

FERMENTATION LOSSES AND CHEMICAL COMPOSITION IN MIXED SILAGES OF ELEPHANT GRASS AND CASSAVA PEELS WITH MANGO RESIDUE¹

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¹Received: 04/06/2019. Accepted: 12/09/2019.

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ABSTRACT: The objective of this study was to evaluate the effect of the inclusion of different levels of mango residue (0, 10, 20 and 30% natural matter) in the mixed silages of elephant grass and cassava peels. The material was ensiled for 60 days in polyvinyl chloride "PVC" experimental bags. There was a maximum loss ($P<0.05$) of the effluent of 48.5 kg/ton of natural matter with the inclusion of 24.3% of mango residue in the elephant grass silage and cassava peel. Maximum dry matter (DM) loss ($P<0.05$) of 22.1% and minimum DM recovery ($P<0.05$) of 78.9% were found with the inclusion of 21.1% and 21.4% of mango residue. Quadratic behavior ($P<0.05$) was observed for the chemical composition of the silages, with minimum DM content (29.2%) and non-fibrous carbohydrates (37.6% NFC), and maximum crude protein (9.64% CP) and neutral detergent fiber (41.6% NDF) contents, with the inclusion of 23.5%, 8.90%, 10.7%, and 9.11% of mango residue, respectively. In the sensory evaluation regarding the characteristics associated with the nutritional value, the classification "good to very good" was recorded for the silages where the elephant grass and the cassava peels were added with 10% and 20% of mango residue. The inclusion of 10.7% of natural mango residue in elephant grass and cassava peel silages is enough to improve crude protein content, with lower effluent loss.

Keywords: crude protein, density, ensiling, effluent loss, sensory evaluation.

PERDAS FERMENTATIVAS E COMPOSIÇÃO QUÍMICA DAS SILAGENS MISTAS DE CAPIM-ELEFANTE E CASCAS DE MANDIOCA COM RESÍDUO DE MANGA

RESUMO: Objetivou-se com esse estudo avaliar o efeito da inclusão de diferentes níveis de resíduo de manga (0, 10, 20 e 30% da matéria natural) nas silagens mistas de capim-elefante e casca de mandioca. O material foi ensilado durante 60 dias em silos experimentais de policloreto de vinil "PVC". Observou-se perda máxima ($P<0,05$) de efluentes de 48,5 kg/t de matéria natural com a inclusão de 24,3% de resíduo de manga. Perda máxima ($P<0,05$) de 22,1% de matéria (MS) e recuperação mínima ($P<0,05$) de 78,9% de MS foram registradas com a inclusão de 21,1% e 21,4% de resíduo de manga. Comportamento quadrático ($P<0,05$) foi observado para a composição química das silagens, com conteúdo mínimo de MS (29,2%) e carboidratos não fibrosos (37,6% de CNF), e conteúdos máximos de proteína bruta (9,64% de PB) e fibra em detergente neutro (41,6% de FDN), com a inclusão de 23,5%, 8,90%, 10,7% e 9,11% de resíduo de manga, respectivamente. Na avaliação sensorial quanto às características associadas ao valor nutritivo registrou-se a classificação "boa a muito boa" para as silagens onde o capim-elefante e a casca de mandioca foram aditivados com 10 e 20% de resíduo de manga. A adição de 10,7% de resíduo de manga na silagem de capim-elefante e casca de mandioca é suficiente para melhorar o conteúdo de proteína bruta, com menores perdas por efluentes.

Palavras-chave: avaliação sensorial, densidade, ensilagem, perda de efluente, proteína bruta

INTRODUCTION

The Brazilian semi-arid will be one of the regions most affected by the climatic changes of the last years and may become arider (ANGELOTTI et al., 2011). One of the aggravating factors of the scarcity of rainfall in this region is the increase of the mortality of animals due to a nutritional deficiency associated to the lack of pasture, and the consequent increase of the hunger of the populations residing in that region.

This scenario demonstrates the need to develop strategies to coexist with drought in the semi-arid region and at the same time increase the production of food for human consumption. Thus, in recent years the use of alternative feed replacing grains conventionally used in the animal diet has been studied as an option to reduce feeding costs. Based on this, the conservation of forages with by-products or feed residue, such as fruit, from losses in the production process have been used as alternative low-cost resources for energy or protein supplementation.

Among the most used forage for conservation in the form of silage, elephant grass (*Pennisetum purpureum* Schum) stands out for the high production of biomass and good nutritive value. However, at the time of cutting, tropical grasses usually present low DM and soluble carbohydrates, and it is necessary to wilt the plant or add moisture absorbing additive to allow better fermentability of the silage. According to Ferreira et al. (2017), the dry matter (DM) content is a major factor in the biochemical process of ensiling and could be corrected using an absorbent additive, such as buriti fruit peel tested in elephant grass silage.

Among the low-cost additives for use in grass silage, post-harvest residues such as coffee peels, corn cob, and cassava residues stand out. Pires et al. (2009) verified improvement in the fermentative characteristics and increase of the *in vitro* digestibility of DM of elephant grass silage with cassava meal. Ferrari Junior et al. (2009) reported increased DM content and adequate fermentation of silage of elephant grass ensiled with citrus pulp.

The ensiling of residue and residues of fruit and alternative forage crops has become an alternative to traditional crops. According to Wadhwa and Bakshi (2013) the peels and remains of mango pulp, banana, citrus,

pineapple, tomato, can be supplied fresh or ensiled for ruminant animals. Rêgo et al. (2010) recorded a satisfactory fermentation process with additions of over 8.6% of mango by-product (*Mangifera indica* L.) in the elephant grass ensilage.

In view of the above, it is important to verify if the cassava peels could function as a good moisture-absorbing additive, increasing the DM content of silage in general; and at the same time investigate the effect of the addition of mango residue on the conservation of elephant grass used to feeding ruminants during drought. Therefore, the aim of this study was to evaluate the fermentative losses, chemical composition and sensory quality of elephant grass and cassava peels ensiling with different levels of mango residue.

MATERIAL AND METHODS

The study was conducted at the Federal University of Western Bahia, located in Barra - BA, Brazil, with coordinates of 11° 05' 20" S and 43° 08' 31" W and 406 m. The treatments analyzed consisted of different levels of inclusion of mango residue in elephant grass and cassava peels silages: 0, 10, 20 and 30% of the natural matter (NM). The NM of elephant grass and cassava peels was equated.

The elephant grass (*Pennisetum purpureum* cv. Napier) was collected at 60 days of regrowth in a farm located in Barra, BA; mango residue and dehydrated cassava peels were obtained in local markets and farms of Barra, Buritirama and Ipirá, BA. These materials (mango pulp and pells, and cassava peels) was ground by hand, and the elephant grass was crushed in a forage machine, to obtain a 2 cm particle size. After this, the additive (mango residue) were mixed to the elephant grass and cassava peels, according to the proposed treatments, and immediately ensiling. Samples of elephant grass, cassava peels, and mango residue were collected and stored as original material for further chemical composition analysis (Table 1).

The experimental unit consisted of an experimental bag of polyvinyl chloride "PVC", 50 cm high and 10 cm in diameter. The bins of the bags were equipped with "Bunsen" valves to allow the quantification of gases from the fermentation. At the bottom of each bag was placed 1.0 kg of sand, separated from the

Table 1 - Chemical composition of the elephant grass, cassava peels and mango residue before ensilage.

Ingredient	DM ¹ (%)	CP ² (%)	EE ³ (%)	NDF ⁴ (%)	ADF ⁵ (%)	MM ⁶ (%)
Elephant grass	18.2	8.70	2.87	70.9	41.9	10.5
Cassava peels	88.3	4.50	1.15	26.1	17.7	4.90
Mango residue	19.9	5.98	1.79	31.8	19.9	2.40

¹DM: Dry matter; ²CP: Crude protein; ³EE: Ether extract; ⁴NDF: Neutral detergent fiber; ⁵ADF: Acid detergent fiber; ⁶MM: Mineral matter.

forage by a cotton cloth, to capture the effluent from the forage silage. The compaction of the material was performed manually using wooden sockets and subsequently sealed with plastic film and PVC bags, for 60 days. Four replicates were adopted for each treatment and arranged following the completely randomized design, totalizing 16 experimental units.

The density of the silages was calculated by the ratio of the ensiled forage mass to the volume of the bag. The empty set (bag, lid, plastic film, sand, and cotton cloth) was weighed to quantify effluent production, gas loss, total DM loss, and DM recovery, using the equations cited by Zanine et al. (2010).

The silages were analyzed for the determination of DM (Method INCT-CA G-003/1), organic matter (OM), mineral matter (MM; Method INCT-CA N-001/1), total nitrogen (N; Method INCT-CA N-001/1), ether extract (EE; Method INCT-CA G-004/1); neutral detergent fiber (NDF; Method INCT-CA F-002/1), and acid detergent fiber (ADF; Method INCT-CA F-004/1), according to methodologies described by Detmann et al. (2012). Non-fibrous carbohydrates (NFC) were estimated by equation recommended by Hall et al. (1999): %NFC = 100 - (%CP + %EE + %NDFap + %MM), where NDFap, corresponds to neutral detergent fiber corrected for ash and protein, and CP corresponds to crude protein (%CP = %N × 6.25).

The sensory evaluation of the silages was carried out according to the methodology described by Meyer et al. (1989). Thirty evaluators, men, and women were randomly selected, who were trained on the completion of the scores in the evaluation form. At the opening of the bags, the sensory evaluation of the silages was carried out according to the criteria: (i) smell; (ii) coloration; (iii) texture; and (iv) contamination (sanitary aspect, evaluated only by smell). The quantification and identification of microorganisms or

microbiological analysis was not the object of the present study. The silages received scores for each of the mentioned aspects and, from the sum of these, were classified as: good to very good, satisfactory, regular and unsatisfactory.

The data were analyzed using the analysis of variance and regression using the System of Statistical Analysis of the software SAEG 9.1 (UFV, 2007), adopting a level of significance of 5% for type I error. The comparisons between the inclusion levels of mango residue in the silages were driven by the decomposition of the sum of the squares into orthogonal contrasts with linear and quadratic effects ($P < 0.05$), with subsequent adjustment of the regression equations.

RESULTS AND DISCUSSION

There was a quadratic behavior ($P < 0.05$) for the density of the silages, with a maximum point of 559.2 kg of natural matter (NM) per m³ with the inclusion of 24.1% of mango residue (Table 2). This result is related to the reduction of the DM content of the silage up to the 23.5% inclusion level of mango residue. According to Sun et al. (2017), the extent of aerobic deterioration depends on the growth rate of aerobic microorganisms and on the bulk density of the silage, with low density of 520-550 kg/m³ and high density of 860-950 kg/m³.

When silages with low density are produced, the probability of containing more residual air in the ensiled mass is increased, as well as lower anaerobic stability of the silage, leading to an increase in silage DM losses (MCDONALD et al., 1991). According to Balieiro Neto et al. (2009) in the silage process, the effluent loss is directly related to the moisture content of the ensiled mass, which justifies the higher effluent production in the silages with 20% and 30% of mango residue (Table 2).

There was a maximum loss ($P < 0.05$) of the effluent of 48.5 kg/ton NM with the

Table 2 - Density, fermentation losses and dry matter recovery of mixed silages of elephant grass and cassava peels with mango residue.

Item	Mango residue (% of NM ¹)				SEM ²	P-value ³	
	0	10	20	30		L	Q
Density (kg NM/m ³)	515.5	505.3	654.0	601.3	9.640	0.013	0.004
Effluent loss (kg/ton NM)	3.72	6.89	54.7	41.5	1.856	0.001	0.001
Gas loss (% DM ⁴)	0.024	0.032	0.029	0.028	0.002	NS ⁵	NS ⁵
Total DM loss (%)	6.56	13.8	25.7	17.9	1.799	0.000	0.000
DM Recovery (%)	93.5	86.2	76.1	82.4	3.863	0.000	0.000

¹NM: natural matter; ²SEM: Standard error of mean; ³L: Linear effect; Q: Quadratic effect; ⁴DM: Dry matter; ⁵NS: Non-significant (P>0.05).

Density: $y = 497.49 + 5.1188x - 0.1062x^2$; Effluent loss: $y = 5.342 + 1.5872x - 0.0376x^2$; Total DM loss: $y = -33.551 + 6.7439x - 0.1385x^2$; DM Recovery: $y = 94.46 - 1.454x + 0.034x^2$

inclusion of 24.3% of mango residue in the elephant grass silage and cassava peel, which was related to the higher density of the ensiled mass (Table 2). This result was higher than that recorded by Mota et al. (2015) of 9.79 kg/ton NM in elephant grass silage with 20% of babassu meal; and by Melo et al. (2016) of 12.3 kg/ton NM in tanzania grass silage with corn meal, molasses, urea and limestone. These results can be related to the lower DM content of the silages of the present study. Andrade et al. (2010) found that the inclusion of 14.2% of the cocoa meal was sufficient to inhibit effluent loss, different from the present study in that the addition of only 10% of mango residue allowed lower effluent losses (6,89 kg/ton NM). Negrão et al. (2016) verify decrease of effluent and gas losses using rice meal in the silage of *Brachiaria decumbens*. According to these authors, the different results are related to the hygroscopic capacity of the different additives, associated with DM content. One of the factors that contributed to the reduction of effluent losses in elephant grass silages in this study was the presence of dehydrated cassava peels (88.3% of DM), which functioned as moisture absorbing additive, otherwise, the effluent losses would be higher.

Santos et al. (2019) verified that the determination of the gas and total DM losses in silages, using the laboratory silos of PVC provided with a cover with a valve for the elimination of gases, was efficient to the evaluation of the quality of the fermentation of the forage silage. In the present study, there was no effect (P>0.05) of inclusion levels of mango residue on gas losses, with a mean value of 0.03% of DM (Table 2). The

reduction of gas losses is associated with the action of homofermentative bacteria and inhibition of gas-producing microorganisms, such as enterobacteria and clostridial bacteria, which develop in poorly fermented silages (PACHECO et al., 2014). Zanine et al. (2010) verify that the inclusion of cassava scrapings in the elephant grass silages improve fermentation profile due to the reduction of gas and effluent losses. Thus, the ensiling of elephant grass with low DM content (21.1%) together with dehydrated cassava peels (88.3% DM) was effective in absorbing the moisture of the ensiled material. In addition, the inclusion of mango residue provided a higher content of soluble carbohydrates in the silage, contributing to the establishment of bacteria suitable to a good fermentation process.

Quadratic behavior was observed in the DM loss and DM recovery, with a maximum DM loss of 22.1% and, consequent, minimum DM recovery of 78.9%, with the inclusion of 21.1% and 21.4% of mango residue, respectively. This result was lower than that recorded by Andrade et al. (2010) of 99.8% DM recovery with the inclusion of 20% of the cocoa meal. According to Pacheco et al. (2014), the DM recovery rate is negatively correlated with effluent and gas losses in the silages, which explains the reduction of DM recovery with the inclusion of up to 21.4% of the additive.

Quadratic behavior (P<0.05) was observed for DM, NFC and MM contents, with minimum contents of 29.2%, 37.6% and 8.85% with the inclusion of 23.5%, 8.90% and 14.6% of mango residue, respectively (Table 3). These lower values could be explained by the low content of DM (19.9%) and MM (2.40%) of the

Table 3 - Chemical composition of mixed silages of elephant grass and cassava peels with mango residue.

Item	Mango residue (%NM ¹)				SEM ²	P-value ³	
	0	10	20	30		L	Q
DM ⁴ (%)	34.5	34.4	27.2	29.5	0.049	0.000	0.000
OM ⁵ (%)	89.2	89.7	91.6	90.9	0.252	0.000	0.000
CP ⁶ (%)	8.56	8.57	10.6	8.98	0.216	0.000	0.000
EE ⁷ (%)	1.50	1.95	1.84	1.57	0.050	0.000	0.008
NFC ⁸ (%)	49.4	39.2	35.7	47.8	1.486	0.000	0.000
NDF ⁹ (%)	29.7	40.0	43.5	32.6	1.434	0.000	0.000
ADF ¹⁰ (%)	17.0	23.2	27.1	20.0	0.969	0.000	0.000
MM ¹¹ (%)	10.8	10.3	8.36	9.11	0.253	0.000	0.000

¹NM: natural matter; ²SEM: Standard error of mean; ³L: Linear effect; Q: Quadratic effect; ⁴DM: Dry matter; ⁵OM: Organic matter; ⁶CP: Crude protein; ⁷EE: Ether extract; ⁸NFC: Non-fibrous carbohydrates; ⁹NDF: Neutral detergent fiber; ¹⁰ADF: Acid detergent fiber; ¹¹MM: Mineral matter.

DM: $y = 35.33 - 0.402x + 0.006x^2$; OM: $y = 88.221 + 0.402x - 0.0138x^2$; CP: $y = 7.6002 + 0.3822x - 0.0179x^2$; EE: $y = 1.2904 + 0.1379x - 0.008x^2$; NFC: $y = 57.595 - 4.4869x + 0.252x^2$; NDF: $y = 21.735 + 4.3687x - 0.2399x^2$; ADF: $y = 11.64 + 2.8341x - 0.1485x^2$; MM: $y = 11.779 - 0.402x + 0.0138x^2$

additive used, while the reduction of the NFC content accompanied the decrease in DM.

The minimum DM content obtained in this study was close to that registered by Andrade et al. (2010) of 29.7% DM, when evaluating elephant grass ensiling with 20% cocoa meal; and by Azevedo et al. (2017), of 29.8% DM, using 16.1% mango residue in the elephant grass silage. However, it was superior to the elephant grass silages evaluated by Rêgo et al. (2010) 27.9% DM, with the addition of 16% by-product of the mango processing; by Ferreira et al. (2015) that obtained 27% DM with addition of 14% dehydrated cashew residue and by Ferrari Junior et al. (2009) which added 10% citrus pulp and reached 24.9% DM. Despite the reduction in NFC content with the addition of mango residue, the minimum value recorded in this study was higher than that found by Azevedo et al. (2017) of 22.8%; by Rêgo et al. (2010) of 12.1% and by Guerra et al. (2016) of 21.7% when adding dehydrated cashew pulp.

In relation to the DM contents with the addition of mango residue in elephant grass and cassava peels silages, the results obtained in this study were considered adequate for good fermentation. In addition, the inclusion of 10% mango residue, obtaining silages with 34.4% DM satisfies the ideal DM value (30-35%), corroborating with the results showed by Ferreira et al. (2017), using buriti fruit peel in the elephant grass silage. According

to Kung Junior et al. (2018), many problems in the quality of the silage, such as clostridial fermentations, are increased when the moisture content is above 70%.

Quadratic behavior was observed for the OM, CP, EE, NDF and ADF with maximum points of 91.1%, 9.64%, 1.88%, 41.6% and 25.2% with inclusion of 14.6%, 10.7%, 8.62%, 9.11%, and 9.54% (Table 3). The maximum (P<0.05) CP content obtained in this study was higher than that recorded by Azevedo et al. (2017) of 6.60% with the inclusion of 16.1% mango residue in elephant grass silage; by Rêgo et al. (2010) of 6.21%, with 16.0% by-product of the mango processing and by Ferreira et al. (2015) and Guerra et al. (2016) 9.10% and 6.45% with the addition of 14% and 20% dehydrated cashew residue, respectively. The reduction in CP levels in elephant grass and cassava peel silages with the addition of mango residue above 11% could be related to the lower protein content of the additive. Zanine et al. (2010) found a similar result, with a reduction in the CP concentration with the addition of cassava scrapings (3.40% CP) in the elephant grass silage. According to Aragão et al. (2012) in the mango peel, there is about 3.90% of CP and 3.40% in the pulp, while in the fresh elephant grass there is around 9% at the 90 days of growth (VALADARES FILHO et al., 2018). Therefore, in the present study, the addition of 10.7% of mango residue in elephant grass and cassava peels silage allowed the minimum content of CP (7%), recommended

by Van Soest (1994), who is necessary by the ruminal bacteria.

For the fibrous components, it was verified that the values recorded in the silages of this study were lower ($P < 0.05$) to those obtained by Rêgo et al. (2010) of 65.8% NDF and 43.1% ADF, with 16% by-product of the mango processing and Ferreira et al. (2015) of 71.9% NDF and 49.3% ADF and Guerra et al. (2016) of 68% NDF and 46.1% ADF with 14% and 20% dehydrated cashew residue, respectively. According to Fustini et al. (2017) the DM intake, feeding behavior, and animal performance can be influenced by fiber digestibility and NDF percentage of the forage. The National Research Council (NRC, 2001) recommends a minimum of 25% NDF in DM from the ruminant animal diet, at least 75% of that NDF from long or coarsely chopped forage to allow rumination stimulation and prevent metabolic disorders, thus, the silage evaluated in the present study could satisfactorily participate in the total mixed diet of ruminants.

In the sensory evaluation regarding the nutritional value characteristics, the "good to very good" classification was recorded for the silages with 10% and 20% of mango residue inclusion (Table 4). In these silages, most of the evaluators considered the pleasant smell (acid). Typically greenish coloration and DM content during proper handling. These results demonstrated that the addition of mango

residue in elephant grass and cassava peel silages provides an adequate fermentation due to the addition of NFC, providing the supply of soluble sugars for acid lactic bacteria. The findings of this study corroborated Guerra et al. (2016) that working with elephant grass silage with dehydrated cashew bagasse obtained similar results, indicating an improvement in the fermentation of the silage.

Regarding the characteristics associated with the sanitary aspect, the majority of the evaluators classified the silages as "good to very good", that is, with absence of unpleasant smell, presence of mold or inadequate consistency (Table 5), indicating that the adequate DM content in the silage, the presence of soluble carbohydrates for the homofermentative bacteria and absence of oxygen by the adequate compaction and silage sealing, protected the forage against the development of microorganisms pathogenic and undesirable to the fermentative process (BORREANI et al., 2018).

The results found in the sensory analysis performed by Jian et al. (2015) evaluating oat (*Avena nuda*) and alfalfa (*Medicago sativa*) and by Teixeira and Fontaneli (2017) when assessing winter grain silage showed that there is a positive correlation between the qualitative attributes (smell, color and texture) with the quantitative attributes, providing important information about the state of conservation of

Table 4 - Sensory evaluation about characteristics associated with the nutritive value of mixed silages of elephant grass and cassava peels with mango residue.

Mango residue (%NM ¹)	Total Score	Classification	Parameter
0	22	Good to very good	21 a 25
10	23	Good to very good	21 a 25
20	22	Good to very good	21 a 25
30	20	Satisfactory	15 a 20

¹NM: natural matter.

Table 5 - Sensory evaluation about characteristics associated with a sanitary aspect of mixed silages of elephant grass and cassava peels with mango residue.

Mango residue (%NM ¹)	Total Score	Classification	Parameter
0	-3	Good to very good	0 a -5
10	-3	Good to very good	0 a -5
20	-3	Good to very good	0 a -5
30	-3	Good to very good	0 a -5

¹NM: natural matter.

the silage material, being able to reflect directly on the acceptability of this food by the animal.

CONCLUSIONS

The inclusion of 10.7% of natural mango residue in elephant grass and cassava peel silages is enough to improve crude protein content, associated with lower losses in the fermentation process and adequate sensory attributes.

ACKNOWLEDGMENTS

The authors would like to thank the National Council for Scientific and Technological Development for the Scientific Initiation Scholarship granted.

REFERENCES

- ANDRADE, I.V.O.; PIRES, A.J.V.; CARVALHO, G.G.P. de; VELOSO, C.M.; BONOMO, P. Perdas, características fermentativas e valor nutritivo da silagem de capim elefante contendo subprodutos agrícolas. **Revista Brasileira de Zootecnia**, v.39, p.2578-2588, 2010. <http://dx.doi.org/10.1590/S1516-35982010001200004>
- ANGELOTTI, F.; FERNANDES JÚNIOR, P.I.; SÁ, I.B. Mudanças climáticas no semiárido brasileiro: medidas de mitigação e adaptação. **Revista Brasileira de Geografia Física**, v.06, p.1097-1111, 2011. <https://periodicos.ufpe.br/revistas/rbgfe/article/view/233622/27212>
- ARAGÃO, A.S.L.; PEREIRA, L.G.R.; CHIZZOTTI, M.L.; VOLTOLINI, T.V.; AZEVEDO, J.A.G.; BARBOSA, L.D.; SANTOS, R.D.; ARAÚJO, G.G.L.; BRANDÃO, L.G.N. Farelo de manga na dieta de cordeiros em confinamento. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.64, p.967-973, 2012. <http://www.scielo.br/pdf/abmvz/v64n4/v64n4a25.pdf>
- AZEVEDO, J.C.; ARAUJO, S.A.C.; ROCHA, N.S.; CARDOSO, A.M.; PANTOJA, L.A.; FATURI, C.; DOMINGUES, F.N. Fruit agribusiness waste as an additive in elephant grass silage. **Semina: Ciências Agrárias**, v.38, p.1987-2000, 2017. <http://dx.doi.org/10.5433/1679-0359.2017v38n4p1987>
- BALIEIRO NETO, G.; SIQUEIRA, G.R.; NOGUEIRA, J.R.; REIS, R.A.; ROTH, A.P.T.P.; ROTH, M.T.P. Perdas fermentativas e estabilidade aeróbia de silagens de cana-de-açúcar aditivadas com cal virgem. **Revista Brasileira de Saúde e Produção Animal**, v.10, p.24-33, 2009. <http://revistas.ufba.br/index.php/rbspa/article/view/1289/761>
- BORREANI, G.; TABACCO, E.; SCHMIDT, R.J.; HOLMES, B.J.; MUCK, R.E. Silage review: Factors affecting dry matter and quality losses in silages. **Journal of Dairy Science**, v.101, p. 3952-3979, 2018. <https://doi.org/10.3168/jds.2017-13837>
- DETMANN, E.; SOUZA, M.A.; VALADARES FILHO, S.C.; QUEIROZ, A.C.; BERCHIELLI, T.T.; SALIBA, E.O.S.; CABRAL, L.S.; PINA, D.S.; LADEIRA, M.M.; AZEVEDO, J.A.G. (ed). **Métodos para análise de alimentos**. Visconde do Rio Branco, MG: Suprema. 2012. 214p.
- FERRARI JUNIOR, E.; PAULINO, R.A.; LUCENAS, T.L. Aditivos em silagem de capim-elefante paraíso (*Pennisetum hybridum* cv. paraíso). **Archivos de Zootecnia**, v.58, p.185-194, 2009. <http://scielo.isciii.es/pdf/azoo/v58n222/art3.pdf>
- FERREIRA, A.C.H.; RODRIGUEZ, N.M.; NEIVA, J.N.M.; PIMENTEL, P.G.; GOMES, S.P.; CAMPOS, W.E.; LOPES, F.C.F. Nutritional evaluation of elephant grass silages with different levels of by-products from the cashew juice industry. **Revista Brasileira de Zootecnia**, v.44, p.434-442, 2015. <http://dx.doi.org/10.1590/S1806-92902015001200004>
- FERREIRA, R.R.; BEZERRA, L.R.; MARQUES, C.A.T.; TORREÃO, J.N.C.; EDVAN, R.L.; ARAÚJO, M.J.; AMORIM, D.S.; SANTANA JÚNIOR, H.A. Fermentation characteristics and nutritional quality of elephant grass silage added the buriti fruit peel. **Semina: Ciências Agrárias**, v.38, p.931-942, 2017. <http://dx.doi.org/10.5433/1679-0359.2017v38n2p931>
- FUSTINI, M.; PALMONARI, A.; CANESTRARI, G.; BONFANTE, E.; MAMMI, L.; PACCHIOLI, M. T.; SNIFFEN, G. C. J.; GRANT, R. J.; COTANCH, K. W.; FORMIGONI, A. Effect of undigested neutral detergent fiber content of alfalfa hay on lactating dairy cows: Feeding behavior, fiber digestibility, and lactation performance. **Journal of Dairy Science**,

- v.100, p.4475-4483, 2017. <https://doi.org/10.3168/jds.2016-12266>
- GUERRA, D.G.F.; MAIA, I.S.A.S.; BRAGA, A.P.; ASSIS, L.C.; LUCENA, J.A.; BIDLER, D.C.; SANTOS NETO, C.F.; MEDEIROS, Y.F.; PEREIRA, M.I.B.; PINTO, M.M.F. Chemical composition of elephant grass silages supplemented with different levels of dehydrated cashew bagasse. **Semina: Ciências Agrárias**, v.37, p.997-1005, 2016. <http://dx.doi.org/10.5433/1679-0359.2016v37n2p997>
- HALL, M.B.; HOOVER, W.H.; JENNINGS, J.P.; WEBSTER, T.K.M. A method for partitioning neutral detergent soluble carbohydrates. **Journal of the Science of Food and Agriculture**, v.79, p.2079-2086, 1999. [https://doi.org/10.1002/\(SICI\)1097-0010\(199912\)79:15<2079::AID-JSFA502>3.0.CO;2-Z](https://doi.org/10.1002/(SICI)1097-0010(199912)79:15<2079::AID-JSFA502>3.0.CO;2-Z)
- JIAN, G.; CUIJUN, Y.; GUIHE, L. Analysis to wilting and mixed silage effect on naked oats (*Avena nuda*) and alfalfa (*Medicago sativa*). **International Journal of Agriculture and Biology**, v.17, p.761-766, 2015. <https://doi.org/10.17957/IJAB/14.0003>
- KUNG JUNIOR, L.; SHAVER, R.D.; GRANT, R.J.; SCHMIDT, R.J. Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. **Journal of Dairy Science**, v.101, p. 4020-4033, 2018. <https://doi.org/10.3168/jds.2017-13909>
- MELO, M.J.A.F.; BACKES, A.A.; FAGUNDES, J.L.; MELO, M.T.; SILVA, G.P.; FREIRE, A.P.L. Características fermentativas e composição química da silagem de capim Tanzânia com aditivos. **Boletim de Indústria Animal**, v.73, p.189-197, 2016. <http://dx.doi.org/10.17523/bia.v73n3p189>
- MEYER, H.; BRONSCH, K.; LEIBTSEDER, J. **Supplemente zu vorlesungen und übungen in der tierernährung**. Hannover: Verlag M. e H. Schaper, 1989. 255p.
- MOTA, P.E.S.; MOURA, R.L.; PORTELA, G.L.F.; CARVALHO, W.F.; OLIVEIRA, M.R.A. Perdas e características fermentativas da silagem de capim-elefante com diferentes aditivos. **Agropecuária Científica no Semiárido**, v.11, p.126-130, 2015. <http://dx.doi.org/10.30969/acsa.v11i1.540>
- NATIONAL RESEARCH COUNCIL - NRC. **Nutrient requirements of dairy cattle**. Washington, DC: National Academy Press, 2001. 381p.
- NEGRÃO, F.M.; ZANINE, A.M.; SOUZA, A.L.; CABRAL, L.S.; FERREIRA, D.J.; DANTAS, C.C.O. Perdas, perfil fermentativo e composição química das silagens de capim *Brachiaria decumbens* com inclusão de farelo de arroz. **Revista Brasileira de Saúde e Produção Animal**, v.17, p.13-25, 2016. <http://dx.doi.org/10.1590/S1519-99402016000100002>
- PACHECO, W.F.; CARNEIRO, M.S.S.; PINTO, A.P.; EDVAN, R.L.; ARRUDA, P.C.P.; CARMO, A.B.R. Perdas fermentativas de silagens de capim-elefante (*Pennisetum purpureum* Schum.) com níveis crescentes de feno de gliricídia (*Gliricidia sepium*). **Acta Veterinaria Brasilica**, v.8, p.155-162, 2014. <https://doi.org/10.21708/avb.2014.8.3.3289>
- PIRES, A.J.V.; CARVALHO, G.G.P.; GARCIA, R.; CARVALHO JUNIOR, J.N.; RIBEIRO, L.S.O.; CHAGAS, D.M.T. Capim-elefante ensilado com casca de café, farelo de cacau ou farelo de mandioca. **Revista Brasileira de Zootecnia**, v.38, p.34-39, 2009. <http://dx.doi.org/10.1590/S1516-35982009000100005>
- RÊGO, M.M.T.; NEIVA, J.N.M.; RÊGO, A.C.; CÂNDIDO, M.J.D.; CARNEIRO, M.S.S.; LÔBO, R.N.B. Chemical and bromatological characteristics of elephant grass silages containing a mango by-product. **Revista Brasileira de Zootecnia**, v.39, p.81-87, 2010. <http://dx.doi.org/10.1590/S1516-35982010000100011>
- SANTOS, R.F.; SILVA, J.L.; FERREIRA, A.A.C.; MELLO, M.S.; FERREIRA, M.A.; SIQUEIRA, M.C.B.; INÁCIO, J.G.; PIMENTEL, A.J.B. Fermentation losses and chemical composition of *Calotropis procera* ensiling with mango and tomato waste. **Livestock Research for Rural Development**, v.31, 2019. <http://www.lrrd.org/lrrd31/7/silva31101.html>
- SUN, Y.; LI, M.; ZHOU, H.; SHAN, G.; CHENG, Q.; JUNGBLUTH, K.H.; BUESCHER, W.; MAACK, C.; LIPSKI, A.; WANG, Z.; FAN, Y. In situ measurements and simulation of oxygen diffusion and heat transfer in maize silage relative to the silo surface. **Computers and Electronics in Agriculture**, v.137, p.1-8, 2017. <http://dx.doi.org/10.1016/j.compag.2017.03.011>
- TEIXEIRA, C.E.F.; FONTANELI, R.S. Sensory

- Evaluation of Winter Cereal Silage. **Journal of Chemistry and Chemical Engineering**, v.11, p.102-106, 2017. <https://doi.org/10.17265/1934-7375/2017.03.004>
- UNIVERSIDADE FEDERAL DE VIÇOSA. **SAEG - Sistema para análises estatísticas, versão 9.1**. Viçosa: Fundação Arthur Bernardes, 2007. 301p.
- VALADARES FILHO, S.C.; MACHADO, P.A.S.; CHIZZOTTI, M.L.; AMARAL, H.F.; MAGALHÃES, K.A.; ROCHA JR., V.R.; CAPELLE, E.R. **CQBAL 3.0 - Tabelas Brasileiras de Composição de Alimentos**. Viçosa, MG, 2018.
- VAN SOEST, P.J. **Nutritional ecology of the ruminant**. Ithaca: Cornell University Press, 1994. 476 p.
- WADHWA, M.; BAKSHI, M.P.S. **Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products**. FAO Publication, 2013.
- ZANINE, A.M.; SANTOS, E.M.; DÓREA, J.R.R.; DANTAS, P.A.S.; SILVA, T.C.; PEREIRA, O.G. Evaluation of elephant grass silage with the addition of cassava scrapings. **Revista Brasileira de Zootecnia**, v.39, p.2611-2616, 2010. <http://dx.doi.org/10.1590/S1516-35982010001200008>