Open Access

Applied Research of Sport Management

Vol. 14(3), (Series 55): 53-68/ 2026

DOI: 10.30473/arsm.2025.75440.3986

E-ISSN: 2345-5551 P-ISSN: 2538-5879

ORIGINAL ARTICLE

Feasibility Study of Bioenergy Production from Waste of Equestrian Centers and Horse Breeding Using Artificial Intelligence-Based Life Cycle Assessment (LCA)

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Receive Date: 18/Aug/ 2025
Accept Date: 30/Sep/2025
Published Online: 24/Dce/2025

How to cite
Khoramnejadian, Sh., & Pirayandeh, N. (2026). Feasibility Study of Bioenergy Production from Waste of Equestrian Centers and Horse Breeding Using Artificial Intelligence-Based Life Cycle Assessment (LCA *Applied Research of Sport Management*, 14(3), 53-68.

EXTENDED A B S T R A C T

Introduction

In recent years, operational costs for sports clubs, especially equestrian centers, have risen due to increased energy prices, waste disposal costs, and environmental regulations. Sustainable resource management and advanced technologies for energy recovery from club-generated waste offer a new competitive advantage in the sports industry. This study proposes a practical model based on field data and Life Cycle Assessment (LCA) to supply part of the energy needs of equestrian centers through recycling horse manure. Previous research integrating life cycle assessment with energy costs and operational consumption shows the importance of combining environmental and economic dimensions, applicable to equestrian waste for sustainable technology choices like direct combustion or anaerobic digestion (Farahani et al., 2021). The rapid growth of horse breeding and equestrian centers in Iran has led to large amounts of organic waste (manure and bedding), which if unmanaged, causes pollution including groundwater contamination and greenhouse gas emissions. Horse manure, rich in organic matter and nutrients, is used in many countries as a renewable energy source via combustion or anaerobic digestion, but a comprehensive scientific approach for Iran is lacking.

Studies highlight pyrolysis and microwave-assisted pyrolysis of horse manure as promising for reducing environmental impacts and enhancing energy production (Mong et al., 2020). Sweden's example shows substantial potential energy recovery from manure biogas, with anaerobic digestion offering multiple environmental benefits (Hansson & Eriksson, 2015). Challenges such as high moisture content and bedding materials influence energy recovery efficiency, but technologies exist to improve this (Liu et al., 2021; Wartel et al., 2012).Research also supports using AI-enhanced LCA models for more accurate environmental and economic assessments of bioenergy systems (Omidkar et al., 2024). Despite

progress, integrating waste conversion technologies with intelligent tools for comprehensive environmental and economic evaluation remains limited. Therefore, this study aims to evaluate the physicochemical properties and energy potential of horse stable waste in Iran using AI-based LCA to assess the efficiency of combustion and anaerobic digestion for bioenergy production, contributing to sustainable waste management and energy recovery in equestrian centers.Other related studies include methane gas estimation from landfills (Ebrahimi Toulon et al., 2023), thermochemical and biochemical conversion processes (Chung et al., 2023), integration of renewable fuels and sustainable practices to reduce carbon footprint in equestrian centers (Phong et al., 2024), and the role of bedding materials on energy recovery (Kusch, 2013; Wartel et al., 2012)

Methodology

This study evaluates energy recovery methods from horse manure waste collected from three equestrian clubs in Tehran. Physical, chemical, and energy content analyses were performed on manure, bedding, and their mixtures. Two energy conversion scenarios-direct combustion and anaerobic digestion-were modeled and assessed using Life Cycle Assessment (LCA) with OpenLCA software, following international standards. Statistical tests examined data characteristics and relationships, while AI techniques like machine learning and decision trees enhanced pollutant classification, environmental prediction, and scenario comparison. The study aimed to identify cost-effective, low-carbon pathways for energy production. The LCA compared environmental impacts per megajoule of energy produced, supporting informed decisions in sustainable waste management and bioenergy production.

Findings

The examined horse manure has high organic carbon content and a high carbon-to-nitrogen (C/N) ratio, making it suitable for anaerobic digestion and biogas production. Although it contains a relatively high ash content which negatively affects combustion efficiency, its heating value is high and acceptable. Anaerobic digestion results in lower greenhouse gas emissions, reduced acidification potential, and more efficient resource use compared to direct combustion, but it produces more wastewater. Direct combustion is simpler and less costly but faces challenges such as ash management. SWOT analysis indicates that horse manure has good potential for sustainable energy supply in equestrian centers, though challenges like ash and effluent management remain. The findings align with global studies and can contribute effectively to renewable energy development and environmental management in sports facilities.

Discussion and Conclusion

The results of this study indicate that waste from equestrian centers, especially the combination of horse manure and bedding, possesses significant potential for sustainable management and bioenergy production due to favorable physical and chemical characteristics such as high organic matter content, an optimal carbon-to-nitrogen (C/N) ratio, and a suitable lower heating value (LHV). Anaerobic digestion is environmentally superior to direct combustion because it substantially

reduces greenhouse gas emissions and produces high-quality organic fertilizer. However, direct combustion, with its lower investment cost and simpler technology, can serve as a temporary and feasible solution in facilities lacking advanced infrastructure. Beyond technical and environmental benefits, the findings offer practical management implications for equestrian clubs, where managers can utilize renewable energy technologies and green economy principles to reduce operating costs while enhancing environmental responsibility. The study recommends that policies related to sports and environment prioritize the use of animal waste as energy resources and promote the development of green clubs as innovative and effective approaches to managing sports centers sustainably.

K E Y W O R D S
Calorific Value, Clean Energy, Artificial Intelligence, Sustainable Sports Complex, Environment.