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Effects of banana residue hay on performance and ingestive behavior of sheep

[*Efeito do feno de resíduos da bananicultura no desempenho e comportamento ingestivo de ovinos*]

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ABSTRACT

The objective of this study was to evaluate the effects of including banana leaf and pseudostem hay, subjected to different drying methods, on the performance and ingestive behavior of sheep. Twenty Santa Inês x Dorper lambs were used and distributed into five diets: Tifton 85 grass hay, shade-dried banana leaf hay, shade-dried pseudostem banana hay, sun-dried banana leaf hay and sun-dried banana pseudostem hay. The inclusion of banana residues reduced the dry matter intake, with the lowest intake observed in animals fed shade-dried leaf hay (67.3g/kg $LW^{0.75}$/day). Despite the lower dry matter intake (82.9g/kg $LW^{0.75}$/day), animals fed pseudostem hay had similar weight gain to those on Tifton 85 grass hay (122.8g/day). The leaf hay resulted in longer chewing time (881.4min/day), rumination time (591.4min/day) and ruminal bolus chews (60.5/bolus), likely due to its higher lignin content. Leaf hay reduces animal performance and is not recommended for sheep confinement, whereas pseudostem hay promotes similar performance to Tifton hay is a viable alternative roughage. Sun drying improved ingestive behavior and offered processing advantages.

Keywords: by-product, lambs, banana leaf, pseudostem, ruminant

RESUMO

Objetivou-se avaliar a inclusão de fenos de resíduos da bananicultura, submetidos a diferentes métodos de secagem, no desempenho e no comportamento ingestivo de ovinos. Utilizaram-se 20 cordeiros Santa Inês x Dorper, distribuídos em cinco tratamentos: feno de Tifton 85, feno de folha de bananeira seco à sombra ou seco ao sol, feno de pseudocaule de bananeira seco à sombra ou seco ao sol. A inclusão de resíduos de banana reduziu o consumo de matéria seca, os animais alimentados com feno de folhas seco à sombra apresentaram menor consumo (67,3g/kg $PV^{0,75}$/dia). Apesar do consumo inferior (82,9g/kg $PV^{0,75}$/dia), os animais alimentados com feno de pseudocaule apresentaram ganho de peso semelhante aos alimentados com Tifton (122,8 g/dia). O feno de folhas resultou em maiores tempos de mastigação (881,4 min/dia), ruminação (591,4 min/dia) e mastigações ruminais por bolo (60,5), o que pode estar relacionado ao teor de lignina. O feno de folhas reduz o desempenho animal e não é recomendado para uso em ovinos confinados, enquanto o feno de pseudocaule promove desempenho semelhante ao Tifton e representa uma alternativa viável de volumoso. A secagem ao sol melhorou o comportamento ingestivo, além das suas vantagens de processamento.

Palavras-chave: coproduto, cordeiros, folha de bananeira, pseudocaule, ruminante

INTRODUCTION

The success of animal productivity depends on factors such as breed, management practices and nutrition. In lamb production, feed costs can represent up to 70% of production expenses (Romão *et al.*, 2017). Therefore, there is a need for alternative feed sources to replace conventional ingredients, including agricultural and agro-industrial by-products, such as banana farming residues (Almeida *et al*., 2019).

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Banana production plays a significant role in the global agribusiness market, accounting for 18% of total fruit production worldwide (World…, 2022). Banana farming generates substantial waste, which is typically unusable for producers but could be incorporated into animal diets (Acevedo *et al*., 2021; Rusdy, 2019). According to Acevedo *et al*. (2021), approximately 114.08 million metric tonnes of banana waste are produced worldwide, contributing to environmental problems.

If properly processed and stored, banana farming residues can provide valuable nutrients. Banana pseudostem hay can offer up to 90.5% dry matter (DM), 3.4% crude protein (CP), and 49.9% neutral detergent fiber (NDF), while banana leaf hay can reach 93% DM, 6.2% CP, and 59.9% NDF (Gerassev *et al.*, 2013: Carmo *et al*., 2018).

The use of banana farming residues in animal diets is primarily achieved through hay production, where the drying method plays a critical role in determining the quality of the resulting feed (Taffarel *et al*., 2014). Shade drying, a slow process that requires frequent turning and a thin layer of material, helps minimise nutrient loss but can reduce soluble carbohydrates, proteins, and lipids. In contrast, sun drying accelerates the dehydration process; however, excessive heat can cause the oxidation of non-structural carbohydrates, increase fibrous components, and degrade proteins (Taffarel *et al*., 2017).

There is limited research on drying methods for hay production from agricultural by-products, such as banana farming waste. The processing method used to produce hay can affect nutrient composition and availability, thereby impacting animal performance. Therefore, the aim of this study was to evaluate the intake, ingestive behavior, and performance of sheep fed diets containing banana leaf and pseudostem hay obtained from different drying methods.

MATERIAL AND METHODS

This research was conducted at the Sheep Farming sector of the Institute of Agricultural Sciences of the Federal University of Minas Gerais, in Montes Claros, Brazil. The study was approved by the Ethics Committee on Animal Experimentation of Federal University of Minas Gerais under protocol number 270/2016.

Twenty Santa Inês x Dorper sheep, consisting of 10 males and 10 females, with an average weight of 18±0.8kg and approximately four months of age were used. The animals were dewormed, vaccinated against clostridiosis, weighed, and identified. They were randomly assigned to two blocks based on sex, and five treatments with four repetitions each. The treatments included the following: Tifton 85 hay (TFH), sun-dried banana leaf hay (LH Sun); shade-dried banana leaf hay (LH Shade); sun-dried banana pseudostem hay (PH Sun) and shade-dried banana pseudostem hay (PH Shade).

The Tifton 85 (*Cynodon* spp.) hay was purchased from the local market, while the banana leaves and pseudostems were sourced from a farm near Montes Claros. For hay production, the pseudostem were cut into blocks and processed in a disintegrator. The leaves were separated and processed in a disintegrator. After chopping, the leaves and pseudostems were individually homogenized, spread in 10cm layers, and dried either in the sun or in the shade. Shade drying was conducted in a well-ventilated shed, free from direct sunlight. During the dehydration process, the materials were turned over three times per day.

Banana leaves dehydrated in the sun reached the desired dry matter content (85-90%) in approximately 72 hours, while shade-dried leaves took around 120 hours to reach the same dry matter level. Pseudostems dried in the sun reached the ideal dry matter content after approximately 120 hours, whereas those dried in the shade took around 168 hours. At the end of the dehydration process, bromatological analyses of the hays were performed (Table 1).

The experiment lasted for 70 days, with the initial 14 days dedicated to adaptation to the facility and diets, and the subsequent 56 days as the experimental period. The animals were housed in experimental cages (1.0m wide, 1.2m long and 1.30m high), equipped with water buckets and feed troughs. The experimental diets were formulated according to the recommendations of the National Research Council (Nutrient…, 2007), for 150g/day of gain and forage:concentrate ratio of 70:30 (Table. 2).

Table 1. Nutritional composition of Tifton 85 grass and banana leaf and pseudostem hays

Nutrients	TFH	LH Sun	LH Shade	PH Sun	PH Shade
DM (% of NM)	88.8	89.0	90.3	87.8	87.5
CP (% of DM)	7.95	11.8	10.9	5.37	8.58
EE (% of DM)	2.10	6.50	6.30	0.80	1.10
NFC (% of DM)	6.35	2.99	4.01	17.8	11.2
NDF (% of DM)	78.8	67.4	65.9	62.4	63.2
ADF (% of DM)	40.3	45.0	43.9	42.5	46.5
NDIP (% of DM)	0.80	1.20	1.20	0.60	1.20
ADIP (% of DM)	0.20	0.80	0.70	0.50	0.80
Ashes (% of DM)	4.85	11.3	12.9	13.7	15.9

DM- dry matter, NM- natural matter CP- crude protein, EE- ether extract, NFC– Non-fiber carbohydrates, NDF- neutral detergent fiber, ADF- acid detergent fiber, NDIP –neutral detergent insoluble protein, ADIP- acid detergent insoluble protein, TFH = Tifton 85 hay. LH Sun = banana leaf hay dehydrated in the sun; LH Shade = banana leaf hay dehydrated in the shade; PH Sun = pseudostem hay dehydrated in the sun; PH Shade = pseudostem hay dehydrated in the shade.

Table 2. Ingredients and nutritional composition of experimental diets

Ingredients (%)	TFH	LH Sun	LH Shade	PH Sun	PH Shade
Tifton 85 hay	70.0	0.00	0.00	0.00	0.00
LH Sun	0.00	70.0	0.00	0.00	0.00
LH Shade	0.00	0.00	70.0	0.00	0.00
PH Sun	0.00	0.00	0.00	70.0	0.00
PH Shade	0.00	0.00	0.00	0.00	70.0
Ground corn	17.4	16.7	16.6	11.0	12.9
Soybean meal	8.45	9.10	9.12	14.65	12.2
Limestone	0.21	0.28	0.28	0.30	0.30
Mineral and vitamins Premix	3.94	3.92	4.00	4.05	4.59
Total (%)	100	100	100	100	100
Nutritional composition					
DM (% of NM)	90.58	88.45	89.32	87.25	84.36
CP (% of DM)	10.98	12.65	12.17	11.67	11.81
EE (% of DM)	1.97	4.53	4.01	1.24	1.07
NFC (% of DM)	27.1	14.4	22.8	24.3	28.2
NDF (% of DM)	53.25	56.96	49.99	49.90	47.44
ADF (% of DM)	28.99	37.40	33.12	33.22	32.86
Ashes	6.63	11.48	11.02	12.94	11.43

DM- dry matter, NM- natural matter CP- crude protein, EE- ether extract, NFC– Non-fiber carbohydrates, NDF- neutral detergent fiber, ADF- acid detergent fiber, NDIP – neutral detergent insoluble protein, ADIP- acid detergent insoluble protein, TFH = Tifton 85 hay. LH Sun = banana leaf hay dehydrated in the sun; LH Shade = banana leaf hay dehydrated in the shade; PH Sun = pseudostem hay dehydrated in the sun; PH Shade = pseudostem hay dehydrated in the shade.

The diets were provided twice daily, at 8:00 am and 5:00 pm. The amount of feed offered to each lamb was adjusted daily to achieve 15%–20% leftovers. Diets and leftovers were weighed daily, sampled at 35% of the total daily amount for each animal, packaged, and stored in a freezer (-20 ºC) for further chemical analysis.

At the start and end of the experimental period, the animals were fasted for 16h (with *ad libitum* access to water) and were weighed. During the experimental period, animals were weighed every seven days. Total weight gain (kg) was calculated as the difference between the initial and final weights, and average daily weight gain (g/day) was determined by dividing the weight gain by the total number of days in the experiment. Feed conversion was calculated by dividing the dry matter intake (DMI) by weight gain.

Diets and leftover samples were ground using a Willey mill with 1 mm sieves and analyzed according to the AOAC (2005) methods for dry matter (DM, method 934.01), ash (method 942.05), crude protein (CP, method 954.01), and ether extract (EE, method 920.39). Neutral and acid detergent fiber (NDF and ADF) analyses were performed according to Van Soest *et al*. (1991) using an ANKOM200 fiber analyzer unit (ANKOM Technology Corporation, Fairport, New York, USA). Heat-stable alpha amylase was used in all aliquots (Termamyl 2X, Novozymes). Non-fiber carbohydrates were calculated as follows: NFC=100 – (% NDF + % EE + % CP + % Ash).

The average dry matter intake (DMI) and nutrient intakes (g/day) were calculated based on intake values and the DM, crude protein (CPI), ether extract (EEI), non-fiber carbohydrates (NFCI), neutral detergent fiber (NDFI), acid detergent fiber (ADFI) and ash (MMI) compositions of the total diets and respective leftovers.

For the ingestive behavior analysis, all animals were observed by three trained observers positioned to avoid influencing the animals. Observations took place on days 53, 54, and 55 of the experiment for five-minute intervals using a digital stopwatch and charts, covering a 24-hour period divided into three intervals (06:00 to 14:00, 14:00 to 22:00, and 22:00 to 06:00). The times spent ruminating, feeding, and resting were recorded (Johnson and Combs, 1991).

On day 56 of the experiment, the counts were made of the number of ruminal chews per bolus (number of chews/bolus) and the time required to ruminate each bolus (sec/bolus). The chewing averages were obtained from three different observations made by each observer, taken during periods of 06:00 to 08:00, 14:00 to 16:00, and 19:00 to 21:00. Artificial lighting was provided in the shed during nighttime hours.

The amounts of dry matter and NDF per ruminal bolus were calculated by dividing the average daily intake of each component by the number of ruminated boluses per day. Feeding and rumination efficiencies were calculated by multiplying nutrient consumption by the time spent in these respective activities. The number of ruminated boluses was calculated by dividing the total rumination time divided by the average rumination time per bolus (Bürger *et al*., 2000).

For the statistical analyzes a randomized block design was used, considering the sex of the animals. The initial body weight was considered a covariate and results were subjected to analysis of covariance and the means compared by the Scott-Knott test at 5% probability, using the RStudio® software (Xie *et al*., 2018). The covariate was significant for total gain, average daily gain, feed conversion, protein intake, and non-fiber carbohydrate intake and the values were adjusted for the covariate.

The Shapiro-Wilk test at 5% significance was used to test the normality of the residuals and the Oneill and Mathews test at 5% significance was used to test the homogeneity of variances.

RESULTS AND DISCUSSION

Sheep fed hays of banana residues showed lower DMI (g/kg $BW^{0.75}$/day) compared to TFH ($p < 0.05$) (Table 3). Previous studies have associated reduced intake, particularly with banana leaf hay, to the presence of antinutritional factors. Lignin content values of 13.5g/kg DM (Chali *et al*., 2018), 88.1g/kg DM (Carmo *et al.,* 2018) and 122g/kg DM (Marie-Magdeleine *et al.,* 2010) have been reported, with variations mainly dependent on the cultivar. Condensed tannin levels have also been documented at 7.1g/kg DM (Freitas *et al.*, 2017) and 7.8g/kg DM (Carmo *et al.,* 2018) for banana leaf hay. In banana pseudostem, lignin content values of 47.3g/kg DM and condensed tannin concentrations of 0.1g/kg DM have been reported (Carmo *et al.,* 2018).

According to Lima Júnior *et al.* (2010), tannins form complexes with dietary proteins, reducing digestibility by inhibiting proteolytic enzymes, reducing microbial growth, and removing substrates essential for microbiota activity. Tannins also interact with cellulose, hemicellulose, pectin and minerals, making them less available. Studies by Carmo *et al*. (2018) and Freitas *et al*. (2017) have associated high tannin content in diets with reduced voluntary feed intake, decreased digestibility of dry matter and crude protein, and an increased risk of foamy bloat. Tannins also decrease palatability due to their astringent properties, which consequently reduces feed intake (Makkar, 2003).

Animals fed LH Shade showed the lowest intake. The difference in DMI for animals on LH Shade versus LH Sun diets may indicate a partial inactivation of tannins due to exposure to sunlight and elevated temperatures. According to Julkunen-Tiitto and Sorsa (2001) drying methods can influence condensed tannin concentrations, with drying at 60°C shown to reduce these compounds.

Table 3. Nutrients intake and performance of sheep fed hays of banana leaf and pseudostem with different drying methods

Variables	TFH	LH Sun	LH Shade	PHSun	PH Shade	CV (%)
DMI (g/day)	1253.1	869.1	727.4	1075.5	857.4	26.72
DMI (g/kg $BW^{0.75}$/day)	111.4a	88.9b	67.3c	86.2b	79.6b	12.01
CPI (g/day)	147.5	106.9	89.0	126.7	103.4	23.45
CPI (g/kg $PV^{0.75}$/day)	11.9	9.2	8.4	10.3	8.6	22.19
EEI (g/kg $PV^{0.75}$/day)	2.5c	6.3a	4.3b	0.7d	0.9d	23.34
NFCI (g/day)	411.3a	175.9c	191.4c	321.4b	293.4b	7.60
NFCI (g/kg $PV^{0.75}$/day)	33.7a	15.3c	18.8c	26.6b	24.2b	9.60
NDFI (g/dia)	599.0	460.4	333.4	491.8	376.6	27.47
NDFI (g/kg $PV^{0.75}$/day)	49.1a	47.2a	30.8b	39.4b	32.1b	17.86
ADFI (g/day)	343.3a	362.8a	223.5b	316.2a	279.8b	17.77
ADFI (g/kg $PV^{0.75}$/day)	28.1a	32.3a	20.7b	25.3b	24.0b	15.92
MMI (g/day)	60.7c	107.6b	96.0b	119.5b	198.0a	14.68
MMI (g/kg $PV^{0.75}$/day)	5.0c	9.5b	8.8b	9.5b	17.0a	12.89
TWG (kg)	7.1a	2.4b	1.6b	7.1a	6.7a	17.26
ADG (g/dia)	126.4a	43.1b	28.3b	126.3a	119.2a	17.26
Feed conversion	11.2a	20.9b	30.7c	7.3a	9.3a	34.70

DMI - dry matter intake, CPI- crude protein intake, EEI- ether extract intake, NFCI– Non-fiber carbohydrates intake, NDFI- neutral detergent fiber intake, ADFI- acid detergent fiber intake, MMI- ashes intake, TWG- total weight gain, ADG- average daily gain, TFH = Tifton 85 hay. LH Sun = banana leaf hay dehydrated in the sun; LH Shade = banana leaf hay dehydrated in the shade; PH Sun = pseudostem hay dehydrated in the sun; PH Shade = pseudostem hay dehydrated in the shade, CV- coefficient of variation. Means followed by different letters on the line show a significant difference by the Scott-Knott Test at a 5% significance level.

The experimental diets did not influence CPI (Table 3), likely due to the similar nutrient content across diets. The CPI of the animals was close to the predicted value of 9.6g/kg $LW^{0.75}$, as recommended by the National Research Council (2007).The EEI was higher for both sun-dried and shade-dried banana leaf hays ($p<0.05$), which could be associated with the greater presence of ether-soluble compounds in the leaves.

Sheep fed banana residues hays showed lower NFCI ($p<0.05$) compared to those fed TFH (Table 3). Among the banana treatments, however, sheep fed pseudostem hay showed the highest NFCI ($p<0.05$). This characteristic tends to provide better ruminal fermentation of the diet, as it has higher digestibility. Except for LH Sun, all banana diets had lower NDFI per kg of metabolic weight than TFH ($p<0.05$), while ADFI was higher for TFH and both sun-dried banana residue hys ($P<0.05$).

In contrast to these findings, Carmo *et al.* (2018) observed no differences in dry matter intake (DMI), CPI, or NDFI when banana leaf or pseudostem hays were included at up to 40% in the diets of crossbred sheep, suggesting that the inclusion level of these residues had only minor effects on diet composition.

The observed effects on NFCI, NDFI, and ADFI of banana residues reflect the impact of drying methods on DMI and fiber fractions. Sun drying can lead to the oxidation of non-structural carbohydrates, increasing the fibrous components (Rotz and Abrams, 1988). With a higher proportion of fibrous carbohydrates, one would expect increased ADF intake; however, reduced fiber quality and lower NFC content may decrease the digestibility of the ingested fibrous portion (Mertens, 1987).

Animals fed banana leaf hay showed lower TWG, ADG and feed conversion ($p<0.05$) compared to other treatments (Table 3). However, the similar performance between pseudostem hay and Tifton-85 grass demonstrates the potential of pseudostem hay as an alternative forage source to reduce diet costs. Silveira Junior *et al*. (2020) also reported satisfactory performance in sheep fed banana pseudostem hay with or without monensin in a feedlot feeding.

The drying method did not affect the performance or intake of animals fed pseudostem hay, suggesting that sun drying could be recommended as it reduces the need for additional steps and requires less time to obtain the final product. Animals fed LH Sun showed higher DMI and feed efficiency compared to those fed LH shade ($p<0.05$), possibly due to partial inactivation of tannins by sunlight and heat (Julkunen-Tiitto and Sorsa, 2001).

Banana residues hays did not significantly affect feeding time ($p>0.05$), but they influenced the time spent on other activities (Table.4).

Table 4. Ingestive behavior of sheep fed hays of banana leaf and pseudostem with different drying methods

Variables	TFH	LH Sun	LH Shade	PH Sun	PH Shade	CV (%)
Feeding (min/day)	382.2	264.9	315.0	269.0	342.8	26.76
Chewing (min/day)	860.5a	866.1a	896.6a	598.9b	776.1a	13.89
Rumination (min/day)	478.2b	601.1a	581.6a	329.9b	456.6b	18.76
Idle (min/day)	579.4b	573.8b	543.3b	841.0a	663.8b	17.73
FE_{DM} (g ofDM/h)	207.9	199.5	142.7	263.2	190.8	36.42
FE_{NDF} (g of NDF/h)	98.6	105.7	65.0	118.9	82.6	34.94
RE_{DM} (g ofDM/h)	139.8a	111.7b	75.1b	173.0a	115.5b	24.16
RE_{NDF}(g of NDF/h)	95.9a	59.0b	34.5b	98.4a	57.8b	32.28
Number of bolus	689.1a	777.8a	774.0a	514.5b	745.3a	16.22
Chewing/bolus	51.2b	59.8a	61.3a	51.0b	45.0b	12.41
Chewing/day	35352.3b	45734.6a	47640.1a	26329.9b	55963.1a	27.36

FE– Feeding efficiency, RE- Rumination efficiency, TFH = Tifton 85 hay. LH Sun = banana leaf hay dehydrated in the sun; LH Shade = banana leaf hay dehydrated in the shade; PH Sun = pseudostem hay dehydrated in the sun; PH Shade = pseudostem hay dehydrated in the shade, CV- coefficient of variation. Means followed by different letters on the line show a significant difference by the Scott-Knott Test at a 5% significance level.

Sheep fed PH shade spent less time chewing ($p<0.05$), leading to increased idle time ($p<0.05$). Animals fed banana leaf hays spent more time ruminating than other groups, which could be associated to their lower DMI but similar NDFI. Another factor may be the higher lignin content in banana leaves, nearly double that in pseudostem and forage hays of the *Cynodon* genus (Carmo *et al*., 2018). Consequently, with potentially lower digestibility, animals required more time to reduce the particle size for passage through the gastrointestinal tract.

Animals fed TFH and PH Sun were more efficient ($p < 0.05$) in the rumination of DM and NDF (Table 4), reflecting their ability to reduce particle size and improve the nutrient quality of these roughages. This emphasizes the role of the fibrous portion as a key factor, as NDF intake is directly associated with the relationship between NDF consumption and the animal's rumination capacity (Mertens and Ely, 1982).

The time per bolus was similar between the groups with average time of 41.7 seconds/bolus. Sheep fed banana leaf hay showed similar bolus numbers compared to TFH, but they had a higher number of chews per bolus and per day ($p < 0.05$). The lignin concentration in banana leaves could negatively affect chewing behavior, as the increased feed bulkiness requires more processing to reduce particle size (Boval and Sauvant, 2021).

The drying method influenced bolus formation and chewing behavior in sheep fed pseudostem diets (Table 4). Animals fed PH Sun had fewer boluses per day ($p<0.05$) but a similar number of chews and time per bolus compared to TFH, resulting in more idle time. In contrast, animals fed PH Shade showed a higher number of chews per day ($p<0.05$) with a similar number of boluses and time per bolus, leading to more chewing time compared to TFH. While excessive heat during sun drying can increase the forage's fibrous fraction (Rotz and Abrams, 1988), this drying method did not affect the ingestive behavior of sheep fed banana residue diets in the current study.

CONCLUSION

Leaf hay reduces animal performance and is not recommended for sheep confinement, whereas sheep fed pseudostem hays exhibit intake and performance comparable to those fed Tifton hay, suggesting that pseudostem hay is a viable alternative for sheep confinement. For pseudostem hays, sun-drying is recommended, as it offers processing advantages and improves ingestive behavior.

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