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Review Article

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Ensiling Wet Distillers By-Products in Ruminant Nutrition: A Pathway Toward Improved Fermentation and Sustainability

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ABSTRACT

Wet Distillers by-products from the corn ethanol industry have become increasingly relevant in ruminant nutrition due to their high protein and fiber content. However, their high moisture content and rapid aerobic spoilage represent major challenges for storage, transportation, and environmental management. Ensiling has emerged as an effective strategy to preserve these by-products, particularly when incorporated into total mixed ration (TMR) or partial mixed ration (PMR) silages. This review discusses the principles of ensiling applied to wet Distillers by-products, with emphasis on wet Distillers grains and wet Distillers bran plus solubles (WDBS). The role of biological and chemical additives in improving fermentation quality, reducing nutrient losses, and enhancing aerobic stability is critically examined. In addition, the environmental implications of using ensiled agro-industrial by-products are discussed, including reductions in feed waste, effluent losses, and greenhouse gas emissions associated with improper disposal. Current challenges, knowledge gaps, and future research directions are also highlighted. The integration of wet Distillers by-products into ensiled rations represents a promising approach for improving feed efficiency and promoting sustainability in ruminant production systems.

List of Abbreviations

WDBS	:	Wet Distillers Bran Plus Solubles
WDGS	:	Wet Distillers Grains with Solubles
TMR	:	Total Mixed Ration
PMR	:	Partial Mixed Ration
LAB	:	Lactic Acid Bacteria
DM	:	Dry Matter
NDF	:	Neutral Detergent Fiber
WSC	:	Water-Soluble Carbohydrates

Keywords: Agro-Industrial Residues, Silage Fermentation, Sustainable Livestock Systems, Total Mixed Ration Silage, Wet Distillers By-Products

Introduction

The rapid expansion of the corn ethanol industry has intensified the generation of agro-industrial by-products worldwide, particularly in major producing countries such as Brazil and the United States [1]. Among these by-products, wet Distillers grains with solubles (WDGS) and wet Distillers bran plus solubles (WDBS) have gained relevance due to their high concentrations of protein and digestible fiber, making them valuable ingredients in ruminant nutrition [2].

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Despite their nutritional advantages, wet Distillers by-products pose significant logistical and environmental challenges. Their high moisture content accelerates microbial spoilage, restricts storage duration, and increases transportation costs, which can result in nutrient losses and environmental contamination when disposal is inadequate [3]. Consequently, effective preservation strategies are essential to ensure their safe utilization and to maximize their contribution to sustainable livestock systems.

Ensiling has emerged as a practical and environmentally sound approach to preserving high-moisture feed ingredients by promoting controlled anaerobic fermentation and nutrient stabilization [4]. In recent years, the incorporation of wet Distillers by-products into total mixed ration (TMR) and partial mixed ration (PMR) silages has received increasing attention as a means of improving fermentation efficiency and feed management [5].

This review synthesizes current knowledge on the ensiling of wet Distillers by-products, with emphasis on fermentation principles, the role of biological and chemical additives, and the environmental implications of these preservation strategies.

Corn Ethanol Industry and Generation of Wet Distillers By-products

Corn ethanol production has expanded rapidly over the past decade, driven by the demand for renewable energy sources and fuel diversification [6]. Advances in processing technologies have increased ethanol yields while diversifying the range of co-products generated during production.

Traditional dry-milling processes produce WDGS, whereas fiber separation technologies have led to the development of WDBS, characterized by distinct physical properties and nutrient profiles (Rausch et al., 2019). Despite these differences, both by-products share a common limitation: high moisture content, which often exceeds 60% and severely restricts storage time.

From an environmental perspective, inadequate management of wet Distillers by-products can lead to nutrient runoff, greenhouse gas emissions, and inefficient resource use [7]. Therefore, strategies that enable their effective preservation and integration into livestock feeding systems are essential to align ethanol production with principles of sustainability and circular economy.

Nutritional Characteristics and Preservation Challenges of Wet Distillers By-products

Wet Distillers by-products are characterized by high concentrations of crude protein, neutral detergent fiber, and digestible energy, supporting efficient microbial protein synthesis in the rumen [8]. These attributes make them attractive alternatives to conventional protein sources in ruminant diets.

However, the same characteristics that confer nutritional value also favor rapid microbial growth under aerobic conditions. Spoilage by yeasts and molds leads to nutrient losses, reduced hygienic quality, and potential mycotoxin risks [9]. In addition, the short shelf life of wet Distillers by-products restricts their use to farms located near ethanol plants (N'Guessan, 2007).
Preservation methods that stabilize nutrients while minimizing environmental losses are therefore critical. Among available strategies, ensiling offers a low-energy alternative to drying and contributes to reduced feed waste and environmental impacts associated with spoilage [10].

To contextualize the preservation challenges associated with wet Distillers by-products within ruminant feeding systems, Table 1 summarizes the main nutritional characteristics and conservation constraints of WDGS, WDBS, and other commonly used agro-industrial by-products.

Table 1: Nutritional characteristics and preservation challenges of selected agro-industrial by-products used in ruminant feeding systems.

By-product	Typical dry matter (%)	Main nutritional attributes	Key preservation challenges	Suitability for ensiling
WDGS	30 to 35	High crude protein; digestible fiber; moderate fat	Rapid aerobic spoilage; short shelf life; high transport cost	High: requires moisture correction or additives
WDBS	30 to 40	High fiber concentration; moderate protein; low starch	Effluent losses; microbial instability if poorly compacted	High: especially in TMR or PMR systems
DDGS	88 to 90	High protein and energy; stable composition	Low palatability in some diets; dustiness	Low: drying already ensures preservation
Soybean hulls	88 to 90	Highly digestible fiber; low protein	Minimal – dry and stable	Low: mainly used as moisture balancer
Cottonseed hulls	90 to 92	High NDF; physically effective fiber	Low digestibility; low energy density	Low: dry roughage source
Beet pulp	20 to 25	Highly fermentable fiber; low protein	High effluent risk; rapid spoilage	High: widely ensiled successfully

Source: Adapted from consolidated literature sources [2-5,9]

Principles of Ensiling Applied to Agro-industrial By-products

Ensiling is based on the rapid establishment of anaerobic conditions that favor lactic acid bacteria and the production of organic acids, primarily lactic acid, resulting in pH reduction and inhibition of undesirable microorganisms [11].

When applied to agro-industrial by-products such as WDGS and WDBS, fermentation dynamics are influenced by dry matter content, buffering capacity, availability of water-soluble carbohydrates, and initial microbial populations [12]. Excess moisture increases the risk of effluent losses, while limited fermentable substrates may impair fermentation efficiency.

Combining wet Distillers by-products with dry ingredients can optimize moisture content, reduce effluent production, and enhance fermentation quality, making TMR and PMR silages particularly effective preservation strategies [5].

Total Mixed Ration and Partial Mixed Ration Silage as Preservation Strategies

Total Mixed Ration Silage

Total mixed ration silage involves the ensiling of a fully formulated diet containing forages, concentrates, by-products, minerals, and additives. This approach improves feed uniformity, reduces sorting behavior, and simplifies daily feed management [13].

The incorporation of wet Distillers by-products into TMR silage allows their high moisture content to be balanced with dry ingredients, improving compaction and fermentation efficiency while reducing aerobic deterioration and dry matter losses during feed-out [5].

Partial Mixed Ration Silage

Partial mixed ration silage consists of a subset of dietary components designed to complement forage-based systems, particularly in grazing or semi-intensive production systems [14]. This strategy provides flexibility and allows producers to adjust supplementation according to seasonal and physiological requirements.

When properly formulated, PMR silage containing wet Distillers by-products can reduce effluent losses and improve fermentation stability, especially under tropical conditions where climatic challenges are more pronounced [15].

Environmental and Sustainability Implications

The ensiling of wet Distillers by-products contributes directly to sustainability in livestock production by reducing feed waste and minimizing environmental risks associated with spoilage and improper disposal [10]. Improved nutrient conservation and reduced effluent production lower the potential for soil and water contamination.

Moreover, the integration of agro-industrial by-products into ruminant diets supports circular economy principles by transforming residues into valuable feed resources, thereby improving resource efficiency and reducing the environmental footprint of both ethanol and livestock production systems [5].

Knowledge Gaps and Future Perspectives

Despite advances in ensiling technologies, knowledge gaps remain regarding long-term environmental impacts, standardized protocols for different by-product compositions, and life cycle assessments to quantify sustainability benefits. Future research should focus on microbial interactions during fermentation, optimization of additive combinations, and region-specific strategies tailored to tropical and subtropical systems [16-20].

Conclusion

Ensiling represents an effective and sustainable strategy for preserving wet Distillers by-products for ruminant nutrition. The use of TMR and PMR silages enhances fermentation efficiency, reduces nutrient losses, and mitigates environmental risks associated with high-moisture residues. When combined with appropriate additives, ensiling supports the integration of agro-industrial by-products into sustainable livestock production systems, contributing to improved feed efficiency and environmental stewardship.

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Conflict of Interest

The authors declare no conflict of interest.

Ethical statements

Not applicable.

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