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Literature Reviews

Tropical grasses used in haylage production: An integrative review

Pastos tropicales utilizados en la producción de henolaje: Una revisión integradora

Gramíneas tropicais utilizadas na produção de pre-secado: Uma revisão integrativa

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Abstract

Background: Haylage is a method of preserving forage with good nutritional value, involving the partial removal of water from the plant through the wilting technique. **Objective:** To identify the main tropical grasses used in haylage production, we conducted an integrative review. **Methods:** Using the PVO mnemonic strategy, which consists of population (P): tropical forage grasses, variables (V): haylage production, and outcome (O): qualitative parameters, we formulated the following question: "What are the main tropical forage grasses used in haylage production?" Papers were selected from three databases: SCOPUS (Elsevier), Web of Science, and Science Direct. **Results:** The search identified 1,049 articles, but only 10 were deemed suitable and included for data extraction. Among the grasses used, 50% belonged to *Cynodon* spp., 30% to *Panicum maximum*, 10% to *Festuca rubra*, 10% to *Dactylis glomerata*, and 10% to *Trisetum flavescens*. **Conclusion:** The main forage grasses used in pre-dried silage production belong to the genera *Cynodon* spp. and *Panicum* spp., with Tifton-85 grass and Tanzania grass being the most notable representatives.

Keywords: *conservation; forage; grass; hay; haylage; nutritional characteristics; pre-dried silage; tropical grasses; wilting.*

Resumen

Antecedentes: El henolaje es un método de conservación de forraje con buen valor nutritivo, que consiste en la retirada parcial de agua de la planta mediante la técnica de marchitez. **Objetivo:** Para identificar las principales gramíneas tropicales utilizadas en la producción de henolaje, realizamos una revisión integradora. **Métodos:** A través de la estrategia mnemotécnica PVO, que consta de población (P): pastos forrajeros tropicales; variables (V): producción de henolaje; y resultados (O): parámetros cualitativos, formulamos la

siguiente pregunta: "¿Cuáles son las principales gramíneas forrajeras tropicales utilizadas en la producción de henolaje?" Se seleccionaron artículos de tres bases de datos: SCOPUS (Elsevier), Web of Science y Science Direct. **Resultados:** La búsqueda identificó 1.049 artículos, pero solo 10 fueron considerados adecuados e incluidos en la extracción de datos. Entre las gramíneas utilizadas, el 50% pertenecía al género *Cynodon* spp., el 30% a *Panicum maximum*, el 10% a *Festuca rubra*, el 10% a *Dactylis glomerata* y el 10% a *Trisetum flavescens*. **Conclusión:** Las principales gramíneas forrajeras utilizadas en la producción de henolaje pertenecen a los géneros *Cynodon* spp. y *Panicum* spp., destacando el pasto Tifton 85 y el pasto Tanzania.

Palabras clave: *conservación; características nutricionales; ensilaje; ensilaje pre-secado; forraje; heno; marchitez; pasto; pastos tropicales.*

Resumo

Antecedentes: O pré-secado é um método de preservação de forragem com bom valor nutritivo, que consiste na retirada parcial de água da planta por meio da técnica de emurchecimento. **Objetivo:** Identificar as principais gramíneas tropicais utilizadas na produção de pré-secado, realizamos uma revisão integrativa. **Métodos:** Utilizando a estratégia mnemônica PVO, que consiste em população (P): gramíneas forrageiras tropicais; variáveis (V): produção de pré-secado; e resultados (O): parâmetros qualitativos, formulamos a seguinte questão: "Quais são as principais gramíneas forrageiras tropicais utilizadas na produção do pré-secado?" Foram selecionados artigos em três bases de dados: SCOPUS (Elsevier), Web of Science e Science Direct. **Resultados:** A busca identificou 1.049 artigos, mas apenas 10 foram considerados aptos e incluídos para extração de dados. Entre as gramíneas utilizadas, 50% pertenciam ao gênero *Cynodon* spp., 30% a *Panicum maximum*, 10% a *Festuca rubra*, 10% a *Dactylis glomerata* e 10% a *Trisetum flavescens*. **Conclusão:** As principais gramíneas forrageiras utilizadas na produção de pré-secado pertencem aos gêneros *Cynodon* spp. e *Panicum* spp., destacando-se o capim-tifton 85 e o capim-tanzânia.

Palavras-chave: *conservação; características nutricionais; feno; forragem; gramíneas; gramíneas tropicais; murcha. silagem; silagem pré-seca.*

Introduction

Feeding is one of the most important aspects within the animal production system, and it is essential to search for low-cost alternatives applicable to the field that maximize animal performance. Due to seasonal variations throughout the year, the forage supply to ruminants is limited. This scenario leads to a drop in animal productivity, and one of the alternatives to mitigate productive losses during this dry period is the conservation of forage (Fluck *et al.*, 2018).

Haylage (pre-dried silage) is a way of preserving forage with good nutritional value, consisting of the partial removal of water from the plant through the wilting technique, with dry matter levels between 400 and 600 g/kg DM (Edvan *et al.*, 2023). The technique aims to control the fermentation process during conservation and reduce undesirable secondary fermentations (Horst *et al.*, 2016).

The choice of forage species for making haylage depends on the region's climatic conditions, soil fertility, applied technology, nutritional requirements of the animals, and the economics of the process. Pre-dried grasses or legumes from temperate climates have lower fiber content and better fiber quality when compared to pre-dried tropical forages (Jimenez, 2013).

The microbiome present in forage promotes the growth of bacteria that produce desirable compounds in anaerobic fermentation, contributing to a balanced pH and maintaining the nutritional quality and stability of the product (Costa *et al.*, 2019). In European countries, pre-dried feed is widely used in horse feeding (Muller, 2011). In Brazil, haylage is primarily used for feeding ruminants, as it allows for the storage of surplus forage for later use during periods of scarcity (Pereira *et al.*, 2007).

Research comparing the two forage preservation techniques, haying and pre-drying, showed positive results regarding the effectiveness of pre-drying as a means of preserving forage quality even in colder environments (Borreani *et al.*, 2007). However, to provide a broader view of the results available through primary studies extracted from the databases and to provide information and suggestions for future research, the objective of this integrative review was to identify the main tropical forage grasses used in haylage production.

Methods

The present study consists of an integrative review that aims to generate a broader view of the main grasses used in the pre-drying conservation technique. Currently, this is the broadest method of review and research for defining current knowledge on a specific topic.

Preparation of the protocol and guiding question

The integrative review protocol was developed so that the research conducted has a high-standard scientific basis, extracting accurate data using a search strategy that meets the established objective. To ensure that the terms used for the search were non-random, an analysis was made of each scientific article published on the topic under study. To elaborate the guiding question of this review, the PVO mnemonic strategy was adopted, which consists of population (P): tropical forage grasses; variables (V): haylage production; and outcome (O): qualitative parameters, leading to the following question: "What are the main tropical forage grasses used in haylage production?"

Database search

The selected scientific papers were searched until September 8, 2023, in three databases that included studies answering the guiding question: SCOPUS (Elsevier), Web of Science, and Science Direct. The CAPES journal portal was used to access the databases through the Federal University of Piauí (UFPI, Brazil). Table 1 shows the terms used in the search and their synonyms.

The articles were available in electronic databases, and articles that answered the guiding question were selected. Studies were considered important when (1) they contained primary research published as a scientific article, (2) they included the use of forage grasses in the production of pre-dried silage, and (3) they analyzed the chemical and fermentative characteristics of the pre-dried grass. Duplicate articles in the same or different databases were considered only once. Articles in the form of letters to the editor, abstracts, theses and dissertations, books or book chapters, lectures, other reviews, and correspondence were discarded. Articles that focused on silage and other forms of conservation that were not pre-dried, as well as fresh forage that was not tropical grasses, were excluded.

Table 1. Terms used in a unicross and high-sensitivity search to study the main tropical forage grasses used in haylage production.

	Keywords
Population (P)	**"Tropical forage grasses"** OR "Forage crops" OR "Crops forage" OR "Fodder" OR "Grass" OR "Grasses" OR "Forage grasses" OR "Grasses forage" OR "Pasture" OR "Tropical pasture" OR "Pasture tropical" OR "Tropical" OR "Forages" OR "Forage" OR "Lawn" OR "*Brachiaria*" OR "*Urochloa*" OR "*Panicum*" OR "*Megathyrsus*" OR "*Cynodon*" OR "*Pennisetum*" OR "Foragers" OR "Tropical forages" OR "Forages tropical" OR "Grass tropical" OR "Tropical grass" OR "Guinea grass" OR "*Megathyrsus maximus*" OR "*Andrapogon gayanus*"

Variables (V)	**"Haylage"** OR "Production haylage" OR "Pre dry forages" OR "confection haylage" OR "fodder pre dry"
Outcome (O)	**"Qualitative parameters"** OR "pH" OR "NH3-N" OR "ammonial nitrogen" OR "aerobic stability" OR "ethanol content and organic acids" OR "microbiological determination" OR "chemical composition" OR "determination of dry matter" OR "crude protein" OR "ether extract" OR "dry matter mineral" OR "detergent fiber neutral" OR "acid detergent Fiber OR "total soluble carbohydrates" OR "*In vitro* ruminal degradability" OR "gas production" OR "fermentation parameters"

Data selection and collection

In the first data collection, articles were evaluated by individually reading the title and abstract; then, the exclusion criteria were applied in accordance with the research objective. In the second stage, the selected articles were read in full, undergoing a new screening to identify those relevant to the research. A form was designed to extract data for study purposes, including information about the publication (article title, indexed databases, authors, country, language, and year of publication), the name of the scientific journal, and methodological aspects of the study (description of the experiment, including treatments and experimental period, analyzed variables, and results), as well as the most used grasses in pre-drying, study limitations, and conclusions.

Assessment of included studies

The studies were classified according to their level of evidence, based on the JBI classification of evidence, and only those with Level 2 support were included to ensure a higher level of reliability. The JBI classifies research according to its level of evidence into: 1) experimental studies; 2) quasi-experimental studies; 3) observational and analytical studies; 4) observational and descriptive studies; and 5) expert opinion. To assess the methodological quality of the studies, the CASP instrument was used to evaluate the type of methodological structure (available at: https://casp-uk.net/casp-tools-checklists/), including only those that met the criteria according to the research method presented in each study.

Results

Overall, 1,049 studies were identified, including 1,000 scientific articles. From this total, 50 articles were identified as potentially relevant. After a complete reading and further evaluation based on the guiding question, ten publications were considered suitable and included due to the robustness of their methodology for data extraction (Figure 1). All results presented level 1 evidence. The selected articles covered publications from 2006 to 2023, with 40% published within the last five years. The studies used were conducted in Brazil (8), Italy (1), and the United States (1), and were published in English and Portuguese. Among the selected studies, the duration of the experiments varied from 3 months to 1 year.

Among the forage grasses most used in haylage production, the predominant genera were *Cynodon* spp. (60%) and *Panicum* spp. (30%) (Table 2). The most frequently analyzed chemical composition parameters in pre-dried forage were dry matter (DM, 100%), crude protein (CP, 100%), neutral detergent fiber (NDF, 100%), acid detergent fiber (ADF, 90%), mineral matter (MM, 60%), lignin (LIG, 50%), hemicellulose (HEM, 60%), organic matter (OM, 60%), ether extract (EE, 50%), total carbohydrates (CHO, 30%), and cellulose (CEL, 10%) (Table 3). Fermentative parameters such as pH, soluble carbohydrates (SC), ammonia nitrogen (NH_3-N), lactic acid, acetic acid, butyric acid, and aerobic stability were reported in 80%, 40%, 50%, 40%, 50%, 40%, and 30% of the studies, respectively (Tables 2 and 4).

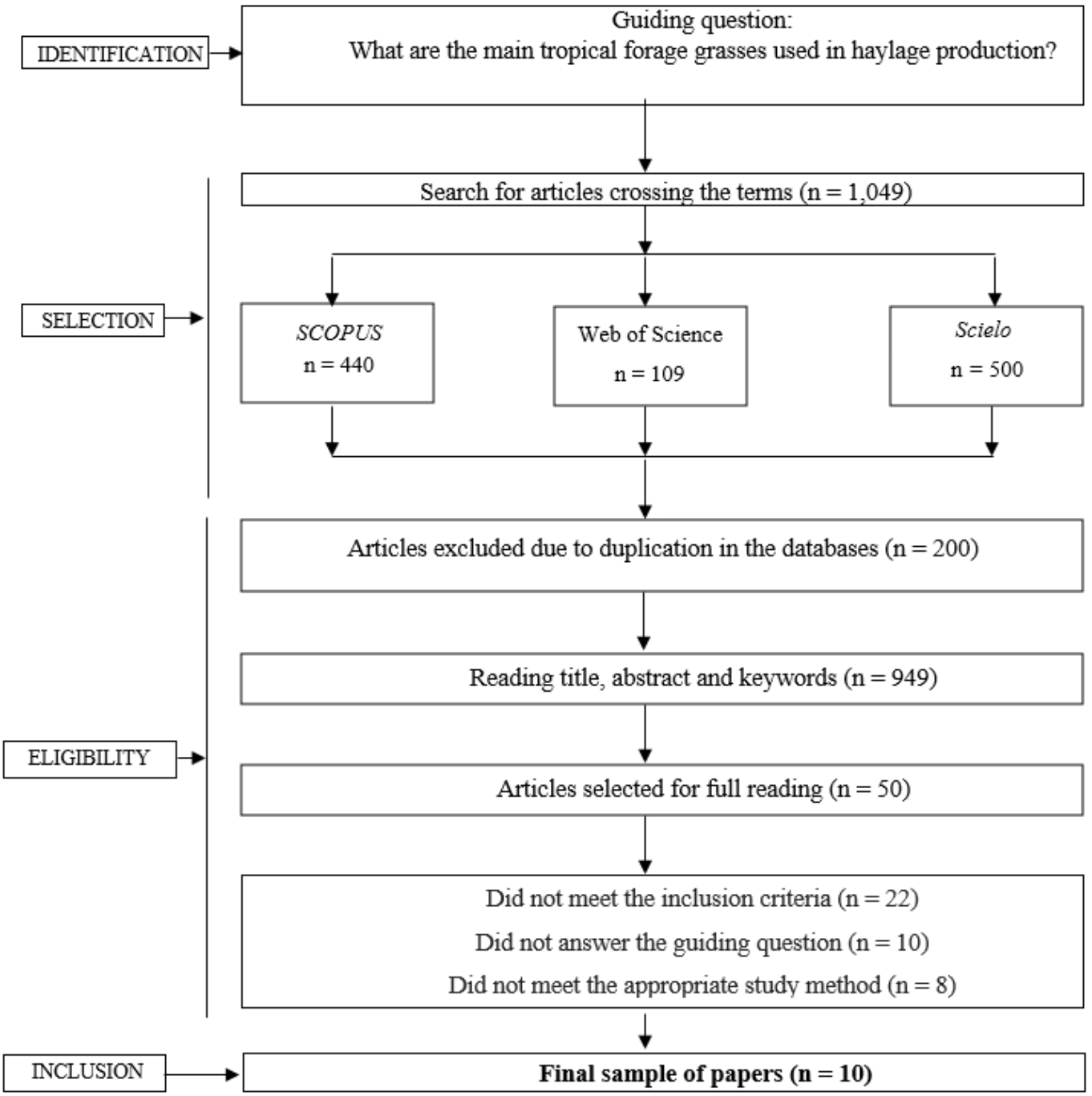

Figure 1. Flowchart of the final sampling selection method used for the integrative review.

Table 2. Main tropical forage grasses used in haylage production.

Author/year	Country	Duration	Common name	Scientific name	Treatments	Level of evidence
Souza *et al.* (2006)	Brazil	90 days	Tifton-85 grass	*Cynodon* spp.	The isonitrogenous diets were formulated to contain approximately 12% CP and a roughage: concentrate ratio of 60:40. As a source of roughage, pre-dried Tifton-85 grass and sorghum silage from the forage hybrid AG 2002 (Agroceres) were used in proportions 100:0, 68:32, 34:66 and 0:100, respectively, based on DM.	1
Gomes *et al.* (2006)	Brazil	65 days	Tifton-85 grass	*Cynodon* spp.	1 - chopped Elephant grass (Pennisetum purpureum Schum. cv. Cameron), of medium maturity, 2 - pre-dried Tifton-85 grass (*Cynodon* spp.), 3 - Signal grass hay (*Brachiaria decumbens* Stapf), 4 - Signal grass hay and concentrate 1 supplied at 0.5% BW, and 5 - Signal grass hay and concentrate 2 supplied at 1% BW.	1
Borreani *et al.* (2007)	Italy	1 year	Orchardgrass	*Dactylis glomerata*	Natural meadow hay harvested late with the addition of 5.1 kg of DM per cow and pre-dried from natural meadow with early cut 3.5 kg of DM of concentrate/cow.	1
			Red fescue	*Festuca rubra*		
			Yellow oats	*Trisetum flavescens*		
Pereira *et al.* (2007)	Brazil	90 days	Tifton-85 grass	*Cynodon* spp.	Pre-dried Tifton 85 grass (*Cynodon* spp.) + Concentrate (corn meal and ground soybeans) in a 60:40 ratio.	1
Arriola *et al.* (2015)	Florida (USA)	112 days	Bermuda grass	*Cynodon* spp.	Use of four inoculants in pre-dried Tifton 85 bermudagrass (Buchneri 500 inoculant, Biotal Plus II inoculant, Silage II inoculant, Silo King inoculant).	1

Table 2 cont. Main tropical forage grasses used in haylage production.

Author/year	Country	Duration	Common name	Scientific name	Treatments	Level of evidence
Guimarães *et al.* (2016)	Brazil	86 days	Tifton-85 grass	*Cynodon* spp.	The Tifton-85 grass (*Cynodon* spp.) was cut after 30 days of growth to produce haylage and remained in the field until reaching 70% dry matter (DM). The Silobac® biological additive was added (2g of product diluted in 2 L of water per ton of forage intended for silage), totaling 56 days of storage.	1
Costa *et al.* (2019)	Brazil	56 dyas	Tifton-85 grass	*Cynodon* spp.	The evaluated treatments consisted of storage times of 1, 3, 7, 14, 28 and 56 days for pre-dried Tifton-85 grass treated with the sprinkled Silobac® biological additive).	1
Galeano *et al.* (2022)	Brazil	90 days	Tamani grass	*Panicum maximum*	Monoculture of Tamani grass, Tamani grass + Crotalaria ochroleuca, Tamani grass + cowpea and Tamani grass + soybeans and Tamani grass + pigeon peas.	1
Silva *et al.* (2023)	Brazil	60 days	Tanzania grass	*Panicum maximum*	Plastic films of different thicknesses were tested on the Tanzania grass wrap, 27 µm polyethylene plastic film and three PVC films, which were 10 µm, 11 µm and 13 µm.	1
Edvan *et al.* (2023)	Brazil	90 days	Tanzania grass	*Panicum maximum*	Four groups of pre-dried Tanzania grass that varied in DM content as follows: fresh plant (not dehydrated), 400, 500 and 600 g kg^{-1} DM (dehydrated in the field until reaching DM content of treatment).	1

Table 3. Chemical characteristics (g/kg DM) of grasses used for haylage production.

Author/year	Species	DM (g/Kg de Fresh matter)	CP	SC	EE	Ash	NDF	ADF	CEL	HEM	LIG	OM
Souza *et al.* (2006)	*Cynodon* spp.	536.5	59.9	85.71	18.5	-	783.7	446.7	-	337.0	75.1	935.6
Gomes *et al.* (2006)	*Cynodon* spp. *Dactylis glomerata*	467.1	169.7	71.41	28.9	87.3	642.2	319.8	-	-	58.0	912.7
Borreani *et al.* (2007)	*Festuca rubra* *Trisetum flavescens*	522.0	107.0	-	21.0	110	570.0	386.0	-	-	59.0	636
Pereira *et al.* (2007)	*Cynodon* spp.	542.5	57.7	85.23	13.5	-	792.8	444.4	-	348.4	77.8	923.5
Arriola *et al.* (2015)	*Cynodon* spp.	536.5	188.8	-	-	-	691.0	321.0	-	352	-	-
Guimarães *et al.* (2016)	*Cynodon* spp.	947.1	127.1	-	-	91.5	547.7	224.8	-	3229	-	-
Costa *et al.* (2019)	*Cynodon* spp.	622.8	173.3	-	28.7	-	723.3	320.4	-	402.9	30.2	-
Galeano *et al.* (2022)	*Panicum maximum*	669.6	57.4	-	-	86.8	700.8	310.5	239.2	394.8	77.6	-
Silva *et al.* (2023)	*Panicum maximum*	655.0	140.9	-	-	64.8	857.4	493.3	-	-	-	935.1
Edvan *et al.* (2023)	*Panicum maximum*	581.6	99.9	45.4	-	71.0	653.9	-	-	-	-	943.6

DM – dry matter; CP – crude protein; EE – ether extract; Ash – mineral matter; NDF –neutral detergent fiber; ADF – acid detergent fiber; CEL – cellulose; HEM – hemicellulose; LIG – lignin; OM - organic matter; SC - soluble carbohydrates.

Table 4. Fermentative parameters of the main grasses used for haylage production, organic acids (g/kg DM), pH, and aerobic stability

Author/year	Species	pH	NH_3-N	Lactic acid	Acetic Acid	Butyric acid	Propionic acid	Microbiology	Break in aerobic stability
Souza *et al.* (2006)	*Cynodon* spp.	4.37	-	-	-	-	-	-	-
Gomes *et al.* (2006)	*Cynodon* spp. *Dactylis glomerata*	-	-	-	-	-	-	-	-
Borreani *et al.* (2007)	*Festuca rubra* *Trisetum flavescens*	5.13	50.6	11.8	6.4	0.8	-	-	-
Pereira *et al.* (2007)	*Cynodon* spp.	4.37	-	-	-	-	-	-	-
Arriola *et al.* (2015)	*Cynodon* spp.	5.37	-	10.4	2.8	-	-	-	yes

Guimarães *et al.* (2016)	*Cynodon* spp.	-	-	-	-	-		-	-
Costa *et al.* (2019)	*Cynodon* spp.	4.70	22.4	-	-	-	-	-	-
Galeano *et al.* (2022)	*Panicum maximum*	4.53	103.6	22.4	28.9	1.3	2.7	-	-
Silva *et al.* (2023)	*Panicum maximum*	5.83	8.5	26.30	1.40	1.0	1.50	5.40 UFC g^{-1}	no
Edvan *et al.* (2023)	*Panicum maximum*	6.37	3.5	-	48.9	3.2	4.1	5.95 UFC g^{-1}	no

Discussion

The studies verified in this review present a high degree of confidence due to the planning and scientific search criteria. In addition, all stages underwent analysis by two reviewers, thus ensuring the reliability of the data presented and certifying the inclusion of studies that do not lead to bias. After reading the full texts, most of the studies that were excluded by the reviewers were eliminated due to the use of grass conservation techniques other than pre-drying. Some studies used pre-dried Tifton-85 grass associated with sorghum silage, supplied together in cattle feed; however, research on the use of these feeds as a roughage source is limited, particularly regarding their evaluation and the animal's physiological response to consuming this feed (Pereira *et al.*, 2007).

Other studies were excluded because they used legumes as a forage source for haylage production. The first studies on pre-drying in Brazil date back to 2006, as a way of conserving forage instead of traditional silage for beef cattle feed (Souza *et al.*, 2006). There was a variation in the duration of published experiments; however, 80% of the studies were carried out within three months, and 20% lasted up to a year. Studies using the pre-drying conservation technique tend to last between 90 and 120 days, as most pastures are already pre-established and at the cutting point for making bales.

The main forage grasses used in haylage production were Tifton-85 (*Cynodon* spp.) and Tanzania (*Panicum maximum*). These grasses showed great production potential and are widely used in direct grazing, with high adaptive capacity to tropical regions around the world and potential for hay and haylage production (Edvan *et al.*, 2023). Cultivars of the *Cynodon* genus gained prominence in this study, probably because they exhibit good productivity and high nutritional value, high DM production, and a fast growth rate, in addition to having thin culms (Souza *et al.*, 2006).

Forage grasses of the *Brachiaria* genus are the most used in Brazil, occupying approximately 85% of cultivated pasture areas. Of this total, *Marandu* grass accounts for 50% and is considered an excellent option for pasture formation (Medica *et al.*, 2017). However, cultivars such as *Marandu* grass (*Brachiaria brizantha*) did not appear in the list of tropical grasses used in pre-dried preparation, probably because this grass has medium-low growth characteristics and is not commonly used for conservation but rather for direct grazing.

Of the treatments applied in the research, 70% included additives on pre-dried grasses, which comprised bacterial inoculants or concentrates. The studies that did not use any additives also had relatively satisfactory results. When compared to other roughage sources, pre-dried Tifton-85 grass exhibited higher apparent digestibility (Gomes *et al.*, 2006). Silva *et al.* (2023) observed that pre-dried *Tanzania* grass wrapped in 13-micron thick polyethylene film had the lowest population of enterobacteria, making it safer for use in animal feed.

Most of the experiments took place in Brazil (80%), as the country has regions characterized by irregular rainfall, which is concentrated in a short period of the year (Schmidt *et al.*, 2018), leading to seasonal variations in forage production and necessitating the use of conservation techniques.

Pre-drying (haylage) is an alternative for the conservation of forage plants used to feed ruminants. Its effects on chemical composition, consumption, and animal performance are influenced by the production system, forage species, and animal characteristics, requiring some considerations when recommending this practice (Edvan *et al.*, 2023). The lack of standardization in experimental methodologies remains a challenge for forage conservation with good nutritional and microbiological quality. Methodological adaptations or the full use of silage evaluation methodologies were commonly used in the analyzed studies, especially concerning fermentative parameters.

Limitations and Proposals for Future Research

One of the limitations of this integrative review is that, although the pre-drying technique has been in use for a long time, the number of articles available is limited, indicating the need for more studies, particularly on how this conservation method affects ruminant nutrition. It is also notable that most of the selected studies did not provide all the data on fermentative parameters, nor was there a standardization of the experimental units, highlighting the necessity of data standardization in future studies.

In this sense, research on the use of additives to improve the quality of tropical grasses preserved in pre-dried form has expanded. Studies using fibrolytic enzymes have gained importance in ruminant nutrition. The use of enzymes in animal feed is a biotechnological approach that has been part of supplementation strategies for improving weight gain since 1960 (Burroughs *et al.*, 1960). These enzymes are extracted from fungi or bacteria and act in conjunction with enzymes produced by rumen microorganisms (Martins *et al.*, 2007).

Fibrolytic enzymes are used in ensilage to increase the efficiency of the fermentation process, enhancing the action of desirable microorganisms, such as lactic acid-producing bacteria (Muck and Kung Jr., 1997). Consequently, Loures *et al.* (2005) highlighted the main fibrolytic enzymes used, such as hemicellulases, cellulases, pectinases, and xylanases, which act to make simple sugars available as a nutrient source for fermenting bacteria. The use of fibrolytic enzymes derived from cultures of filamentous fungi in ruminant feed has shown positive results, including increased digestibility of dry matter and neutral detergent fiber, higher milk production, and greater milk fat content (Schingoethe *et al.*, 1999).

The addition of fibrolytic enzymes to corn silage and *Tifton* hay enhanced the activity of β-1,4-endoglucanase in rumen fluid during the early stages of incubation. Furthermore, the average enzymatic activity of β-1,4-endoglucanase in ruminal fluid was higher in diets containing corn silage (Martins *et al.*, 2006). The addition of xylanase improved cellulose degradation and tended to increase ADF degradation. The use of multiple enzymes (cellulase, xylanase, and glucose) enhanced the ruminal degradation of NDF and DM, without affecting the other feed fractions (Antonio *et al.*, 2018).

Given the above, further research is needed on the use of fibrolytic enzymes in pre-dried tropical grasses, aiming to boost the activity of enzymes produced by rumen microorganisms, enhance fiber degradation, increase DM digestibility, and improve animal performance.

Conclusions

The main forage grasses used in haylage production belong to the genera *Cynodon* spp. and *Panicum* spp., with Tifton-85 and Tanzania grass being the most notable representatives, respectively. Globally, the pre-drying preservation technique has been gradually adopted, often with the use of additives to improve fermentative

parameters and enhance the quality of the material.

Declarations

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Conflicts of interest

The authors declare that they have no competing interests regarding the work presented in this report.

Author contributions

ABAD, TPDS ALCG, MJA, LRB, RRN, CATM, RLE, LCVI and AJCC conducted experiment, collected the samples, and wrote the manuscript; ABAD and WCCV conceived and designed the study and wrote the manuscript; ABAD, TPDS ALCG, MJA, LRB, RRN, CATM, RLE, LCVI and AJCC wrote and reviewed the manuscript; All authors read and approved the manuscript.

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

Data availability

The data sets used in the current study are available from the corresponding author on request.

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