

# Effective dairy farm waste management for sustainable integrated farming system

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*The current agricultural system in India is grappling with the dual challenges of production pressure and sustainability concerns over resources needed to feed the country's 1.4 billion people. Each product in any field has its own production cycle; similarly, all agricultural products have their cycle, and waste generation is a common phenomenon at the end of the production chain. The dairy industry generates a variety of wastes from the beginning to the end of their management, which can be categorized into major solid and liquid wastes. Solids constitute mainly leftover feed, bedding, and faeces, while liquids constitute urine and water used for cleaning. Dairy wastes are generally organic in nature, have a high carbon content, and contain multiple nutrients. The nutrient richness makes it very vulnerable to losses, which may have several consequences for the environment. Understanding the stages of waste generation and timely management is critical for utilizing it efficiently. Simultaneously, the process prevents leaching losses, gaseous emissions, and any other pathogenicity, thereby enhancing its environmental friendliness. Therefore, it is crucial to manage dairy farm wastes efficiently, understanding their importance as nutrient resources and potential losses if not managed properly.*

**Keywords:** Climate resilience, Dairy sector, Livestock residue, Nutrient recovery mechanism, Waste management

The dairy industry is an important part of the global food system as milk and other dairy products contain important nutrients and are part of the diet since ages. As per Ministry of Fisheries, Animal Husbandry and Dairying 2023, dairy is India's single largest agricultural commodity, contributing 5% to the national economy and directly employing more than 80 million farmers. India leads in milk production, accounting for 24.64% of the global production. The dairy farming is responsible for managing a large number of livestock for milk production and generates a multitude of wastes, including leftover feed, bedding, excrement, urine, and cleaning water. The total number of milch animals (including milk and dry in cows and buffaloes) are 125.34 million, with an average production of 18–30 kg of manure/day, resulting in 823.5–1,372.5 million tonnes of manure annually from the

milch animals (Press Information Bureau 2019). Taking into account of total milk production, which is 230.58 million tonnes during 2022–23, on average, 1 L of milk results in the production of 3.5–5.9 kg of dung. Consequently, climate change is a major concern that has a considerable impact on dairy farming. Improper management such as open dumping leads to serious environmental hazards. Hence, efficiently implementing manure management systems in the dairy farming sector is critical for optimizing the economic benefits of nutrient recycling while also minimizing its environmental impact. Overall, the dairy industry's impact on the environment is substantial and raises important concerns for sustainability as livestock manure alone contributes 51–118 million metric tonnes of carbon dioxide equivalent annually. By understanding the effectiveness

of different waste management techniques, we can identify areas for improvement and implement more sustainable solutions.

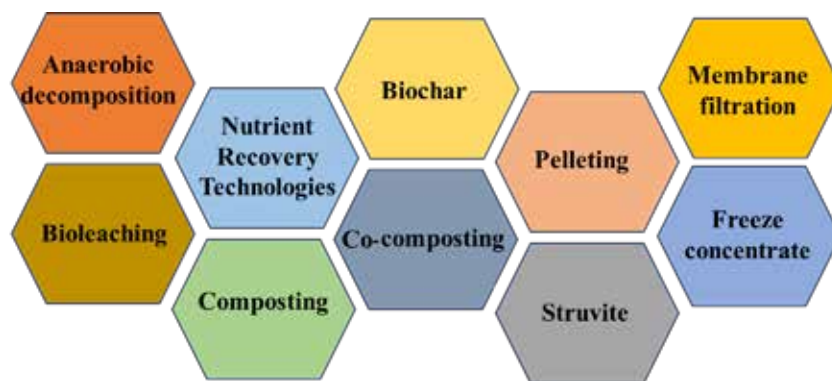
## Dairy wastes and their environmental impact

Dairy wastes, including manure, bedding, wastewater, and dairy by-products, pose significant environmental problems. Manure, rich in nutrients like nitrogen (0.5%) and phosphorus (0.2%), may contribute to eutrophication when runoff reaches aquatic bodies, triggering algal blooms and consequent oxygen depletion. During anaerobic decomposition, dairy waste generates methane, which is a powerful greenhouse gas that contributes to 12–41% of global methane emissions and 30–50% of global nitrous oxide emissions during 2022–23. Wastewater from dairy operations after the cleanup of animal barns, which often

contains organic matter, pathogens, and antibiotics, has the potential to pollute both surface water and groundwater. Untreated wastewater application directly into the crop or soil may lead to heavy metal accumulation. The use of antibiotics in animal diets has also increased in intensive dairy farming, and their residue in manure is an important source of contamination. Food animals excrete the majority (30–80%) of the antibiotic dose due to partial metabolism. By coming into contact with the soil, they have a negative impact on the natural soil microbes. In addition, inappropriate treatment and disposal of dairy by-products may lead to soil deterioration and odour problems, which can have an impact on nearby communities. To lessen the negative effects that these environmental consequences have on the ecosystem, it is essential to use efficient waste management strategies.

#### Potential solutions to minimize dairy waste impact

The impact of dairy waste especially manure is huge and there is a big opportunity that lies in its use of making it sustainable. Separating animal manure into solid and liquid fractions is the foremost important consideration for improved nutrient balance and facilitating better utilization. Dairy farms and industries have adopted several solutions to minimize waste impact and improve sustainability, anaerobic digestion of manure has emerged as a promising solution for waste management and energy production. In Latin America, implementing biodigesters and combined heat and power systems on dairy farms could lead to energy self-sufficiency and significant greenhouse gas emission



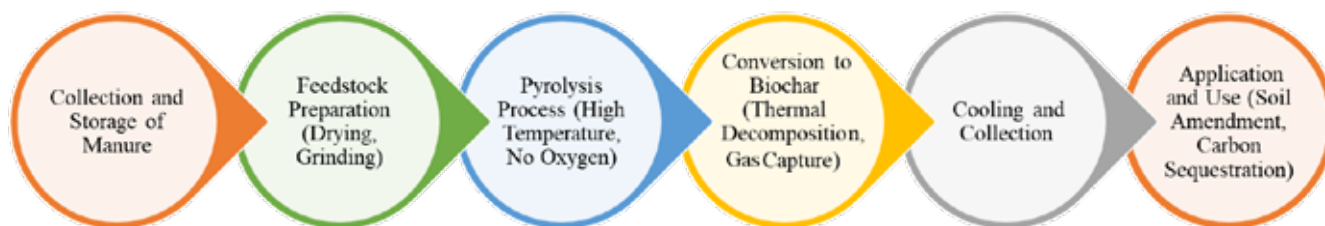
Solutions for managing dairy farm waste

reductions. Some dairy farms have focused on improving farming intensity and efficiency. Factors such as increased milk production per cow, improved dairy efficiency, and optimized stocking density have been associated with reduced environmental impacts per kg of product. Farmers have shown willingness to implement better management and distribution of livestock manure and fertilizers, which can potentially reduce total environmental impacts by 6–7%. Indian dairy farms and industries are adopting innovative strategies to manage dairy wastes sustainably. Approaches such as the circular economy, as modeled by the Taruna Mukti farmer group in Indonesia, demonstrate how cow dung can be converted into organic fertilizer, reducing waste and creating valuable by-products. Several technological advancements have been suggested as:

- **Anaerobic decomposition:** Implementation of manure to convert into biogas is one effective solution that can help reduce greenhouse gas emissions and generate renewable energy. Some industrial facilities and dairy farms use it to create biogas.
- **Bioleaching:** It is a low-cost technology based on

nutrient solubilisation from solid substrates by a leaching microorganism, either through direct or indirect metabolism. Some potential microorganisms that have been identified for bioleaching are *Acetobacter*, *Acidithiobacillus*, *Ferroxidans*, *Penicillium*, *Fusarium*, *Sulfobacillus thermosulfidooxidans*, and *Aspergillus*.

- **Nutrient recovery technologies:** Another potential solution is the utilization of recovery technologies to extract valuable resources from dairy waste, such as phosphorus and nitrogen, for reuse in agricultural applications.
- **Composting:** On farms, manure and bedding materials are commonly composted as part of the waste management process. Several methods are available for making compost, but the basic concept is keeping the manure for a period till all the manure gets decomposed. By acting as organic fertilizers, composted materials improve soil quality while decreasing the need for synthetic fertilizer and further decreasing the industry's carbon footprint.
- **Biochar:** Biochar from dairy manure is one of the new areas of research. By the



Steps involved in the production of biochar from dairy manure

process of pyrolyzing it in an anaerobic environment, a high carbon black colour material is produced with high carbon stability. This is also linked with carbon sequestration.

- **Co-composting:** Sole manure compost sometimes leads to gaseous emissions and nutrient leaching. Several additives have been suggested for the use, such as straw-based, gypsum-based, biochar-based, etc.
- **Pelletizing:** This technique utilizes physical procedures such as baling and pelletizing to enhance the handling and storage of solid materials found in manure. Throughout the pelletizing process, there is a substantial rise in the density of animal excrement, which makes it easy to handle and offers long term persistency to improve nutrient mobilization.
- **Struvite:** It is precipitation of manure in order to get a slow release of fertilizing compounds into the soil.
- **Membrane filtration:** Membrane technologies are designed to handle effluents that contain compounds or elements. These compounds or elements can either be held or allowed to pass through a thin physical barrier, depending on factors such as molecular or particle size, concentration of particular compounds, operational temperature, and applied pressure.
- **Freeze concentrate:** The utilization of animal waste by biological or physical-chemical methods is not often, primarily because of presumed expenditures or limited area for implementation. Freezing concentration has demonstrated potential in extracting nitrate-nitrogen and phosphate nutrients from wastewater, providing a means for nutrient recovery and biofertilizer production.

Optimal manure management on small farms encompasses several approaches. Initially, it is important to ensure that animals are housed in

well managed pasture in order to directly regulate the disposal of manure. Composting is a significant technique for effectively using manure. In addition, the practice of accumulating manure for future use and establishing vegetative buffers surrounding storage places also contributes to improved management. Well-designed and well-maintained manure storage facilities are crucial. Implementing a nutrition management strategy and acquiring knowledge about successful methods are essential components of a holistic approach.

#### Challenges and future directions

Financial barriers to implementing waste management technologies continue to be a challenge for many dairy producers, as the initial costs can be significant. Additionally, regulatory hurdles and a lack of awareness about the benefits of circular economy practices can hinder progress in the industry. However, as more success stories emerge and the demand for sustainable products grows, there is hope that the dairy industry will continue to adopt more environmentally friendly practices in the future. Current regulations and guidelines for dairy waste management must be rigorously enforced to ensure that dairy farms dispose of waste in an environmentally responsible manner. Additionally, research and innovation in waste management technologies can help to reduce the overall environmental footprint of the dairy industry. Key areas for research and innovation in waste management technologies include optimizing anaerobic digestion for biogas production, developing efficient nutrient recovery methods, advancing water treatment and recycling techniques and creating value added products from dairy processing byproducts and manure. Other important



Overview of biochar co-composting at National Dairy Research Institute, Karnal

domains encompass implementing smart systems for precision waste management, developing biodegradable packaging materials, researching technologies to mitigate greenhouse gas emissions, exploring circular economy approaches, investigating bioplastics production using dairy waste as feedstock, and studying algae cultivation potential.

#### SUMMARY

Efficiently managing dairy farm wastes is essential for enhancing environmental sustainability and maximizing economic benefits. Implementing advanced waste management strategies, such as anaerobic decomposition, bioleaching, nutrient recovery technologies, composting, and biochar production is very crucial. These approaches not only mitigate negative environmental effects but also convert waste into valuable resources, promoting a circular economy within the dairy sector. Despite the financial barriers, regulatory challenges, and lack of awareness that hinder widespread adoption, addressing these issues through stringent regulation enforcement, increased research and innovation, and raising awareness about sustainable waste management practices will drive progress. By embracing these measures, the dairy industry can significantly reduce its environmental footprint while improving resource efficiency and sustainability.

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