

Silage from heart-of-palm waste produced from Alexander palm tree[⌘]

Ensilaje de residuos de palmito producidos a partir de Palma Real

Silagem de resíduos de palmito produzidos a partir da Palmeira Real

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⌘ To cite this article: Bayão GFV, Queiroz AC, Pimentel RM, Freitas SG, Sousa KRS, Cardoso LL, Marcondes MI, Batalha CDA, Oliveira GB, Silva TE. Silage from heart-of-palm waste produced from Alexander palm tree. Rev Colomb Cienc Pecu 2019; 32(1):64-70.

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(Received: October 26, 2016; accepted: April 10, 2018)

Abstract

Background: Production of heart-of-palm from Alexander palm tree generates a waste that could be used as silage for feeding ruminants.

Objective: To evaluate the chemical composition, fermentation parameters, and quality of silage made from waste of heart-of-palm production using Alexander palm.

Methods: Three types of silage made from waste of heart-of-palm production were evaluated: 1) leaf silage, 2) sheath silage, and 3) compound (leaf + sheath) silage. The processed waste was packed in experimental silos and distributed in a completely randomized design with 10 replications. Means were compared pairwise using Tukey's test at the 5% significance level.

Results: Leaf silage had the highest pH ($p < 0.05$) and the lowest ammonia nitrogen ($p < 0.05$) in relation to the other silages. No difference was observed ($p > 0.05$) for lactic and butyric acids, whereas acetic acid was higher ($p < 0.05$) in the sheath and compound silages. Dry matter and crude protein contents were the highest ($p < 0.05$) in leaf silage. Neutral detergent fiber was higher ($p < 0.05$) in sheath silage, followed by leaf and compound silages, respectively. The highest lignin content ($p < 0.05$) was observed in sheath silage.

Conclusions: Based on the fermentative parameters, waste from heart-of-palm from Alexander palm tree has potential for silage production. However, differences in silage composition at the time of feeding ruminants should be considered.

Keywords: *Archontophoenix alexandrae*, byproduct, fermentation, forage, organic acid, pH.

Resumen

Antecedentes: Los residuos de la producción de palmito de Palma Real podrían utilizarse como ensilaje para alimentación de rumiantes.

Objetivo: Determinar la composición, parámetros químicos de fermentación, y calidad del ensilaje elaborado a partir de residuos procedentes de la producción de palmito de Palma Real.

Métodos: Tres tipos de ensilaje hechos con los residuos generados a partir de la producción de palmito fueron evaluados: 1) ensilaje de hojas, 2) ensilaje de vainas, y 3) ensilaje compuesto (hojas + vainas). Los residuos tratados fueron empacados en silos experimentales y distribuidos en un diseño completamente al azar con 10 repeticiones. Las medias fueron comparadas mediante la prueba de Tukey, con un nivel de significancia del 5%. **Resultados:** El ensilaje de hojas mostró el pH más alto ($p < 0,05$) y el nivel más bajo de nitrógeno amoniacal ($p < 0,05$) en comparación con los otros ensilajes. No se observaron diferencias ($p > 0,05$) en los ácidos láctico y butírico, mientras que el ácido acético fue mayor en el ensilaje de vainas y en el compuesto en relación con el otro ensilaje. La materia seca (MS) y el contenido de proteína cruda (PC) fueron mayores ($p < 0,05$) en el ensilaje de hojas. Los contenidos de fibra detergente neutra fueron mayores ($p < 0,05$) en los ensilajes de vainas, seguido por los ensilajes de hojas y compuesto, respectivamente. El contenido de lignina fue más alto ($p < 0,05$) en el ensilaje de vainas.

Conclusiones: Según los parámetros fermentativos, los residuos de la producción de palmito de Palma Real tienen potencial para la producción de ensilaje. Sin embargo, se deben considerar las diferencias en la composición de los ensilajes al momento de alimentar rumiantes.

Palabras clave: ácidos orgánicos, *Archontophoenix alexandrae*, fermentación, forraje, pH, subproductos.

Resumo

Antecedentes: Resíduos da produção de palmito da palmeira Real são um problema para a agroindústria devido sua falta de utilização e o seu uso na forma de silagem pode ser uma alternativa na alimentação de ruminantes.

Objetivo: Avaliar a composição química e os parâmetros fermentativos, e verificar a qualidade da silagem produzida a partir do resíduo da produção de palmito da Palmeira Real Australiana.

Métodos: Foram avaliadas três tipos de silagem de resíduo da produção de palmito da Palmeira Real: silagem de folha, silagem de bainha e silagem da composta (folha + bainha). O resíduo processado foi acondicionado em silos experimentais e distribuídos em um delineamento inteiramente casualizado com 10 repetições e as médias comparadas pelo teste de Tukey a 5% de significância.

Resultados: A silagem de folha apresentou maior pH ($p < 0,05$) em relação as demais silagens, enquanto para o nitrogênio amoniacal ($p < 0,05$), apresentou menor teor em relação as demais silagens. Não observou-se diferença ($p > 0,05$) para os ácidos láctico e butírico, enquanto o ácido acético foi maior para as silagens de bainha e composta em relação as demais silagens. O teor de matéria seca (MS), proteína bruta (PB) foi maior ($p < 0,05$) na silagem de folha em relação as demais silagens. A fibra em detergente neutro analisada estimada apresentou maiores valores ($p < 0,05$) para a silagem de bainha, seguida pela silagem de folhas e silagem composta, respectivamente. O teor de lignina foi maior ($p < 0,05$) para a silagem de bainha.

Conclusões: De acordo com os parâmetros fermentativos, os resíduos da produção de palmito da Palmeira Real apresentam potencial para a produção de silagem. No entanto, as diferenças na composição das silagens devem ser consideradas quando oferecidas para animais ruminantes.

Palavras-chave: ácidos orgânicos, *Archontophoenix alexandrae*, fermentação, forragem, subprodutos, pH.

Introduction

World production of heart of palm has shifted from extractive to cultivated due to current extraction prohibition in many forests, consumer market demands for sustainable products, and reduction of natural palm reserves. Some species have been cultivated to explore its economic feasibility and to avoid possible extinction of some species, as is the case of Alexander palm (*Archontophoenix alexandrae*).

There are approximately 39 palm tree species in the Atlantic forest, in which Juçara (*Euterpe edulis*; Fermino et al., 2014), açai (*Euterpe oleracea*), and pupunha (*Bactris gasipaes*) species stand out for the production of heart of palm. To exploit heart of palm, however, the palm tree must be cut down to extract the material. Processing of the Alexander palm for heart-of-palm production discards the leaves, sheath, and part of the stems, which are considered waste without commercial value for the agroindustry (Bayão et al., 2014). One plant yields approximately 0.4 kg of commercial heart of palm and generates approximately 13 kg of waste, including leaves, stems, and sheaths (Fermino et al., 2014), corresponding to 96.9% of waste per plant. In addition, the waste is a source of contamination.

Degradation of the organic wastes depends on factors such as the carbon/nitrogen ratio, physicochemical and biological characteristics, and temperature and moisture of the soil (Figueiredo et al., 2012). Because of the difficulty of degradation, areas in the production sites are used to store waste that could be used for other purposes. Therefore, the use of waste from heart-of-palm production in ruminant feeding could be an alternative to discarding waste in the environment, representing an economic advantage because the waste is low cost and could be used as a fiber source for ruminants (Bayão et al., 2014).

Given that the waste from heart-of-palm production from the Alexander palm has high lignin and low protein content, this study was undertaken to evaluate the chemical composition, fermentation parameters, and quality of its silage.

Materials and methods

Ethical considerations

All procedures were conducted in accordance with the guidelines of the Brazilian College of Animal Experimentation (Code of Practice for the Care and Use of Animals for Experimental Purposes) and were reviewed and approved by the Ethics Committee on Use of Animals for Research of the Federal University of Viçosa. The project and registration numbers are 166682 and 50448459244, respectively.

Location

The experiment was conducted in the Animal Nutrition Laboratory of the Department of Animal Science at the Federal University of Viçosa (UFV), located in Viçosa, Minas Gerais, Brazil.

The waste from heart-of-palm production of Alexander palm used in this study was provided by the Real Palm® canned heart-of-palm industry located in Cajuri, Minas Gerais, Brazil.

Residue silage preparation

The waste consisted of the sheaths that surround the heart of palm, and the palm tree leaves. Three types of silage were used: leaf silage, sheath silage, and compound (leaf + sheath) silage. The compound silage was formulated proportionally according to the average percentage of leaves and sheaths present in an Alexander palm tree, 453.0 g/kg and 547.0 g/kg, respectively, on a natural matter basis.

The waste was processed using a knife mill (Cremasco, Itapira, SP, Brazil) to a theoretical particle size of 2 to 3 cm and packed in 30 experimental polyvinyl chloride (PVC) silos (5 cm diameter × 50 cm length), equipped with Bunsen valves to allow the escape of fermentation gases. The roughage was compacted manually to reach a fixed density between 450 kg/m³ and 600 kg/m³ of natural matter. Waste samples were collected to determine the chemical composition before ensiling (Table 1).

Chemical analyses and fermentation parameters

After 40 days of storage, silos were opened and the silage was weighed, deteriorated parts were discarded, the content was homogenized, and samples were collected for analyses.

For the evaluation of pH, ammonia nitrogen, and fatty acids from fermentation (lactate, acetate, propionate, and butyrate), 10 g silage samples were collected after silo opening. Samples were diluted in 90 mL distilled water, homogenized in an industrial blender (Metvisa, Brusque, SC, Brazil) for 1 min, and filtered through a fine sieve. Afterwards, the pH of this solution was measured. Ammonia nitrogen in the extract filtrate was analyzed using

a distiller with a Kjeldahl-type condenser (Tecnal – TE 0364, Piraciaba, SP, Brazil), (Method – 1.6R, AFIA), following Cunniff (1995) methodology. An aliquot of the filtrate extract prepared from a chopped silage sample was used for determination of ammonia nitrogen concentration through distillation and titration, where the ammonium ion was converted back to ammonia, and the titrant volume was recorded for calculation of the result. One milliliter of a 20% metaphosphoric acid solution was added to 2 mL of this filtrate and the solution was centrifuged at 3,000 rpm for 15 min, and then organic acids were determined by high-performance liquid chromatography (HPLC) following the recommendations of Wilson (1971) .

Fresh and ensiled waste samples were dried in a forced-air oven (65 °C/72 h; Marconi - MA035/1152, Piracicaba, SP, Brazil), ground through a knife mill (1 mm; Solab - SL32, Piracicaba, SP, Brazil), packed in plastic containers, and subsequently the dry matter (DM) contents (Method 967.03 - AOAC, 1990), crude protein (CP) (Method 981.10 - AOAC, 1990), and ether extract (EE) (Method 920.29 - AOAC, 1990) were evaluated. To determine the neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents, the methodology of Van Soest et al. (1994) was used with the modifications proposed in the Ankon device manual (Ankon Technology Corporation, Macedon, New York, US). Corrections of NDF and ADF for ash and protein (ap) were performed according to Mertens (2002) and Licitra et al. (1996), respectively. Acid detergent lignin (ADL) was determined according to method 973.18 (AOAC, 2002), in which the vADF residue was treated with 72% sulfuric acid. Non-fibrous carbohydrates (NFC) were calculated using the equation $NFC = OM - (NDF_{cp} + CP + EE)$, where OM = organic matter and NDF_{cp} = neutral detergent fiber.

The analysis of indigestible neutral detergent fiber (iNDF) was obtained after in situ incubation in triplicate inside non-woven fabric bags [“TNT”, 100 g m-2 for 240 h in a bovine rumen (Casali et al., 2008).

Afterwards, the NDF was analyzed following Mertens (2002) to quantify the iNDF content.

Experimental design and statistical analyses

A completely randomized experimental design was used, with 10 replicates for each of the three treatments, totaling 30 experimental silos. The experimental model was:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

Where:

Y_{ij} = experimental response that received treatment i in replicate j.

μ = overall constant.

τ_i = effect of treatment i (waste).

ε_{ij} = experimental error.

Data were analyzed using SAS[®] software version 9.2 (SAS Institute Inc., Cary, NC, USA, 2008), and means were compared by Tukey’s test at 5% significance.

Results

The composition of the residues in the natural material is shown in Table 1.

Table 1. Chemical composition of wastes from heart-of-palm production using Alexander palms *in natura*.

Variable	Leaf	Sheath	Compound
Dry matter	307.1	203.4	201.1
Organic matter ¹	948.3	951.1	960.4
Crude protein ¹	76.4	31.2	51.4
Ether extract ¹	7.2	2.9	6.3
Non-fiber carbohydrates ¹	157.9	164.2	198.1
Neutral detergent fiber (ap) ¹	707.1	753.9	704.1
Acid detergent fiber (ap) ¹	467.5	479.2	442.3
Lignin ¹	106.4	122.8	114.3
Neutral detergent insoluble protein ²	272.3	206.7	243.6
Acid detergent insoluble protein ²	155.1	129.2	140.2

¹ g/kg of dry matter; ² Percentage of crude protein; ap = corrected for ash and protein.

Crude protein content was higher for leaf silage, followed by compound and then sheath silage ($p < 0.05$; Table 2). Both neutral detergent insoluble protein and acid detergent insoluble protein (ADIP) were higher in the sheath silage, followed by the compound and then leaf silage (Table 2). The NDF and iNDF contents were higher for sheath silage (Table 2). There was no difference ($p > 0.05$) between lignin content of the leaf and compound silages; however, both were lower ($p < 0.05$) than sheath silage (Table 2).

The highest pH value ($p < 0.05$) was observed in the leaf silage, whereas that of the compound and sheath silages did not differ ($p > 0.05$) (Table 3).

The lowest values ($p < 0.05$) for ammonia nitrogen were in the leaf silage, followed by the compound and then the sheath silage (Table 3). No statistical difference was observed ($p > 0.05$) in the concentration of lactic acid between silages (Table 3), although the concentration of lactic acid was higher in relation to the other acids originating from fermentation. No difference was detected ($p > 0.05$) for acetic acid content in the sheath and compound silage; however, their values were higher ($p < 0.05$) than that of leaf silage (Table 3). The concentration of butyric acid was not statistically different ($p > 0.05$) between the three waste silages, with values lower than 0.5 g/kg in all three (Table 3).

Table 2. Chemical composition of silages from heart-of-palm waste using Alexander palm.

Variable	Waste						
	Leaf	SEM	Sheath	SEM	Compound	SEM	p value
Dry matter	411.1 ^a	±0.09	361.4 ^b	±0.16	353.9 ^c	±0.10	< 0.01
Organic matter [†]	936.1 ^c	±0.07	956.5 ^a	±0.09	946.2 ^b	±0.09	<0.01
Crude protein [†]	93.1 ^a	±0.06	37.2 ^c	±0.05	67.4 ^b	±0.07	< 0.01
Ether extract [†]	14.6 ^a	±0.022	4.8 ^c	±0.004	10.3 ^b	±0.005	< 0.01
Non-fiber carbohydrates [†]	116.4 ^c	±0.14	124.7 ^b	±0.24	186.7 ^a	±0.20	< 0.01
Neutral detergent fiber (ap) [†]	712.3 ^b	±0.10	789.1 ^a	±0.12	681.6 ^c	±0.22	< 0.01
Acid detergent fiber (ap) [†]	465.3 ^b	±0.24	494.8 ^a	±0.36	432.9 ^c	±0.25	< 0.01
Lignin [†]	109.0 ^b	±0.15	127.2 ^a	±0.11	114.3 ^b	±0.15	< 0.01
Indigestible neutral detergent fiber [†]	324.1 ^c	±0.17	408.1 ^a	±0.20	384.3 ^b	±0.23	< 0.01
Neutral detergent insoluble protein ²	329.0 ^c	±0.21	407.1 ^a	±0.19	389.2 ^b	±0.40	< 0.01
Acid detergent insoluble protein ²	227.2 ^c	±0.16	284.6 ^a	±0.09	251.0 ^b	±0.14	< 0.01

[†] g/kg of dry matter; ² g/kg of crude protein; ap = corrected for ash and protein.

Means followed by different superscript letters (^{a, b, c}) within the same row are significantly different (p<0.05) by Tukey's test.

Table 3. Qualitative characteristics of silages from heart-of-palm waste using Alexander palm.

Variable	Waste						
	Leaf	SEM	Sheath	SEM	Compound	SEM	p-value
pH	4.3 ^a	±0.04	3.6 ^b	±0.08	3.6 ^b	±0.02	<0.01
Ammonia (NH ₃) ²	10.3 ^c	±0.001	47.4 ^a	±0.001	17.9 ^b	±0.001	<0.01
Lactic acid [†]	37.6	±0.60	48.4	±0.51	55.1	±0.48	0.0947
Acetic acid [†]	26.8 ^b	±0.33	42.3 ^a	±0.57	46.8 ^a	±0.34	0.0094
Propionic acid [†]	13.2 ^b	±0.07	16.4 ^b	±0.14	22.2 ^a	±0.16	0.0002
Butyric acid [†]	0.39	±0.002	0.43	±0.002	0.37	±0.002	0.1209

Means followed by different superscript letters (^{a, b, c}) within the same row are significantly different (p<0.05) by Tukey's test.

[†] g/kg of dry matter; ² g/kg of total nitrogen.

Discussion

According to Jobim et al. (2009), the DM content of an ensiled plant forage should be between 280.0 and 400.0 g/kg. Values below this range could impair silage quality due to growth of microorganisms that compromise quality and promote effluent losses. Thus, the sheath and compound wastes had DM contents that could compromise silage quality (Table 1), although the concentration of water-soluble carbohydrates also influences fermentation (Santos et al., 2006). However, these variables were not evaluated in the present study.

Comparing DM contents of the fresh material (Table 1) to the contents of their respective silage (Table 2) we observed an increase in DM content in silage, which may be related to effluent losses occurring during fermentation, although this variable was not estimated in the present study.

Alexander palm leaves, and consequently leaf silage, have higher CP content than that of the sheath (Tables 1 and 2). Likewise, because the compound silage included leaves, it also had greater CP levels in relation to the sheath silage. In an experiment with enriched wilted peach palm silage, Oliveira et al. (2010) found 45.0 g/kg average CP content, whereas Schmidt et al. (2010) found 46.0 g/kg in silages from the sheath surrounding the heart of peach palms. Neto et al. (2001) studied peach palm silage (stem, leaves, and sheath) with additives (25.0 g/kg sugar, 10 g/kg citrus pulp, and 100 g/kg cornmeal) and observed 102.0 g/kg average CP content; this value was probably

caused by the presence of leaves from peach palms in the silage, as well as protein additives.

The observed lignin values for the three silages were relatively high in comparison to some forage plants used in animal feeding because of the advanced age of the Alexander palms (four years) required to produce heart of palm from this species. It is known that sheaths have higher lignin concentration compared to leaves (Table 2) because of the support function of this substance within the plant.

Values of pH between 3.8 and 4.2 are considered appropriate for well-preserved silages, because plant proteolytic enzymes and enterobacteria are restricted to this range (Tomich et al., 2004), and the sheath and compound silages were close to this range (Table 3). Acidity is considered an important factor in silage preservation because it inhibits or controls the development of harmful microorganisms, such as the bacterial genus *Clostridium*, which is sensitive to pH below 4 (Whittenbury et al., 1967).

Oliveira et al. (2010) found 70.7 g/kg ammonia nitrogen in wilted peach palm silage. According to Van Soest (1994), low ammonia nitrogen content in the silage, below 100.0 g/kg of the total nitrogen, indicates that the fermentation process did not result in an excessive breakdown of proteins into ammonia, and amino acids constitute the largest part of the non-protein nitrogen. Thus, ammonia nitrogen content higher than 100.0 g/kg could represent low quality silage, because the higher the ratio, the more protein has been degraded, and the lower the quality (Jianxin and Jun, 2002). However, all silages displayed ammonia nitrogen contents lower than 100.0 g/kg (Table 3), characterizing the silage, from this perspective, as good quality.

The concentration of lactic acid in the silages was higher in relation to the other acids from fermentation. This is a positive factor, because crop residues generally do not present favorable lactic fermentation, and this could impair the final quality of the silage. Despite the contribution of butyric, acetic, and propionic acids to the pH decrease, lactic acid plays a more efficient role in this process because of its greater dissociation in relation to the other acids (Silva et al., 2011).

The silages with sheath in their composition had higher ($p < 0.05$) acetic acid content (Table 3) compared to that of leaf silage. Lactic acid bacteria can be homofermentative, i.e., able to produce only lactic acid, whereas the heterofermentative lactic acid bacteria produce lactic and acetic acids (Lopes and Evangelista, 2010). Thus, the silages with higher sheath content likely influenced the development of heterofermentative lactic acid bacteria, increasing the acetic acid content. Acetic acid assists in the aerobic stability of the silage (Danner et al., 2003), thus maintaining its quality. Plant residues, usually with low nutritional quality, especially substrates for fermentation, tend to have higher butyric acid content. In addition, despite the low DM content present in the fresh sheath and compound (Table 1), which might benefit butyric acid production, these acids were found at low levels (Table 3).

In conclusion, according to the fermentative parameters, waste from heart-of-palm production using Alexander palms has potential for silage production. However, the differences in the composition of silages at the time of ruminant feeding should be considered, mainly with regard to lignin and protein content.

Acknowledgments

At Fundação de Amparo à pesquisa do Estado de Minas Gerais (FAPEMIG) for financial support. Thanks to Prof. Carlos Machado for supplying the residue from palm production.

Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

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