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Review

Agro-Industrial Residues as Additives in Tropical Grass Silage: An Integrative Review

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Abstract

Agro-industrial residues can improve the fermentation quality of tropical forage grass silages when used as additives, but a systematic synthesis of their effectiveness is limited. This integrative review aimed to identify the main residues used as additives in silages and assess their effects on the fermentation process. Following the PVO (population, variable of interest, and outcome) protocol, searches were conducted in the Wiley Online Library, Web of Science, and SCOPUS databases, with no restrictions on language, time, or region. The guiding question was: "What are the main agro-industrial residues used as additives in the ensiling of tropical forage grasses?" Of the 1414 documents initially retrieved, 138 were selected after screening titles, abstracts, and keywords. After removing duplicates and full-text evaluation, 58 studies met the inclusion criteria. Brazil led in the number of studies (89.66%). Elephant grass (*Pennisetum purpureum* Schum.) was the most studied forage (34.21%). Citrus pulp (13.79%) and coffee husk (12.07%) were the most evaluated residues. The addition of residues promoted a reduction in pH (66.07%), ammonia nitrogen (71.74%), buffer capacity (57.14%), and the concentrations of acetic (52.17%), propionic (52.63%), and butyric (55.00%) acids. Lactic acid content increased in 32.76% of studies; gas and effluent losses decreased in 69.57% and 86.36% of cases, respectively. Citrus pulp and coffee husk are the most used residues, enhancing fermentation quality. It is concluded that the use of agro-industrial residues in the ensiling of tropical forage grasses has the potential to improve fermentation quality.

Keywords: agricultural by-products; fermentation process; forage conservation; tropical forages; sustainability; waste disposal

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1. Introduction

During dry seasons, forage availability decreases, making conservation strategies such as silage production essential to mitigate the effects of seasonal feed shortages on animal nutrition [1,2]. At the moment of ensiling, the dry matter concentration of the forage

is a critical factor that influences fermentation dynamics and silage quality [2]. Forage fermentation is a complex process involving several microorganisms that produce different metabolic end-products [3]. Excess moisture in silage increases gas and effluent losses by favoring the proliferation of *Clostridium* bacteria, which, under high pH conditions, produce CO_2 and butyric acid instead of lactic acid [4]. Undesirable clostridial fermentations result in the formation of ammonia and butyric acid, compounds that impair rumen fermentation due to the excess of rapidly available nitrogen. Furthermore, butyric acid is converted into beta-hydroxybutyrate, increasing the levels of ketone bodies in the blood and potentially leading to ketosis in ruminants, thereby negatively affecting animal performance [5].

Tropical grasses generally have low dry matter and water-soluble carbohydrate content, along with high buffer capacity at the optimal harvest stage [6]. These characteristics favor undesirable fermentations and high storage losses, making the use of additives essential to promote a rapid pH drop and silage stabilization, thereby improving fermentation quality and preserving nutritional value. If a forage is ensiled with high moisture (>70%), undesirable fermentations may occur, leading to significant dry matter (DM) losses [7] and reduced nutritional value, thereby decreasing silage intake by ruminants [8]. Silage effluents contain high concentrations of organic compounds such as sugars, organic acids, and proteins [4], which not only reduce the nutritional value of the silage but also pose environmental risks. Silage effluent is a pollutant with a high nutrient load that can cause eutrophication of water bodies [9]. Its production varies primarily with forage species and dry matter content [10]. If disposed of into water sources, it can deplete dissolved oxygen due to microbial activity, causing rapid negative effects on aquatic ecosystems [11].

To mitigate effluent losses, the use of moisture-sequestering additives is a widely recommended practice [12]. Some additives also serve as sources of fermentable carbohydrates, enhancing lactic acid fermentation by increasing the availability of soluble sugars [6]. An ideal additive should have high dry matter and water-soluble carbohydrate content, be well accepted by animals, be easily available in the market, and be economically viable for use in silage production [13]. Brazil is one of the world's leading agro-forest producers, and the harvesting and processing of these products generate large amounts of biomass residues. Brazil produces over 679.5 million tons of agricultural residues [14], which reinforces the importance of seeking alternative uses, such as adding them to tropical grass silages, promoting a circular economy and sustainability.

Research on additives has focused on improving silage quality while enhancing its nutritional and hygienic attributes. The inclusion of agro-industrial residues in animal feeding as silage additives has been widely studied and is aligned with sustainability principles, as agro-industries face major challenges in the disposal of these materials, which could otherwise contribute to environmental contamination [15]. Furthermore, improvements in the fermentative and nutritional quality of silage, achieved through the use of additives, are associated with increased dry matter intake, enhanced digestibility, and consequently improved productive performance of ruminants [3,16].

Integrative review research is not yet as widespread in the agricultural sciences, but it is an important tool for synthesizing existing knowledge, allowing studies using different methodologies (experimental, non-experimental, qualitative, and quantitative) to be combined in order to offer a broad and critical view of a specific topic. Therefore, this review aimed to identify agro-industrial residues used as additives in the ensiling of tropical forage grasses and assess their effects on the forage conservation process.

2. Materials and Methods

The integrative literature review that was conducted in this research is a method that aims to gather and synthesize research findings on a specific topic or question in a

systematic and organized manner, contributing to the advancement of knowledge on the investigated subject. Through integrative reviews, it is possible to generalize specific topics studied by researchers in different locations and periods of time, keeping stakeholders up to date and facilitating changes in daily practices as a result of scientific evidence [17].

The review protocol was developed and tested in advance to ensure the search and extraction of articles with a high level of scientific evidence, following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-ScR, 2020). The PVO (population, variable of interest, and outcome) mnemonic research strategy was used to define the guiding research question: "What are the agro-industrial residues used as additives in tropical forage grass silage?". This strategy is an adaptation of the PICO method (Population, Intervention, Comparison, and Outcome), widely employed in systematic reviews in the health field, for the context of agricultural sciences. The PVO mnemonic strategy (population, variable of interest, and outcome) was applied, where P (population) refers to the silage of tropical forage grasses, V (variable of interest) refers to agro-industrial residues, and O (outcome) refers to the quality of the fermentation process. Since there are no controlled descriptors specifically established for agricultural sciences, a preliminary analysis of scientific articles on the topic was conducted to identify the most commonly used descriptors, based on the PVO framework (Table S1). The formulation of this guiding question was based on a preliminary analysis of the scientific literature on additives used in tropical forage grass silages. This step allowed the identification of a gap related to the absence of integrative syntheses focused specifically on agro-industrial residues, which motivated the conduction of this review.

For article selection, searches were conducted in April 2024 by two researchers across the following databases: SCOPUS (Elsevier), and Web of Science—Core Collection (Clarivate Analytics/Thomson Reuters), which were accessed through the CAPES Journals Portal via the proxy of the Federal University of Piauí (UFPI), and Wiley Online Library, using the UFPI institutional email. The Wiley Online Library, Web of Science, and SCOPUS databases were selected for their broad multidisciplinary coverage, indexing high-quality journals of international relevance. These platforms gather scientific publications that address both agronomic and animal science aspects, including studies on forage production and conservation, ruminant nutrition, and the use of agro-industrial by-products. The choice of these databases aimed to ensure the retrieval of relevant and representative studies for the research question. Furthermore, some of the main journals in the field of Forage Science are indexed in these databases, such as Grasses (indexed in SCOPUS) and Grass and Forage Science (indexed in Wiley Online Library). The search strategy involved the use of descriptors combined with Boolean operators (OR, AND, and NOT) in a single cross-referenced query in each database (Table S2). In SCOPUS, the "advanced search" function was used with the following Boolean expression: (TITLE-ABS-KEY ("population-related descriptors"), AND ("variable-related descriptors"), AND ("outcome-related descriptors"), and AND NOT ("irrelevant descriptors")), with descriptors alternated using the "OR" operator. Similar procedures were adopted for the other databases (Figure 1).

This review included full-text experimental studies available in any language, without temporal restrictions, and with open access. The inclusion criteria were as follows: (1) primary research articles directly related to the topic of the study; (2) studies investigating agro-industrial residues as additives in the ensiling of tropical forage grasses; and (3) studies evaluating the quality of the silage fermentation process. Exclusion criteria included reviews, abstracts, theses, undergraduate dissertations, dissertations, editorials, letters to the editor, expert opinions, and book chapters. The study selection process was conducted independently by two reviewers. In cases of disagreement regarding the inclusion or exclusion of a study, the decision was made through discussion until consensus

was reached. When consensus could not be achieved, a third reviewer was consulted for the final decision, ensuring impartiality and quality in the selection process. After the search process, the extracted data were compiled into a single spreadsheet in Google Sheets for article assessment. Reviewers analyzed the research results independently by screening titles, abstracts, and keywords. A standardized extraction form was developed to record key information from each study, including the following: publication details (DOI, article title, indexed database, authors, journal, country, language, and year of publication); methodological aspects (soil type, climate, experimental design, treatments, experimental period, forage species, agro-industrial residues used, inclusion levels, and compaction density); fermentation quality parameters assessed qualitatively (increase or reduction in pH, ammonia nitrogen—N-NH_3, silage temperature, buffer capacity, dry matter recovery, soluble and total carbohydrates, organic acids, and gas and effluent losses); and study conclusions.

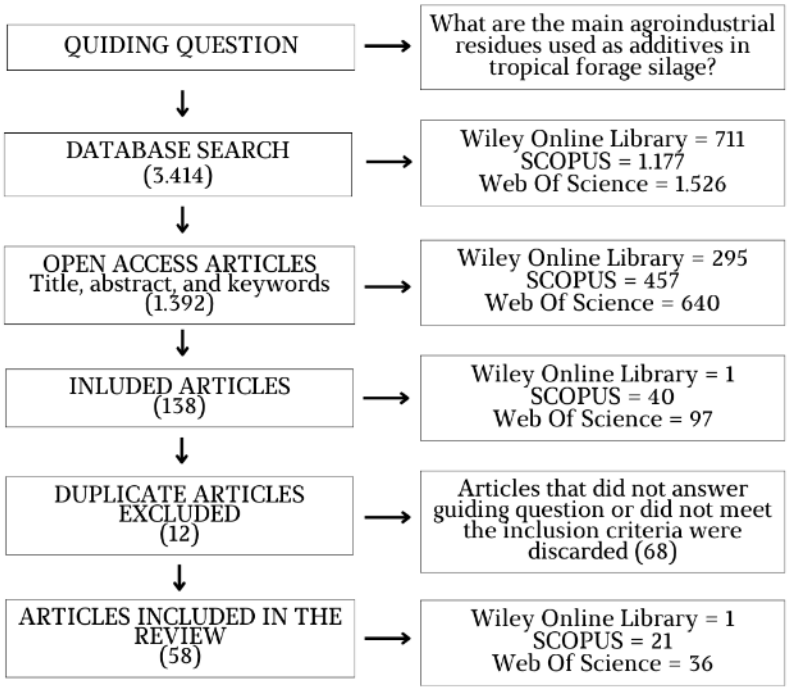


Figure 1. Integrative literature review flow diagram.

Data extracted from the included studies were analyzed descriptively and qualitatively by the reviewers. In cases of disagreement regarding the inclusion or exclusion of a study, the decision was made through discussion until consensus was reached. When consensus could not be achieved, a third reviewer was consulted for the final decision, ensuring impartiality and quality in the selection process. Statistical meta-analysis procedures were not applied, considering that the aim of this integrative review was to provide a qualitative synthesis and critical interpretation of the literature. Duplicate articles and those that did not address the guiding search question were excluded during the initial screening. Only articles classified as level 2 or higher, according to the Joanna Briggs Institute (JBI) levels of evidence, were included to ensure methodological rigor. The methodological quality of the selected studies was assessed using the Critical Appraisal Skills Programme (CASP) tool, adapted according to the methodology of each study, available at https://casp-uk.net/casp-tools-checklists/ accessed on 11 June 2024). Studies were included only if they met the essential criteria and methodological standards established for their respective designs. After full-text reading of the filtered articles, those that did not align with the research question or criteria were excluded.

3. Results

3.1. Methodological Aspects of the Studies

From the database search, a total of 3414 documents were retrieved, of which 1392 were open-access scientific articles (Table S3). After screening titles, abstracts, and keywords, 138 studies were considered eligible. However, following the removal of duplicates (articles indexed in multiple databases) and full-text analysis, only 58 studies met the inclusion criteria for this integrative review.

Scientific articles on this topic have been published since 2000, with the highest number of publications occurring in 2014, accounting for 10.34% of the total studies included up to the search date. English was the predominant language (63.79%), followed by Portuguese (36.21%). The majority of articles (62.07%) were indexed in the Web of Science database. Brazil was the leading country in research on agro-industrial residues in the ensiling of tropical forage grasses, accounting for 89.66% of the studies. Other contributing countries included China (3.45%), Japan (1.75%), Pakistan (1.75%), Thailand (1.75%), and Taiwan (1.75%).

The completely randomized design (CRD) was employed in 89.66% of the studies, with all experiments conducted using small-scale silos, such as polyvinyl chloride (PVC) tubes, plastic buckets, or plastic bags, with an average compaction density of 550 kg/m^3 and a mean fermentation period of 96 days (Table 1). The most studied tropical forage grass was *Pennisetum purpureum* Schum. (elephant grass) (34.21%), followed by *Saccharum officinarum* L. (23.68%), *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs (13.16%), and *Urochloa brizantha* (Hochst. ex A. Rich.) R.D.Webster cv. Marandu (10.53%).

Table 1. Methodological aspects of studies included in the integrative review.

Methodological Aspects of the Study	Distribution of Studies	Percentage (%)
Ensiled grass	*Pennisetum purpureum: 33*	56.9
	Saccharum officinarum: 8	13.8
	Urochloa brizanthaspp.: 6	10.3
	Megathyrsus maximus: 5	8.6
	Others (e.g., Sorghum, Cynodon): 6	10.3
Types of residues used	Citrus pulp: 8	13.8
	Coffee husk: 7	12.1
	Soybean hulls: 5	8.6
	Cashew bagasse: 3	5.2
	Wheat bran: 3	5.2
	Cassava bran: 3	5.2
	Castor bean meal, dendê cake, and others: 29 *	50
Residue inclusion levels	Up to 20% of DM: 18	31
	From 21 to 40%: 27	46.6
	Above 40%: 13	22.4
Fermentation period	Up to 30 days: 9	15.5
	31–60 days: 29	50
	61–90 days: 14	24.1
	Over 90 days: 6	10.4
Experimental unit	PVC silos (different volumes): 33	56.9
	Plastic/metal buckets: 17	29.3
	Other containers (bottles, bags, tubes): 8	13.8
Compaction density	400–499 kg/m^3: 6	10.3
	500–599 kg/m^3: 30	51.7
	600–699 kg/m^3: 16	27.6
	700 kg/m^3 or more: 4	6.9
	Not informed: 2	3.5
Experimental design	CRD (with or without factorial scheme): 52	89.7
	RBD, Latin square or split-plot: 4	6.9
	Not informed: 2	3.5

* Other residues were each studied in only one study. PVC: polyvinyl chloride; CRD: completely randomized design; RBD: randomized block design.

Among the agro-industrial residues evaluated, citrus pulp (13.79%) and coffee husk (12.07%) were the most frequently studied. The most common inclusion levels were 10% (20 studies), 15% (14 studies), 20% (14 studies), and 5% (11 studies). The main variables assessed were pH and ammonia nitrogen (N-NH_3) in comparison to other parameters of fermentation quality.

3.2. Fermentative Parameters of Silages Evaluated in the Studies

The inclusion of agro-industrial residues resulted in improvements in the fermentation process of ensiled tropical forage grasses (Table 2). The main effects observed included a reduction in pH (66.07%), a decrease in N-NH_3 (71.74%), a lower buffer capacity (57.14%), and reductions in acetic (52.17%), propionic (52.63%), and butyric (55.00%) acid concentrations. Additionally, lactic acid content increased in 70.37% of studies, while 7.41% reported a reduction. Of the 58 studies included in the review, 31 did not evaluate the lactic acid content (53.45% of the studies). Gas and effluent losses were reduced in 69.57% and 86.36% of the studies, respectively; however, 61.21% of the studies did not assess these losses. An increase in dry matter content was observed in 75.00% of the studies, while 7.14% reported no reduction in dry matter. Supplementary Information can be found in Table S4.

Table 2. Effects of residue utilization on fermentative parameters in tropical forage ensiling in the studies included in the integrative review.

Fermentative Parameters	Increased	Decreased	Not Significant
	% Of Studies		
N-NH_3 (%total N)	21.74	71.74	6.52
pH	25.00	66.07	8.93
°C (silo opening)	50.00	50.00	0.00
Buffer capacity	14.29	57.14	28.57
Water-soluble carbohydrates (% DM)	50.00	16.67	33.33
Dry matter recovery (%)	75.00	7.14	17.86
Total carbohydrates (% DM)	0.00	50.00	50.00
Lactic acid (% DM)	70.37	7.41	22.22
Acetic acid (% DM)	13.04	52.17	34.78
Propionic acid (% DM)	21.05	52.63	26.32
Butyric acid (% DM)	25.00	55.00	20.00
Gas losses (g/kg DM)	17.39	69.57	13.04
Effluent losses (kg/t AF)	0.00	86.36	13.64

DM: dry matter; AF: as fed.

4. Discussion

4.1. Methodological Aspects of the Studies

Most of the studies excluded during the selection phase were disregarded because they did not address the guiding research question. The primary reasons for exclusion were the evaluation of microbial inoculants in silage or the use of temperate grasses and legume plants.

Brazil's dominance in research on the use of agro-industrial residues in tropical forage grass ensiling can be attributed to several factors, such as the favorable tropical climate for forage grass cultivation, extensive agro-industrial production (grains, fibers, oilseeds, fruits, and biofuels), and the strong emphasis on sustainability. These conditions position Brazil as a natural hub for studies in this area. The predominance of studies conducted in Brazil (89.66%) reflects the country's advances in forage research and the use of agro-industrial by-products, driven by its strong agricultural sector and availability of such residues. However, this concentration may limit the direct generalization of the results to other geographical, climatic, and production contexts, highlighting the need for similar

studies in other tropical and subtropical regions [18]. Agro-industrial production in Brazil generates a substantial amount of residues. It is estimated that the 14 main crops produce approximately 291 million tonnes of residues per year [19]. Of this, around 108 million tonnes consist of by-products with potential use as biomass or additives in processes as ensiling [19].

The predominant experimental design employed was the completely randomized design (CRD), with all studies utilizing small-scale experimental silos, including PVC tubes, plastic buckets, and plastic bags. The use of homogeneous experimental units and controlled environments made CRD the most suitable design, ensuring uniform treatment application while maintaining randomness and replication [20].

The mean fermentation period across studies was 96 days, aligning with the literature findings that suggest silage is ready for animal consumption after 14 days of fermentation [21]. However, in practical applications, a minimum waiting period of 30 days post-sealing is recommended to allow the ensiled mass to stabilize before being used as animal feed [22].

Oxygen concentration and the depth of air penetration within the silo are critical factors affecting silage quality. The specific mass (kg of silage/m^3) directly influences silage porosity and, consequently, oxygen concentration at the silo surface [23]. The average compaction density reported across studies was 550 kg/m^3, with values ranging from 402 kg/m^3 to a maximum of 1120 kg/m^3, which was observed in only one study.

Tropical grasses have gained popularity in silage production due to their high productivity [24]. However, their growth and nutritional composition are influenced by seasonal climate variations. *Pennisetum purpureum* (elephant grass) stands out for its resilience to water scarcity, tolerance to high temperatures, short vegetative cycle, low soil fertility requirements, and ability to maintain nutritional value even as it matures. These attributes make it a cost-effective alternative for silage production compared to crops like corn [25,26]. Additionally, elephant grass is widely used in forage banks as a strategic feed reserve, where ensiling serves as a key preservation method. These characteristics justify its frequent use in studies on tropical forage grass silages.

The inclusion levels of agro-industrial by-products in silages ranged from 5% to 20% on an as fed basis. Most of these residues have dry matter contents exceeding 80%. Since optimal fermentation of tropical grass silages requires a dry matter content between 30% and 40%, inclusion levels above 20% may negatively impact compaction, hinder anaerobic fermentation, and increase effluent production, promoting undesirable fermentations.

Agro-industrial residues and by-products are valuable nutritional resources that often serve as substitutes for conventional feeds such as corn and soybean [27]. Over recent decades, numerous studies have investigated their use in animal feeding, either directly in diets or as silage additives. This review identified studies published between 2000 and 2024 evaluating several agro-industrial residues in silage production.

Among these residues, citrus pulp was the most frequently studied. As the world's largest exporter of orange juice [28], Brazil generates significant amounts of solid waste during processing. For every 100 kg of fresh fruit, approximately 7.3 kg of citrus pulp is produced [27]. Citrus pulp production is concentrated in São Paulo, followed by Minas Gerais and Paraná [29]. Consequently, this residue is easily available in Brazil's Southeast and South regions. However, in the major cattle-producing states in the Midwest, North, and Northeast, citrus pulp is less accessible, leading to its limited use as a silage additive in these regions. The studies found no mention of which crops and varieties were used in agribusiness for the production of citrus pulp.

Coffee husk was the second most researched residue, and Brazil is also the world's largest coffee producer [30]. In 2024, the country set a new record by exporting 50.5 million

60-kg coffee bags, reflecting a 28.8% increase compared to the previous year [31]. Coffee processing generates substantial waste, with approximately 11.9% of the dry matter derived from husks after pulping [32].

4.2. Fermentative Parameters of Silages Evaluated in the Studies

Some agro-industrial by-products improve fermentability; however, their availability is often limited to regions where the corresponding raw materials, such as corn, soybeans, citrus fruits, rice, cotton, and cassava, are cultivated [33]. The inclusion of agro-industrial residues improved the fermentation process of ensiled tropical grasses (Table 2), as evidenced by the key evaluated parameters: pH reduction in 66.07% of studies, N-NH_3 reduction in 71.74%, buffer capacity reduction in 57.14%, and decreases in acetic (52.17%), propionic (52.63%), and butyric (55.00%) acids. The reduction in pH inhibits the proliferation of enterobacteria and *Clostridium* species, which produce acids, thereby lowering their concentrations in silage [4,21]. Consequently, proteolytic bacterial activity declines, leading to lower N-NH_3 levels.

An increase in lactic acid content was observed in 70.37% of studies, whereas 7.41% reported a reduction (53.45% of studies did not evaluate this parameter). The rise in lactic acid levels is associated with increased dry matter and water-soluble carbohydrate availability, fostering the growth of lactic acid bacteria. These bacteria thrive in low-oxygen and low-pH conditions, producing lactic acid, which accelerates pH reduction and enhances silage stability both before and after the silo is opened [22]. In well-fermented silages, lactic acid typically accounts for over 60% of total organic acids, with concentrations ranging from 3% to 8% of dry matter [34].

Dry matter content increased in 75.00% of studies, while only 7.14% reported a reduction, and 51.72% did not present this information. Gas and effluent losses decreased in 69.57% and 86.36% of studies, respectively. Gas losses are associated with secondary fermentation by aerobic and facultative anaerobic microorganisms, which thrive in poorly fermented silages. In contrast, well-fermented silages dominated by lactic acid fermentation minimize nutrient losses [4]. Effluent losses decreased due to the higher dry matter content provided by the addition of agro-industrial residues. McDonald et al. [21] recommend a minimum dry matter content of 25% to effectively control effluent production. However, 61.21% of studies did not evaluate effluent losses. The reported 86.36% reduction in effluent losses represents, on average, a savings of up to 12 to 15 L of effluent per ton of ensiled forage, depending on the initial moisture content. This contributes to nutrient preservation, reduced environmental contamination, and greater ensiling efficiency [18].

Many studies primarily focused on pH and N-NH_3 as indicators of fermentation quality, often neglecting other important parameters, such as water-soluble carbohydrate content, organic acid production, and losses from effluents and gases. While pH is a useful indicator, it should not be the sole criterion for assessing fermentation quality [21,34]. The inclusion of by-products in tropical forage silages can optimize fermentation, increase feed efficiency, and improve animal performance [35], since inadequate fermentation results in an estimated potential loss of 5 to 20% of the material [36].

Considering the heterogeneity of the studies included in this review, particularly regarding experimental designs, residue inclusion levels, and evaluated parameters, conducting a meta-analysis was not feasible. It is recommended that future studies adopt more uniform methodologies and standardized evaluation criteria, which would enable quantitative synthesis through meta-analyses and level–response modeling. In addition to the technical and qualitative aspects discussed, the economic feasibility of using agro-industrial residues as additives in the ensiling of tropical grasses remains underexplored in the literature. Detailed economic assessments considering acquisition, transport, process-

ing costs, and potential productivity gains are essential to support the practical adoption of these strategies. It is recommended that future studies include a dedicated economic analysis, presented as a specific subsection, to complement the technical evidence and enhance the applicability of the results. Although there are many studies on the use of residues in silage, it is necessary to evaluate the financial impact of this practice, as well as animal productivity in production systems.

5. Conclusions

The primary agro-industrial residues used in the ensiling of tropical grasses are citrus pulp and coffee husks. Inclusion levels ranging from 10% to 30% of citrus pulp (on as fed basis) and from 5% to 10% of coffee husk have been commonly associated with improved fermentation parameters and reduced losses during the ensiling process of tropical grasses. It is important to emphasize that these values represent ranges reported in the analyzed studies and do not constitute recommendations derived from aggregated quantitative analyses. With the inclusion of such residues, there is a reduction in undesirable fermentation parameters and an increase in those that are preferable for proper fermentation. Future research should explore the use of other residues as silage additives. Additionally, it is important to assess the direct incorporation of additive-treated silage into animal diets and to expand the range of variables analyzed in the fermentation process.

It is recommended that future research be directed towards cost–benefit analyses, as the use of residues contributes to a circular economy by adding value to agro-industrial by-products and minimizing residue disposal, thereby promoting more sustainable agricultural practices. In addition, the present study provided the necessary foundation for subsequent investigations to collect homogeneous data and produce quantitative effect estimates (meta-analyses or meta-regressions).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/grasses4030038/s1, Table S1. Descriptors used to search for articles in the databases according to the PVO strategy; Table S2. Search strategies by database; Table S3. Characteristics of the studies included in the integrative review with agro-industry waste used [4,9,11,24–26,37–87]; Table S4. Fermentation characteristics evaluated in the studies included in the integrative review.

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