DOI: 10.5433/1679-0359.2024v45n3p945

Potential use of pineapple crop residue silage to replace sorghum silage for crossbred lactating cows

Potencial uso de silagem de resíduos culturais de abacaxi em substituição à silagem de sorgo para vacas mestiças em lactação

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Highlights

The pineapple silage inclusion did not affect dry matter intake.
The pineapple silage inclusion prompted a linear increase in the protein intake.
The pineapple silage inclusion prompted a linear increase in the intake of fat.
The pineapple silage inclusion had a positive effect on milk yield.
Pineapple silage can replace sorghum silage in diets for lactating crossbred cows.

Abstract

The use of crop residue silages is a viable alternative for producers to reduce feed costs. The present study was developed with the objective of investigating the inclusion of pineapple silage in replacement of sorghum silage in the diet of lactating cows regarding feed intake, production, and quality of milk. Eight crossbred (Holstein × Gir) cows with an average weight of 555±30 kg and an average milk yield of 12.50±3.25 kg/day, between 60 and 90 days in milk, were distributed into two simultaneous 4 × 4 Latin squares, at one animal per experimental unit. Silage of pineapple crop residue (PS) using plants

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Received: Feb. 19, 2024 Approved: June 03, 2024

after the harvest of the fruits was included in the roughage portion of the diet at increasing levels, with simultaneous and proportional removal of sorghum silage (SS) from the diets. The studied treatments thus consisted of the roughage portion containing: 1- 0% PS and 100% SS (100SS); 2- 34% PS and 66% SS (34PS66SS); 3- 67% PS and 33% SS (67PS33SS); 4- 100% PS and 0% SS (100PS). The diets were supplied twice daily, allowing 5% leftovers in relation to the quantity offered. The amounts of feed supplied, and orts of each animal were weighed for a subsequent determination of intake. The experiment was divided into four 21-day sub-periods, the first 14 days of which were used as an adaptation to the diet, while the others served for data collection. The milk was weighed from the 15th to the 19th day of each experimental period, and milk samples were collected on the last day of each period. Milk samples were sent to the laboratory, where they were analyzed. Dry matter, mineral matter, and lignin concentrations in the diet did not vary (P>0.05) as a function of PS inclusion in the roughage portion, while protein content, fiber content, and fat content levels were influenced. No effect of PS inclusion was observed (P>0.05) on the intakes of dry matter, neutral detergent fiber, mineral material, or lignin. However, PS inclusion prompted (P<0.05) a linear increase in the intakes of protein and total fat. The inclusion of pineapple plant silage in the roughage part of the diet had a positive effect (P<0.05) on milk yield, 4% fat-corrected milk yield, and on the milk fat and total solids contents. Milk production, as well as fat and total solids content, increased moderately with inclusion of pineapple plant silages in the roughage portion of the diet. Therefore, pineapple silage can replace sorghum silage in the roughage part of diets for lactating crossbred cows.
Key words: By-products. Milk quality. Milk yield. Pineapple silage. Ruminants.

Resumo

A utilização de silagens de resíduos culturais é uma alternativa viável para os produtores reduzirem custos com alimentação. O presente estudo foi desenvolvido com o objetivo de investigar a inclusão da silagem de abacaxi em substituição à silagem de sorgo na dieta de vacas lactantes quanto ao consumo de ração, produção e qualidade do leite. Oito vacas mestiças (Holstein × Gir), com peso médio de 555±30 kg e produção média de leite de 12,50±3,25 kg/dia, entre 60 e 90 dias de lactação, foram distribuídas em dois quadrados latinos 4 × 4 simultâneos, em um animal por unidade experimental. A silagem de resíduo da cultura do abacaxi (PS) utilizando plantas após a colheita dos frutos foi incluída na porção de volumoso da dieta em níveis crescentes, com retirada simultânea e proporcional da silagem de sorgo (SS) das dietas. Os tratamentos estudados consistiram, portanto, na porção de volumoso contendo: 1- 0% PS e 100% SS (100SS); 2- 34% PS e 66% SS (34PS66SS); 3- 67% PS e 33% SS (67PS33SS); 4- 100% PS e 0% SS (100PS). As dietas foram fornecidas duas vezes ao dia, permitindo sobras de 5% em relação à quantidade oferecida. As quantidades de ração fornecida e sobras de cada animal foram pesadas para posterior determinação do consumo. O experimento foi dividido em quatro subperíodos de 21 dias, sendo os primeiros 14 dias utilizados como adaptação à dieta, enquanto os demais serviram para coleta de dados. O leite foi pesado do 15º ao 19º dia de cada período experimental, e as amostras de leite foram coletadas no último dia de coleta de cada período. As amostras de leite foram enviadas ao laboratório, onde foram analisadas. As concentrações de matéria seca, matéria mineral e lignina na dieta não variaram (P>0,05) em função da inclusão de PS na porção de volumoso, enquanto os teores de proteína, teor de fibra e teor de gordura foram influenciados. Não foi observado efeito da inclusão de PS (P>0,05) nos consumos de matéria seca, fibra em detergente neutro, material mineral ou lignina. No entanto, a inclusão de PS provocou (P<0,05) um aumento linear na ingestão de proteínas e gorduras totais. A inclusão de silagem de abacaxi na parte volumosa da dieta teve efeito positivo (P<0,05) na produção de leite, na produção de leite corrigida em 4% para gordura e nos teores de gordura e sólidos totais do leite. A produção de leite, bem como o teor de gordura e sólidos totais aumentaram moderadamente com a inclusão de silagens de abacaxi na porção de volumoso da dieta. Portanto, a silagem de abacaxi pode substituir a silagem de sorgo na parte de volumoso das dietas de vacas mestiças em lactação.

Palavras-chave: Subprodutos. Qualidade do leite. Produção de leite. Silagem de abacaxi. Ruminantes.

Introduction

Brazil occupies a prominent position in pineapple growing as the third largest world producer, with almost 1.5 billion fruits harvested from approximately 64,147 ha of cultivated area (Instituto Brasileira de Geografia e Estatística [IBGE], 2022). The industrialization of tropical fruit farming has provided enormous surpluses of by-products, which in the natural or processed form could contribute a significant portion to ruminant nutrition (Cunha et al., 2009; S. C. Santos et al., 2014). After harvesting the fruit, there is a large amount of crop residue, with the potential to increase animal production, which often, due to lack of information, ends up being unused and wasted (Lallo et al., 2003; Buliah et al., 2019).

One of the main components of the ruminant diet is roughage, with variable chemical composition and nutritional values, depending on several factors such as type, species and variety of forage plants, types of processing and storage, as well as climate, maturity, among others (S. C. Santos et al., 2014). Despite the great use of corn, it is a silage that has a high production cost in periods of scarcity, obtaining an alternative food for the animals becomes of great importance for the intensive farming system, reducing feed costs. Current studies and work on the use of pineapple crop residues have shown very promising results with the use of silage as a form of forage storage and with good results from its use in feeding ruminants (Fagundes & Fagundes, 2010; Lallo et al., 2003; Prado et al., 2003; S. C. Santos et al., 2014), as well to minimize environmental contamination with the large amount of vegetable waste produced (M. Santos, 2010).

In addition to constituting an option to reduce feed costs, the use of agro-industrial wastes in animal feeding contributes to lessening the environmental impact caused by other production activities. These products possess nutritional properties that enable their use as raw materials in animal feeding. However, for its use to be possible, producers must know specific characteristics such as its chemical composition, factors that limit consumption, cost, local or regional availability and the limit of replacement, of traditional roughage with pineapple crop residue silage, without causing harm to the performance of the animals.

The hypothesis of this study is that pineapple crop residue silage will have the potential to replace traditional silage partially or completely without compromising consumption and, consequently, animal performance. Given the current scenario, the present study was developed with the objective of investigating the inclusion of pineapple silage in replacement of sorghum silage in the diet of lactating cows regarding consumption, production, and quality of milk.

Material and Methods

Animals and treatments

The experiment was conducted in an Experimental Farm from partners UFSJ/EPAMIG in São João del Rei, Minas Gerais, Brazil (21º 08′ 08″ S latitude and – 44º 15′ 42″ W longitude). Eight crossbred (Holstein × Gir) cows with an average weight of 555±30 kg and an average milk yield of 12.50±3.25 kg/day, between 60 and 90 days in milk, were housed in concrete stalls, partially covered with clay tiles, with size 2 per 6 meters, with individual trough feeders and drinkers and during the entire experimental period.

Cows were distributed into two simultaneous 4 × 4 Latin squares, at one animal per experimental unit. The experiment lasted 84 days, which were divided into four 21-day sub-periods, the first 14 days of which were used as an adaptation to the diet, while the others served for data collection.

Silage of pineapple crop residue (PS) using plants after the harvest of the fruits was included in the roughage portion of the diet at increasing levels, with a simultaneous and proportional removal of sorghum silage (SS) from the diets. The studied treatments thus consisted of the roughage portion containing: 1- 0% PS and 100% SS (100SS); 2- 34% PS and 66 SS (34PS66SS); 3- 67% PS and 33% SS (67PS33SS); 4- 100% PS and 0% SS (100PS). The control diet (100SS) was formulated based on the nutritional requirements of the animals, as recommended by the Research Council - National Academies of Sciences, Engineering, and Medicine [NASEM] (2021). The diets were supplied twice daily, allowing 5% leftovers in relation to the quantity offered. The amounts of feed supplied, and orts of each animal were weighed for a subsequent determination of intake.

Pineapple crop residues (plants) were purchased in the municipality of Frutal-MG and transported to the Federal University of São João Del Rei. The silages were produced according to conventional EPAMIG procedures, described below. The material for silage was harvested at the ideal point of maturation, where the dry matter (DM) content is around 35%. After harvesting, the forage was crushed into particles of adequate size to facilitate compaction and fermentation. The crushed particles were compacted in a trench-type silo and sealed with plastic canvas. The silos with pineapple harvest residue silage and sorghum silage were opened after 38 days to be used in the study. The silos were sized so that the slice of silage removed per day was at least 30 cm, which helps prevent silage oxidation.

Weighing, sample collection

Samples of the tested feedstuffs were weighed and dried in a forced-air oven at 55ºC for 72 h. Then, the material was weighed again to obtain the partial DM. Feedstuffs were ground in Wiley mills to pass through a 1-mm round-curved sieve (Theodorou et al., 1994). DM, method 967.03 (Association of Official Analytical Chemists [AOAC], 1990), crude protein, method 2001.11 (Thiex et al., 2002), total fat, method 2,003.06 (Thiex et al., 2003), and ash, method 942.05 (AOAC, 1990) were determined by following specific recommended methods. Neutral detergent fiber (NDF) was evaluated as proposed by the protocol suggested by Mertens (2002).

The cows were milked by mechanical milking, twice a day, the first milking started at 6:30 am and the second milking at 2:30 pm. The milk was weighed from the 15th to the 19th day of each experimental period, and milk samples were collected harvested on the last collection day of each period. Morning samples were refrigerated, and at the end of the day, the morning and afternoon samples were homogenized and immediately stored in a container with preservative (Bronopol®) at the rate of 2/3 of morning milking and 1/3 of the afternoon milking. The samples were weighed manually using a unique, duly calibrated piece of equipment and always by the same person. Immediately after collection, the milk samples were sent to the Clínica do Leite laboratory in Piracicaba -SP, where they were analyzed for their total fat (TF), protein, lactose, total solids (TS), solids-not-fat (SNF), urea nitrogen contents and somatic cell count (SCC).

Milk yield was corrected for 4% fat using the following formula described in National Research Council [NRC] (1998):

4%FCMY = 0.4 (milk (kg)) + 15 (milk fat (kg)) Eq. (1)

Statistics

For the variables DM, MM, TF, CP, NDF, lignin, fat content, protein content, lactose content, TS, SNF, SCC, and urea nitrogen, an a priori BOX-COX transformation was applied (BOX; COX, 1964). Logarithmic transformation was applied for the variables that showed a lambda value equal to zero, considering log Y ~ Normal (μ, σ_l^2). For the other variables, the following assumption was used: Y ~ Normal (μ,σ^2).

For the data analysis, the model suggested by Tempelman (2004) was employed, as shown below:

$$Y_{ikl} = \mu + \alpha_i + c_k + \beta_l + \alpha_{\beta il} + e_{ikl} \qquad \text{Eq. (2)},$$

in which Y_{ikl} is the value observed in the variable measured in cow k fed treatment i during period l. Fixed effects are the mean (μ), the treatments (α_i), and the interaction between treatment and period ($\alpha_{\beta il}$). Random effects were the cow (c_k) and the error (e_{ikl}), considering the measures as repeated over time.

The variance-covariance matrix was adjusted with the following structures: variance component, composite variance, and first-order autoregressive correlation (Littell et al., 2006). For the fitting of variance structures and of the best model, the maximum likelihood (ML) method was used, while Akaike's criterion was employed for the choice of the best model (Akaike, 1974; Sugiura, 1978). After defining the best fit, the restricted maximum likelihood (REML) method was adopted to estimate the model parameters using the MIXED procedure of SAS software.

For the transformed variables that showed no treatment effect, the overall mean was estimated adopting the following equation:

$$Y = \exp(\theta_0 + \sigma_l^2/2) \qquad \text{Eq. (3)}$$

The equation below was used for the variables that showed a linear effect of treatment:

$$Y = \exp(\theta_0 + \theta_1 x + \sigma_l^2/2) \qquad \text{Eq. (4),}$$

in which θ_0 is the intercept; θ_1 is the angular coefficient; and σ_l^2 is the residual variance on the logarithmic scale.

Results and Discussion

Dry matter, mineral matter, and lignin concentrations in the diet did not vary (P>0.05) as a function of PS inclusion in the roughage portion, while protein content, fiber content, and fat content levels were influenced (P<0.05). Regression simulation revealed a trend of linear effect for these last three variables (Table 1).

Table 1
Chemical composition of silages and effect of pineapple plant silage inclusion in the roughage portion on the chemical composition of the diets

Silages	DM	MM	CP	TF	FDN	Lignin	CNF
Sorghum	288.6	12.4	59.7	18.7	475.7	38.6	433.6
Pineapple	271.3	17.3	101.8	26.5	390.4	38.9	464.0
Unaffected variables	Mean		Lower limit		Upper limit		
DM (g/kg)	283.39		267.05		300.73		
MM (g/kg)	14.82		12.94		16.99		
Lignin (g/kg)	38.79		33.95		44.32		
Affected variables	Regression equation						
CP	$CP_{g/kg}$ = exp(4.0356 + 0.0053X + (0.0616/2))						
NDF	$NDF_{g/kg}$ = exp(6.1526 - 0.0019X + (0.0144/2))						
TF	$TF_{g/kg}$ = exp(2.9360 + 0.0035X + (0.0180/2))						

DM - dry matter; MM - mineral matter; CP - crude protein; TF - total fat; NDF - neutral detergent fiber.

To evaluate these variables linked to intake and animal performance, some adjustments were made using statistical tools (Table 2). The study of the different variance-covariance structures revealed alternation between the variance component (VC) and autoregressive (ar(1)) structures. The investigation of the best variance-covariance structures based on the calculation of corrected Akaike criterion showed that the errors are correlated, in some cases.

Table 2
Probability values and variance-covariance (v-c) matrix of the measured variables

Variable	P-value			v-c matrix
	Treatment	Period	Treatment × Period	
Milk yield[1]	0.010	<0.001	0.102	VC
4%FCMY[1]	0.001	<0.001	0.148	CS
Fat content[1]	0.021	0.438	0.176	CS
Protein content[1]	0.626	0.375	0.914	CS
Lactose content[1]	0.926	0.004	0.915	CS
Total solids[1]	0.025	0.330	0.317	CS
Solids-not-fat[1]	0.847	0.586	0.925	CS
SCC	1.000	<0.001	<0.001	UN
Urea nitrogen	0.165	0.052	0.067	VC
DM intake	0.178	0.044	0.595	CS
MM intake	0.023	0.013	0.113	VC
CF intake	<0.001	0.145	0.148	VC
CP intake	<0.001	0.266	0.032	VC
NDF intake	<0.001	<0.001	0.093	VC
Lignin intake	0.058	0.074	0.279	ar(1)

4%FCMY - 4% fat-corrected milk yield; SCC - somatic cell count; DM - dry matter; MM - mineral matter; CF - crude fat; CP - crude protein; NDF - neutral detergent fiber. 1 in g kg^{-1}.
VC - variance component, CS - compound symmetry; UN - unstructured; ar(1) - first-order autoregressive.1 in g kg^{-1}.

No effect of PS inclusion was observed (P>0.05) on the intakes of DM, NDF, MM, or lignin, therefore, we chose to describe the respective mean values to represent the values observed in them, irrespective of the treatment. However, PS inclusion prompted (P<0.05) a linear increase in the intakes of protein and total fat (Table 3). The higher feed intake of CP and TF is probably due to the higher concentration of these nutrients in pineapple silage.

Table 3
Effect of pineapple plant silage inclusion in the roughage portion on nutrient intake

Unaffected variables	Mean	Lower limit	Upper limit
DM intake (kg cow^{-1} day^{-1})	12.45	10.79	14.10
NDF intake (kg cow^{-1} day^{-1})	5.40	4.67	6.13
MM intake (kg cow^{-1} day^{-1})	0.18	0.14	0.23
Lignin intake (kg cow^{-1} day^{-1})	0.48	0.39	057
Affected variables	Regression equation		
CP intake (kg cow^{-1} day^{-1})	CP = 0.7020+0.0052X		
TF intake (kg cow^{-1} day^{-1})	TF = 0.2337+0.0011X		

DM - dry matter; NDF - neutral detergent fiber; MM - mineral matter; CP - crude protein; TF - total fat.

As the pineapple production chain can result in different types of waste, they are generally not nutritionally similar, as they are made up of different tissues and do not have the same chemical composition. Pineapple industrial waste silage can be considered a bulky food with considerable protein content; however, this content varies depending on the material collected and the period of use (Fagundes & Fagundes, 2010; Prado et al., 2003; S. C. Santos et al., 2014).

Prado et al. (2003) did not observe significant effects on the intakes of DM or CP after replacing corn with silage of pineapple industrial waste. However, there is a clear difference in the respective chemical and tissue compositions between the industrial waste from the processing of pineapple fruit and pineapple crop residue post fruits harvest.

Inclusion of pineapple plant silage in the roughage part of the diet had a positive effect ($P<0.05$) on milk yield, 4% fat-corrected milk yield, and on the milk fat and total solids contents. The simulation of regression equations revealed a trend of quadratic effect for milk yield and a trend of linear effect for all the other abovementioned variables (Table 4). The maximum point for milk yield was estimated as 16.2 kg/day at the replacement level of 69.4%. However, the variables protein, lactose, SNF, urea nitrogen, and SCC in milk were not influenced by the inclusion of pineapple plant silage in the diet. Thus, we chose to describe the respective mean values to represent the values observed in them, irrespective of the treatment (Table 4).

Table 4
Effect of pineapple plant silage inclusion in the roughage portion of the diet on milk yield and composition

Unaffected variables	Mean	Lower limit	Upper limit
Protein (g/kg)	31.66	28.56	35.10
Lactose (g/kg)	45.30	42.44	48.36
SNF (g/kg)	86.14	81.66	90.85
Urea nitrogen (mg/dL)	17.17	15.08	19.55
SCC (× 1,000/mL)	95.44	32.54	279.93
Affected variables	**Regression equation**		
Milk yield	$MY_{kg\ cow-1\ day-1} = 12.0989+0.118X+ 0.0009X^2$		
Corrected milk yield	$4\%FCMY_{kg\ cow-1\ day-1} = 11.3079+0.0227X$		
Fat content	$F_{g\ kg-1} = \exp(3.3233 - 0.002X + (0.0284/2))$		
Total solids content	$TS_{g\ kg-1} = \exp(4.7363-0.0004X + (0.0016/2))$		

SNF - solids-not-fat; SCC - somatic cell count.

The higher milk yield of cows that received diets with greater concentrations of pineapple plant silage can be explained in part by their higher daily intakes of protein and total fat. However, this yield increase was moderate.

Some authors have shown that the use of pineapple industrial waste silage as an alternative feed in the finishing of beef cattle with replacement levels of 20 to 60% of corn silage is favorable without altering animal performance, feed conversion and yield of carcass (Lallo et al., 2003; Prado et al., 2003). Other authors recommend that this replacement of roughage with ensiled pineapple residues occurs at levels between 25 and 50% (Kyawt et al., 2020; Sruamsiri, 2007).

Suksathit et al. (2011) evaluated the effect of levels of pineapple residue (silage) and Pangola hay, 100% pineapple residue; 65% pineapple residue and 35% Pangola hay; 35% pineapple residue and 65% Pangola hay, as roughage sources for cattle native to Southern Thailand. They observed that with the increased inclusion of pineapple residue silage in the diets, there was an improvement in the digestibility of nutrients, without having a harmful effect on the ruminal microbiota, concluding that pineapple residue silage is viable as an alternative source of roughage for southern Thailand for native cattle compared to Pangola hay.

S. C. Santos et al. (2014) worked on replacing sugarcane silage with silage from pineapple crop residues in sheep feeding with five treatments, 100% pineapple silage; 75% pineapple silage and 25% sugar cane silage; 50% pineapple silage and 50% sugar cane silage; 25% pineapple silage and 75% sugar cane silage and 100% sugar cane silage, with roughage and concentrate ratios of 60 and 40. It concluded that, depending on the rate of DM disappearance from the rumen, digestibility and DM feed intake, replacing sugar cane silage + 0.5% urea with pineapple crop residue silage is possible in sheep feeding.

The lack of negative effects on most variables related to nutritional composition, nutrient intake, as well as milk yield and composition indicate that inclusion of pineapple plant silage in the roughage portion of the diet is a viable strategy. Moreover, its use allows for a rational destination of an environmental liability with a high carbon:nitrogen ratio, which slows its degradation in the environment.

Conclusions

Milk production, as well as fat and total solids content, increased moderately with inclusion of pineapple plant silages in the roughage portion of the diet. Therefore, pineapple silage can replace sorghum silage in the roughage part of diets for lactating crossbred cows.

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