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Cassava peel ensiling with tomato waste submitted to dehydration: fermentative losses and chemical composition

Casca de mandioca ensilada com descarte de tomate submetido à desidratação: perdas fermentativas e composição química

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A B S T R A C T

The aim of this study was to evaluate the effect of different dehydration times of the tomato waste (0, 4, 24, 60 and 96 hours) added in the cassava peel silages on the density, fermentative losses, dry matter recovery, chemical composition, and sensorial quality. The material was ensiled for 60 days in polyvinyl chloride (PVC) silos. There was a linear reduction of 0.406 kg $tonne^{-1}$ of fresh matter in the effluent production in the silages. A maximum dry matter (DM) loss ($p<0.01$) of 7.00% was found with 8.10 h of dehydration of the tomato wastes. There was a quadratic behavior ($p<0.01$) for crude protein (CP) and non-fibrous carbohydrates (NFC), with minimum content of 9% CP and maximum content of 66.0% NFC with 3.53 h and 7.35 h of dehydration of the tomato wastes, respectively. The "satisfactory" classification was observed to the silages with 4, 24 and 96 h of dehydration of tomato waste in the sensory evaluation of the characteristics associated with the conservation. Cassava peel ensiling with tomato waste submitted to dehydration time of 7.35 hours is enough to promote an adequate non-fibrous carbohydrates content, associated with lower losses in the fermentation process.

Keywords: additive, effluent loss, *Manihot esculenta*, silage, *Solanum lycopersicum*.

R E S U M O

O objetivo deste trabalho foi avaliar o efeito de diferentes tempos de desidratação do descarte de tomate (0, 4, 24, 60 e 96 horas) adicionado nas silagens de casca de mandioca sobre a densidade, perdas fermentativas, recuperação de matéria seca, composição química e qualidade sensorial. O material foi ensilado por 60 dias em silos de cloreto de polivinila (PVC). Houve redução linear de 0,406 kg ton^{-1} de matéria fresca na produção de efluente nas silagens. Máxima perda de matéria seca (MS) ($p<0{,}01$) de 7,00% foi encontrada com 8,10 h de desidratação do descarte de tomate. Houve comportamento quadrático ($p<0{,}01$) para os teores de proteína bruta (PB) e carboidratos não fibrosos (CNF), com mínimo de 9% de PB e máximo de 66,0% de CNF com 3,53 e 7,35 h de desidratação do descarte de tomate, respectivamente. A classificação "satisfatória" foi observada nas silagens com 4, 24 e 96 h de desidratação do descarte de tomate na avaliação sensorial das características associadas à conservação. A casca da mandioca ensilada com descarte de tomate submetido ao tempo de desidratação de 7,35 horas é suficiente para promover um conteúdo adequado de carboidratos não fibrosos, associado a menores perdas no processo fermentativo.

Palavras-chave: aditivo, *Manihot esculenta*, perdas de efluentes, silagem, *Solanum lycopersicum*.

INTRODUCTION

In the semiarid regions during periods of extreme drought, the most vulnerable communities suffer pressures with reduced subsistence production, due to the significant damage to crops, consequently affecting the family-run agriculture business (Alvalá *et al*., 2019). One of the options to alleviate the problem of the low supply of animal feed in the dry season is the conservation of feed in the form of silage. In addition to conventional fodder, Wadhwa and Bakshi (2013) report that residues (peels and seeds) and wastes from the production of fruits and vegetables, may be ensiled and used in the feeding of ruminants.

In spite of the modernization of production systems and the logistics and distribution of perishables in the last decades, postharvest losses continue to be a persistent and relevant problem (Henz *et al*., 2017). The use of these wastes in livestock, as an alternative source of feeding ruminants, has supported the environmental problem and reduced animal hunger. Tomato, as a fresh feed for animals, presents restrictions related to its high-water content, which limits the time of storage, accelerating its deterioration. According to Galló *et al*. (2017) the wet tomato has a limited fermentation capacity, but it is possible to store under anaerobic conditions, and recommends to use dried additive to increase dry matter (DM) and energy content.

The addition of a moisture-sequestering additive, like cassava (*Manihot esculenta* Crantz) by-products, would be an interesting alternative to increase the DM content of the tomato wastes silage. In the literature, it is verified that the use of cassava by-products in ruminant feed is an excellent strategy (Santos *et al*., 2015), both for the supply of energy from roots and peels, or from protein by leaves. However, despite the well-known feed value of cassava by-products and the availability of tomato wastes in the semiarid regions, the storage of these sources in the form of silage has not been satisfactorily researched. It is hypothesized that cassava peel ensiled with tomato waste submitted to dehydration may improve the fermentation pattern and increase the conservation of these feeds to be used during periods of forage shortage for the ruminants.

Therefore, the objective of this study was to evaluate the effect of different dehydration times of the tomato waste (0, 4, 24, 60 and 96 hours) added in the cassava peel silages on the density, fermentative losses, dry matter recovery, chemical composition, and sensorial quality.

MATERIAL AND METHODS

The study was conducted at Barra – Bahia, Brazil, with coordinates of 11° 05′ 20 ″S and 43° 08′ 31″ W, and 406 m. The treatments analyzed consisted of different dehydration times of the tomato waste (0, 4, 24, 60 and 96 hours) added in the cassava peel silages. In each treatment, the proportion of cassava peel and tomato waste was equated.

Tomato (peels, pulp, and seeds) wastes were obtained in farms of Lapão – BA, and the cassava peels were obtained in rural properties of Buritirama and Ipirá – BA. The material (tomato waste and cassava peel) was ground by hand to obtain a 2 cm particle size, and the tomato wastes were placed in the sun on plastic canvas for dehydration according to proposed treatments. After this period, the cassava peel and dehydrates tomato waste were mixed and immediately ensiling. Samples of cassava peel and dehydrates tomato waste were collected and stored as original material for further DM analysis.

The experimental unit consisted of an experimental silo of polyvinyl chloride (PVC), 50 cm high and 10 cm in diameter. The bins of the silos were equipped with "Bunsen" valves to allow the quantification of gases from the fermentation. At the bottom of each silo was placed 1.0 kg of sand, separated from the 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 lids, for 60 days. Four replicates were adopted for each treatment and arranged following the completely randomized design.

The density of the silages was calculated by the ratio of the ensiled forage mass to the volume of the silo. The empty set (silo, lid, plastic film, sand and cotton cloth) was weighed to quantify effluent production, gas loss, total dry matter (DM) loss, and DM recovery, using the equations proposed by Jobim & Nussio (2013).

The silages were analyzed for the determination of DM (Method INCT-CA G-003/1), organic matter (OM), ash (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 + %ash), where NDFap, corresponds to neutral detergent fiber corrected for ash and protein, and CP corresponds to crude protein (%CP = %N x 6.25).

For the sensory evaluation of the silages, 30 evaluators, men, and women were randomly selected, who were trained on the completion of the scores in the evaluation form. At the moment of opening of the silos, the sensory evaluation of the silages was carried out according to the criteria established by Meyer *et al*. (1989) regarding (i) odor; (ii) coloration; iii) texture; and iv) contamination (sanitary aspect, evaluated only by odor). 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 of the System of Statistical Analysis of SAEG software (version 9.1), 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 linear reduction (p<0.01) of 2.93 kg of fresh matter (FM) per m^3 in the silage density at each hour of increase in the dehydration time of the tomato waste (Table 1). This result is related to the increase of DM content of the silages with dehydrated tomato waste.

Only the silage without dehydration of tomato waste presented density (708.6 kg $FM.m^{-3}$) within the range considered adequate (550 to 850 kg $FM.m^{-3}$) by Ruppel *et al*. (1995), for better conservation of the forage in the form of silage. According to McDonald *et al*. (1991), in silages produced with low density, as those obtained in this study with dehydrated tomato waste, whose values ranged from 349.7 to 271.7 kg of $FM.m^{-3}$, the probability of containing residual air in the silage mass and lower anaerobic stability of silage, with a consequent increase in silage DM losses.

In the effluent production and gas loss there were a linear reduction (p<0.01) of 0.406 kg $tonne^{-1}$ FM and of 0.23% of the DM in the form of gases in the silages at each hour of increase in the dehydration time of the tomato waste (Table 1). A maximum DM loss (p<0.01) of 7.00% and minimum recovery of DM of 91.0% were found at 8.10 and 40.6 h of dehydration times of the tomato waste, respectively (Table 1).

Table 1 - Density, fermentation losses, dry matter recovery and pH of cassava peels silage with tomato waste submitted to different dehydration times

Item	Dehydration times (h)					SEM	p-value	
	0	4	24	60	96		L	Q
Density (kg $FM.m^3$)[1]	708.6	349.7	355.3	284.3	271.7	3.220	0.000	0.000
Effluent loss (kg $tonne^{-1}$ of FM)[2]	70.7	3.64	3.59	0.89	0.88	0.365	0.000	0.000
Gas loss (% DM)[3]	32.9	10.6	8.33	1.38	1.38	0.374	0.002	0.009
Total DM loss (%)[4]	3.57	10.2	10.3	2.79	3.26	0.930	0.000	0.003
DM Recovery (%)[5]	97.8	93.7	86.0	96.4	97.5	1.261	0.038	0.001

FM, Fresh matter; SEM, Standard error of mean; L, Linear effect; Q, Quadratic effect; DM, Dry matter.
[1]$y = 501.57 – 2.9252x$; [2]$y = 30.88 – 0.406x$; [3]$y = 19.52 – 0.2337x$; [4]$y = 7.4 + 0.0113x – 0.0007x^2$; [5]$y = 94.918 – 0.2029x + 0.0025x^2$

In the ensiling process, the increased quantities of effluents, gases and DM loss is directly related to the moisture content of the ensiled forage, according to McDonald (1991). The main factor contributing to the reduction of fermentative losses in the cassava peels ensiling with tomato waste was the dehydration process, absorbing almost all the moisture of the ensiled mass, leading to the production of a haylage rather than silage. This result was positive, since it is related to the quality of the silage fermentation (Jobim & Nussio, 2013), since the reduction of the losses by gases indicates the action of lactic acid bacteria (LAB) and inhibition of gas-producing microorganisms (enterobacteria and clostridia bacteria), which develop in poorly fermented silages.

The chemical composition of silages was changed by the dehydration times of tomato waste, with a linear increase ($p<0.01$) of 0.44% for the DM contents at each hour of increase in the dehydration time (Table 2). This result could be explained by the high DM content of the material (cassava peels and tomato waste) at ensilage, ranging from 31.0% (without dehydration) to 87.0% (96 h of dehydration). Due to the high moisture content of the tomato waste (94.0%), dehydration allowed better conservation of the ensiled mass. The cassava peels ensiled with the dehydrated tomato waste showed a DM content ranging to 62.0-84.0%, that were more similar to a product called "haylage" (moisture less than 50%) than to a proper silage (moisture higher than 50%).

The DM content of 27.0% found to the cassava peel ensiled with tomato waste without dehydration was similar to that obtained by Napasirth *et al.* (2015), of 27.0% for cassava peels silage. Lounglawan *et al.* (2010) verified high DM content (44.0%) at 28 days of ensiling of the cassava peels with corn straw and brewery residue; as well as Galló *et al.* (2017) that obtained 41.0% in the tomato pulp silage with corn grain. Although the higher value, this DM content is still lower than that recorded in the silages with dehydrated tomato waste used in this study. According to McDonald *et al.* (1991), the DM content is positively related to the fermentation time, which could explain the results obtained in this study (60 days of ensiling) compared to those of Lounglawan *et al.* (2010).

The OM and NFC contents showed a quadratic behavior ($p<0.01$), with maximum values of 93.0% and 66.0% at 8.38 and 7.35 h of dehydration of the tomato waste, respectively (Table 2). This maximum OM content was higher than that reported by Napasirth *et al.* (2015), of 65.0%, when evaluating cassava peels ensiling with bacterial inoculant. The maximum NFC content found in this study was higher than that obtained by Pimentel *et al.* (2017), of 61.0%, when they evaluated the industrial residue silage of tomato with 23.0% of crude glycerin. These results were positive since the dehydration of the tomato waste promoted an increase in the energy components (OM and NFC) and silage proteins, responsible for improving animal performance; and reduction of fibrous components, which in a ruminant diet when in high concentrations could limit DM intake.

Table 2 - Chemical composition of cassava peels silage with tomato waste submitted to different dehydration times

Item	Dehydration times (h)					SEM	p -value	
	0	4	24	60	96		L	Q
DM (%)[1]	26.8	62.3	65.0	84.0	84.3	0.124	0.000	0.000
OM (%)[2]	89.3	93.7	93.8	91.6	91.3	0.303	0.000	0.000
CP (%)[3]	9.97	8.66	9.88	13.9	12.6	0.523	0.000	0.000
EE (%)[4]	1.55	0.93	1.67	1.97	2.07	0.110	0.000	0.000
NFC (%)[5]	56.1	68.2	68.3	57.3	56.3	1.539	0.000	0.000
NDF (%)[6]	21.7	15.9	13.9	18.3	20.3	0.778	0.000	0.042
ADF (%)[7]	14.9	10.7	9.65	12.7	13.7	0.524	0.000	0.021
Ash (%)[8]	10.7	6.34	6.20	8.44	8.72	0.451	0.000	0.000

SEM, Standard error of mean; L, Linear effect; Q, Quadratic effect; DM, Dry matter; OM, Organic matter; CP, Crude protein; EE, Ether extract; NFC, Non-fibrous carbohydrates; NDF, Neutral detergent fiber; ADF, Acid detergent fiber.

[1]$y = 47.415 + 0.4437x$; [2]$y = 88.078 + 1.2531x - 0.0748x^2$; [3]$y = 9.1394 + 0.0451x + 0.0183x^2$; [4]$y = 1.4396 - 0.053x + 0.0075x^2$; [5]$y = 52.686 + 3.5906x - 0.2443x^2$; [6]$y = 24.813 - 2.3295x + 0.1436x^2$; [7]$y = 16.631 - 1.4634x + 0.0898x^2$; [8]$y = 11.922 - 1.2531x + 0.0748x^2$

The contents of CP, EE, NDF, ADF, and ash showed a quadratic behavior ($p<0.01$) with minimum contents of 9.00% of CP, 1.00% of EE, 15.0% of NDF, 10.7% of ADF, and 7.00% of ash when the tomato waste were submitted to the dehydration at 1.23 h, 3.53 h, 8.11 h, 8.15 h, and 8.38 h, respectively (Table 2). Although silages of cassava peels and dehydrated tomato waste up to 1.23 h showed a reduction in protein, they were higher than the minimum recommended by Van Soest (1994) of 7.00%, required by ruminal bacteria. In addition, at 60 h of dehydration, protein contents higher than control silage were recorded. This result was higher than those reported by Santos *et al*. (2009), of 4.00% CP in sugar cane silage with *L. buchneri*; as well as Napasirth *et al*. (2015), of 1.00% CP; Pimentel *et al*. (2017), of 7.00% CP; and by Galló *et al*. (2017), of 15.0%. It can be inferred that these results are related to the low content of fibrous compounds of the cassava peels and high protein content of the tomato waste. Napasirth *et al*. (2015) verified NDF and ADF content in cassava peels of 37.0 and 23.0%, respectively. However, in the fresh tomato residue, Galló *et al*. (2017) verified CP contents of 20%; while in the dehydrated tomato residue for 4.00 h.

Although the minimum values of fibrous components (NDF and ADF) recorded in the silages of this study; these results were higher to those obtained by Napasirth *et al*. (2015), of 37.0% NDF and 22.0% ADF; by Lounglawan *et al.* (2011), of 68.0% NDF and 32.0% ADF. To allow stimulation of rumination and to prevent metabolic disturbances in ruminant animals, the National Research Council (NRC, 2001) recommends a minimum of 25.0% NDF in the DM dietary, with at least 75.0% of that NDF coming from long or coarsely chopped forage. Thus, to attach adequate protein and fiber content, the silage of the present study could compose part of the roughage of a total mixed ration of the ruminant.

The "satisfactory" classification for most of the silages tested was recorded in the sensory evaluation of the characteristics associated with the conservation, except for cassava peel ensiling with dehydrated tomato waste for 60 h, which was classified as "good to very good" (Table 3). In the cassava peel ensiling with dehydrated tomato waste, more than 50% of the evaluators considered the silage odor as "pleasant". The DM content in silage manipulation was considered "adequate" by more than 50% of the evaluators only in the control silages and with dehydrated tomato wastes for 4 h. This result showed that the dehydration of the tomato waste does not affect the odor of the cassava peel silages, with the "typical acid odor" remaining. However, the DM content during the manipulation showed low moisture content, which decharacterized it as silage, but evidenced a new product, called "haylage", which has low moisture without changing the nutritive value of the forage.

Table 3 - Sensory evaluation about characteristics associated with the conservation of cassava peels silage with tomato waste submitted to different dehydration times

Dehydration times (h)	Total Score	Classification	Parameter
0	20	Satisfactory	15 a 20
4	19	Satisfactory	15 a 20
24	20	Satisfactory	15 a 20
60	22	Good to Very Good	21 a 25
96	20	Satisfactory	15 a 20

In relation to the characteristics associated with the sanitary aspect, most of the evaluators classified the silages as "good to very good", except for the tomato waste submitted to 24 h of dehydration, which was classified in "assessing the possibilities of risk" (Table 4). In general, the silages classified as "good to very good" indicate that the conservation process from the cutting, compacting and sealing of the silos was carried out adequately, preserving the material. The results of the sensorial analysis demonstrated the importance of this evaluation to recommend the correct form of conservation. According to Teixeira and Fontaneli (2017) and Jian *et al*. (2015) there was a higher correlation

Table 4 - Sensory evaluation about characteristics associated with a sanitary aspect of cassava peels silage with tomato waste submitted to different dehydration times

Dehydration times (h)	Total Score	Classification	Parameter
0	-2	Good to Very Good	0 a -5
4	-5	Good to Very Good	0 a -5
24	-9	Assessing the possibilities of risk	-5 a -10
60	-4	Good to Very Good	0 a -5
96	-4	Good to Very Good	0 a -5

between qualitative (sensorial) and quantitative analysis (chemical composition); in other words, the sensorial attributes (odor, color, texture, and fungi presence) may interfere directly on the acceptability of the diet by the animal.

CONCLUSIONS

Cassava peel ensiling with tomato waste submitted to dehydration time of 7.35 hours is enough to promote an adequate non-fibrous carbohydrates content, associated with lower losses in the fermentation process and satisfactory sensory attributes.

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