (with heat-stable α-amylase) and acid detergent fiber (ADF), according to AOAC (1997).

Total tract apparent digestibility of diets was calculated as the proportion of consumed nutrient not recovered in feces. For its calculation, the digestibility coefficients of DM, OM, CP, EE, non-fibrous carbohydrates (NFC) and NDF were determined. The digestibility coefficients of CP, NFC, EE and NDF were used to estimate the total digestible nutrients (TDN). The net energy (NE_L) was calculated by an equation proposed by NRC (2001): $NE_L (Mcal/kg) = 0.0245 \times TDN (\%) - 0.12$, where TDN = total digestible nutrients.

Milk production control was performed during five consecutive days in each period. Goats were milked twice daily, at 7:00 a.m. and 3:00 p.m. by a portable milk machine (Westfalia RPT 200) and the daily milk production was recorded. Composite milk samples were collected in the morning and afternoon milking in two days of milk production control, stored in plastic tubes containing 2-bromo-2-nitropropane-1.3-diol and analyzed for fat (FAT), protein (PRO), lactose (LAC), total solids (TS), solids non fat (SNF) and milk urea nitrogen (MUN), by using a Bentley 2000 instrument (Bentley Instruments Inc., USA).

For the conversion of milk production to 3.5% fat-corrected milk, it was used the formula proposed by Gaines (1928): *FCM 3.5% (kg/d) = (0.4255 × kg of milk) + [16.425 × (% fat / 100) × kg of milk]*. For the correction of milk to total solids, it was used the formula proposed by Tyrrell & Reid (1965): CMTS = (12.3 × g of fat) + (6.56 × g of non fat solids) – (0.0752 × kg of milk). Feed efficiency (FE) was calculated by the relationship between milk production (MP) and dry matter intake (DMI) according to the formula: FE = MP / DMI.

Experimental data was submitted to variance analysis and regression which included linear and quadratic effects. The criteria used for choosing the equations were: biological behaviour, coefficient of determination (r^2) and the probability of significance, for the regression parameters obtained by the "t" test, for the level of 5% of probability. Statistical analyses were performed by the PROC GLM and PROC REG procedures of the SAS (2001).

Results and Discussion

It was not observed linear nor quadratic effects in intake of DM (kg/d and %BW), CP, NFC and TDN (Table 2).

Regardless of the treatment, average dry matter intake was 1.64 kg/d, which is lower from what is expected for dairy goats in lactation. On the other hand, average dry matter intake in relation to body weight (3.87%) was within the range recommended by AFRC (1998), NRC (1981) and indicated by Wilkinson & Stark (1987), who cited that dry matter intake of goats is usually around 3 and 5 % of body weight. In Alpine goats fed different levels of NDF and CP, Carvalho et al. (2006) and Fonseca et al. (2006) observed dry matter intakes of 4.60 and 4.21% of body weight, respectively, values higher than those found in this experiment. This indicated a wide variation of dry matter intake when compared to dairy cows. Literature on HMCS utilization in diets for goat is scarce, which is not observed for dairy cows. Wilkerson et al. (1997), Knowlton et al. (1998), San Emeterio et al. (2000) and Alvarez et al. (2001) compared HMCS and DGC in

Table 2 - Intake and apparent digestibility of nutrients of Alpine goats at four levels of dry-ground corn replaced by high moisture corn silage

Variable	High moisture corn silage (%)				Estimated equation	r^2	SEM
	0	33	67	100			
Intake							
Dry matter (kg/d)	1.62	1.67	1.63	1.57	Y = 1.62	—	0.04
Dry matter (%BW)	3.87	3.94	3.92	3.75	Y = 3.87	—	0.09
Crude protein (kg/d)	0.22	0.23	0.22	0.21	Y = 0.22	—	0.01
Neutral detergent fiber (%DM)	0.51	0.54	0.54	0.53	$Y = 0.51 + 0.00105X - 0.00000886X^2$*	0.99	0.01
Non fiber carbohydrate (kg/d)	0.79	0.80	0.75	0.72	Y = 0.76	—	0.02
TDN (kg/d)	1.27	1.34	1.30	1.27	Y = 1.29	—	0.04
Net energy (Mcal/d)	2.77	2.87	2.82	2.73	Y = 2.65	0,95	0.04
Total tract apparent digestibility (%)							
Dry matter	70.6	72.8	74.3	75.5	$Y = 70.6 + 0.07196X - 0.00023332X^2$*	0.99	0.86
Crude protein	72.5	74.3	74.2	76.3	Y = 74.32	—	0.80
Neutral detergent fiber	44.5	46.5	51.4	51.2	Y = 48.40	—	1.79
Non-fibrous carbohydrates	99.7	93.5	94.6	96.9	Y = 91 + 0.05925X*	0.98	0.71

r^2 = Coefficient of determination; SEM = Standard error of the mean; * P<0.05; ** P<0.01.

the nutrition of lactating cows and did not observe differences in dry matter intake.

Dry matter intake is regulated by physiological and physical mechanisms. In physiological regulation, when the animals are fed diets high in energy and low in fiber, they eat to maintain constant ingestion of energy and dry matter intake could be decreased. In physical regulation, when there are great quantities of fiber in diets, intake is limited by low degradation and reduced passage rate of fiber, promoting repletion of the rumen-reticulum compartment (Mertens, 1996). Thus, the observed values in this experiment suggested that DM intake was similar in different treatments possible due to high ratio of concentrate:forage of experimental diets, which is physiologically regulated.

It was observed a quadratic effect (P<0.05) of HMCS levels in NDF intake. The highest values were observed at the levels 33 and 67% and the lowest at 0 and 100% where the inflexion point was in the regression equation of 59.25% of HMCS. The highest values observed in the intermediary diets were probably related to the highest DM intake in these diets and also to greater selection in diets with 0 and 100% of HMCS.

The average NDF intake of 0.53 kg/d is below from what was observed by Carvalho et al. (2006), who verified values of 0.624 to 1.102 kg/d in studies with dairy goats fed different levels of NDF from roughage. These values could be considered low, by decreasing the effective fiber which aims to maintain the fat percentage in milk. There is no information of optimum levels of fiber recommended for goats and it is possible that it is different from what is suggested for dairy cows. Similarly, in a study with dairy cows fed different forms of high moisture corn (shelled or ear) and dry grain (finely or coarsely ground) once a day, San Emeterio et al. (2000) noticed that there was no difference in NDF intake.

It was not observed linear and quadratic effect (P>0.05) in the different treatments for NE intake (Table 2). These values are below from what is recommended by NRC (1981) for dairy goats, which can impair milk production.

It was not observed linear and quadratic effect (P>0.05) for the levels of HMCS inclusion for total tract apparent digestibility of CP and FDN (Table 2). Possibly, the low synchronization of CP with the available energy in the rumen and the low effective fiber for milk production can lead to the loss of these nutrients in feces, affecting their digestibility.

Nutrient digestibility of a diet indicates the characteristic of the feed to be utilized by the animal. The apparent digestibility of DM linearly increased (P<0.01) with the increasing levels of HMCS (Table 2). This greater DM digestibility could be explained by the increased availability of starch of high rumen degradability in HMCS, where disruption of the membrane and structure of granules, as well as solubilization of the protein matrix occur. Several authors reported higher DM digestibility in diets with HMCS compared with DGC (Wilkerson et al., 1997; Knowlton et al., 1998 and Krause et al., 2002). However, San Emeterio et al. (2000) did not observe difference in apparent digestibility of DM among diets with HMCS and DGC for dairy cows.

There was a significant (*P*<0.01) linear effect of HMCS levels for total tract apparent digestibility of NFC (Table 2). This observation may indicate that there was a greater absorption of NFC by HMCS than DGC in the digestive tract. Non fibrous carbohydrates are represented by A fraction composed by sugars and organic acids of fast degradation and B fraction composed by starch, pectin and glucan of intermediary degradation (Sniffen et al., 1992). Corn grain processing increases starch digestibility by the reduction of grain particle in the ensilage process. An increase in starch digestibility can be reflected in an increment of milk production, microbial protein in rumen and improvement in the nitrogen utilization by the animal (Jobim et al., 2003). Rumen fermentation is also favoured by the high availability of starch which increases ammonia utilization and provides more energy to the animal. Therefore, Wilkerson et al. (1997) and San Emeterio et al. (2000) also reported greater digestibility of NFC in diets with HMCS compared with DGC for dairy cows.

It was not observed linear or quadratic effects (P>0.05) of HMCS levels for milk production (Table 3). The average value of 1.86 kg/d is low for this breed. This drop in milk production may be a consequence of low NE intake for milk production.

The literature on HMCS utilization in nutrition for dairy goat is scarce, which is not observed for dairy cattle. Thus, in a study with dairy cows, Knowlton et al. (1998) and Alvarez et al. (2001) reported that milk production was not influenced by HMCS inclusion in diets when compared with DGC. However, Wu et al. (2001) obtained opposite results when HMCS inclusion was compared with DGC in diets for dairy cows and observed 2.4 kg/d more milk in animals fed diets with HMCS. San Emeterio et al. (2000) compared different types of corn processing (HMCS and DGC) and particle size (fine or coarse) in diets for dairy cows and did not observe difference on milk production in animals fed once daily whereas when they were fed twice daily, milk production was higher in animals fed diets with HMCS.

Similar to cow milk, the composition of goat milk varies due to several factors such as breed, age, stage of lactation and nutrition. However, there were no linear or quadratic effects (P>0.05) of HMCS levels for milk production, feed efficiency (milk production/DM intake), 3.5% fat-corrected milk production, fat, protein, lactose and total solids (TS). Soriano et al. (2000) and Alvarez et al. (2001) evaluated the performance of Holstein cows supplemented with HMCS and DGC and did not observe differences in the percentages of fat, protein and lactose.

There were no linear or quadratic effects (P>0.05) of HMCS levels for milk urea nitrogen (MUN) (mg/dl) (Table 3). A wide range of MUN values from 9.7 to 35.4 mg/dl was reported by Todaro et al. (2005) and from 12.1 to 22.5 mg/dl by Cabiddu et al. (1999) for dairy goats in herbaceous pasture where the average found in the present study is within these parameters. According to Rajala-Schultz et al. (2001), greater concentrations of MUN may be related to the fact that the available energy was not used for milk production, but probably for microbial protein synthesis by ruminal bacteria in function of ammonia excess in the rumen. According to Hof et al. (1997) and Rios et al. (2001), the values of MUN may be used as a tool to monitor protein feed efficiency and the ratio of protein to energy in dairy cows diets. Because there is a linear relationship between CP content in the diet and MUN concentration allowing its use to estimate the CP present in the diet, it can be used as a tool for nutrition strategies (Bonanno et al., 2008). San Emeterio et al. (2000) did not observe influence of HMCS inclusion in dairy cows diets in MUN concentration.

Table 3 - Effect of high moisture corn silage levels on milk production and milk components of dairy goats

Variable	High moisture corn silage (%)				Estimated equation	r^2	SEM
	0	33	67	100			
Milk production (kg/day)	1.86	1.85	1.90	1.81	Y = 1.86	—	0.04
Milk production/Dry matter intake (kg/day)	1.13	1.09	1.15	1.11	Y = 1.12	—	0.03
Milk correction to fat 3.5% (kg/day)	1.68	1.68	1.73	1.67	Y = 1.69	—	0.04
Fat (%)	2.87	2.97	2.96	3.02	Y = 2.95	—	0.03
Protein (%)	2.83	2.86	2.86	2.85	Y = 2.85	--	0.02
Lactose (%)	4.35	4.34	4.35	4.40	Y = 4.36	—	0.02
Solids non fat (%)	7.95	7.99	8.00	8.03	Y = 7.95 + 0.00072634x*	0.92	0.02
Total solids (%)	10.8	11.0	10.9	11.1	Y = 10.96	—	0.09
Milk urea nitrogen (mg/dl)	16.2	16.9	16.8	18.3	Y = 17.06	—	0.51

r^2 = coefficient of determination; SEM = standard error of the mean; * P<0.05, ** P<0.01.

The percentage of solids non fat (SNF) linearly increased (P<0.05) with the increasing levels of HMCS (Table 3), probably due to a higher contribution of net energy of HMCS in the percentages of protein and lactose of milk. Soriano et al. (2000) and Alvarez et al. (2001) observed opposite results from the present study in diets for dairy cows.

Conclusions

High moisture corn silage can be used in substitution of dry-ground corn in diets for dairy goats. High moisture corn silage can be used in formulation of diets of goats a because it improves dry matter digestibility.

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