Article ID 42402121

Dairy Waste Management: One step ahead to Sustainable Dairying

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Waste production is a natural byproduct of industrialization. Industrial sectors are especially aware of the worldwide pollution problem caused by their operations because of their high-water consumption and the wastewater they produce per unit of output. One relevant example of a globally functioning industry producing a variety of goods, such as cheese, butter, milk powder, and powdered milk, is the dairy sector, which produces waste streams that are both liquid and solid. In order to address these issues, the dairy industry must actively promote sustainable production methods, improve waste management procedures, and reduce waste output. The dairy industry has experienced substantial global expansion due to the increasing demand for milk and milk products; however, this fast industrial growth is also increasing pollution emissions into the atmosphere and water bodies, which can have a negative impact on productivity and pose risks to human health and other ecosystem components. Untreated dairy effluents that are released into the environment immediately cause a decrease in the amount of dissolved oxygen in the water. This is made worse by fat-rich effluents that accumulate on the surface of the water and create levels that are too low for aquatic life to survive. Rich in organic components, lactose, nutrients, lipids, sulphates, and chlorides, dairy effluent is distinguished by high biological and chemical oxygen demands (BOD and COD). Treatment usually involves a combination of physico-chemical and biological approaches, with the preference going to biological procedures due to their higher capacity and lower cost of removal of COD. The main objective of this article is to investigate how technology could improve waste management practices. Embracing contemporary solutions not only facilitates a more resource- and environmentally-conscious waste management approach but also aids in fulfilling sustainability objectives (Agrawal et al., 2020).

Dairy Waste: Characterization and categorization

Throughout the stages of dairy product production, processing, and distribution, the dairy sector is a major producer of waste. Dairy waste can originate from a number of sources, such as extra milk from spills, whey, and residue from machinery, cleaning supplies, and other organic elements. The ecological balance, air quality, and water sources are all threatened by these waste products. Putting into practice efficient dairy waste management techniques is essential to reducing negative effects on the environment and human health. The dairy industry is unwavering in its dedication to adopting sustainable practices, with the goal of being a key player in the development of sustainable food systems. A key component of this project is dealing with food waste in its entirety. One of the biggest environmental issues facing the dairy sector is wastewater discharge; Figure 1 shows the most common kinds of effluents produced by dairy processors.

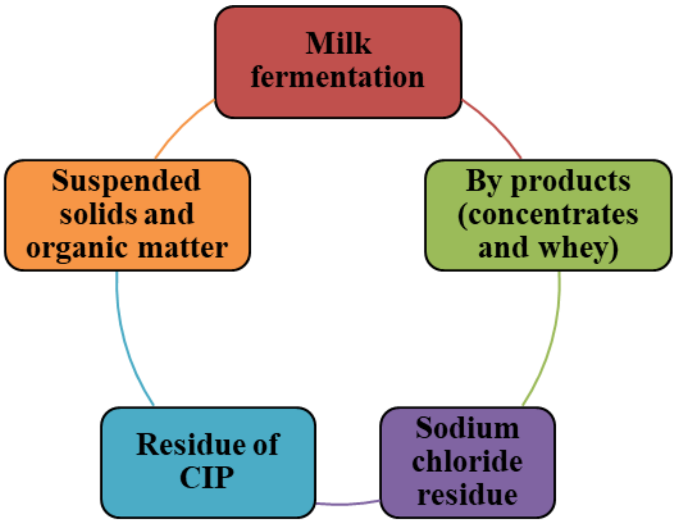

Fig. 1. Common kinds of effluents produced by dairy processors

Processing dairy products frequently results in waste from milk fermentation or by-products, which may be useful in the creation of other dairy products like whey concentrates made from cheese whey. Dairy wastes typically include organic debris, suspended particles, high phosphate and nitrogen levels, and oil and grease residues. The dairy sector has experienced significant growth in several nations due to rising demand for milk and its byproducts. As a result, the amount of effluent that dairy businesses release has increased along with this rise. Around 6 - 10 liters of effluent are usually produced by the dairy industry for every liter of processed milk (Yonar et al., 2018).

Treatments for Dairy waste management

Although some countries still discard dairy waste into waterways, this practice is discouraged because of the well-established consequences. Consequently, other therapy modalities have been created and are shown in Figure 2. These techniques provide more environmentally friendly options and include biological, physico-chemical, and wetland treatments.

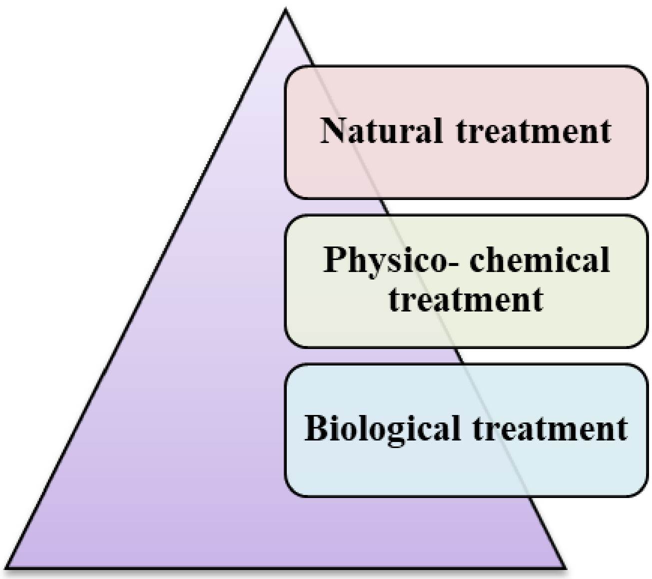

Fig. 2. Different treatment for dairy waste management

Natural treatment (wetland)

Wetlands show great promise as a wastewater treatment technology since they are as successful as conventional techniques and have additional benefits in terms of economy, ecology, and energy efficiency. Because of its straightforward design and lack of sludge recycling requirements, this system, which consists of aggregate materials, microbes, and wetland plants (hydophytes) finds special use for treating dairy wastewater in underdeveloped countries. The use of low-cost materials and local labor, the capacity to adjust to soil differences so that building can take place on aerated upland soils, and the ability to create hydric soil conditions through flooding are some of the notable advantages of wetlands over traditional systems. Worldwide, the use of wetlands for the purification of dairy effluent has shown promise; significant examples of this include Argentina, Italy, Canada, and Ireland.

Physico-chemical treatment

Physico-chemical treatments are an effective way to degrade and mitigate protein colloids and milk fat in dairy effluent. Coagulation, also known as flocculation, is one of these techniques that is essential to the treatment of industrial wastewater. This procedure facilitates the breakdown of organic materials that raise COD and BOD levels while also assisting in the reduction of suspended and colloidal particles, which add to the turbidity of water. The use of a coagulant causes the particulate matter in wastewater to become unstable, which in turn causes particle collisions and floc formation, which ultimately results in flotation or sedimentation. With an initial concentration of 1.93 g L^{-1}, oxidation pretreatment with $FeSO_4$ and H_2O_2 has proven to be highly effective, removing up to 80% of the fat found in cheese wastewater.

Biological treatment

The most popular approach to managing dairy wastewater is biological treatment, which includes a number of procedures such anaerobic filters, aerated lagoons, trickling filters, activated sludge, up flow anaerobic sludge blankets (UASB), and sequential batch reactors (SBR). It is the method that shows the most promise for removing organic material from dairy waste. However, the production of sludge during aerobic biodegradation presents difficult disposal problems and frequently results in high treatment costs for sewage sludge. Anaerobic and aerobic techniques are the two branches of biological treatment that are categorized according to the amount of oxygen required. Although aerobic procedures are commonly utilized in dairy wastewater treatment facilities, their effectiveness is diminished due to the quick acidification and filamentous development that arise from insufficient water buffer capacity and elevated lactose levels, respectively.

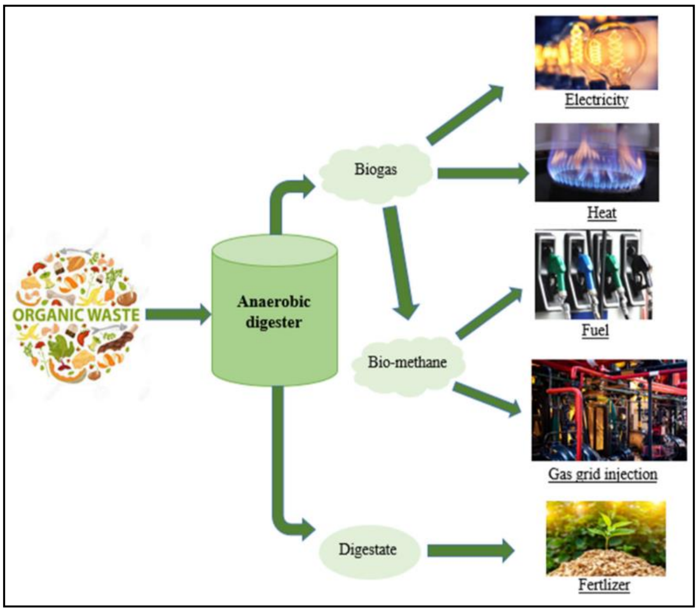

Fig. 3. Biological treatment of dairy waste management

In aerobic biological treatment, microorganisms are essential. In order for aerobic biological treatment to occur, oxygen-rich conditions must support microorganisms that can oxidize organic molecules into carbon dioxide, water, and cellular material. As opposed to their anaerobic counterparts, aerobic equivalents are less efficient. Anaerobic treatments (Figure 3) show promise as more affordable options, especially for wastewater with a high organic load from the cheese sector. Since aerobic technology mainly removes carbon-containing pollutants and has a lower efficacy in removing nutrients, it should be considered an initial stage that needs to be improved (Roufou et al., 2021).

Utilization of Dairy waste

Bioconversion is accomplished by biotechnological processes such anaerobic digestion, aerobic and anaerobic microbial fermentation, and fuel cells. Additionally, the manufacture of value-added goods can also be achieved through the combination of biotechnological and physiochemical processes. The main biotechnological methods used in dairy industry wastes are shown in Table 1 (De Jesus et al., 2015; Ahmad et al., 2019; Kumar Sarangi et al., 2023).

Table 1 Biotechnological methods used in dairy industry wastes

Product	Waste	Processing	Product
Food (Dairy) products	Whey	Fermentation with lactose fermenting organisms	Whey derived products
Biomass	Whey	Cultivation of mixture whey and oil press water with *Geotricum candidum*	Biomass
Bio fuels	Whey	Fermentation with *Kluyveromyces fragilis*	Ethanol produced is used in alcoholic beverages
	Whey powder	Fermentation with *Kluyveromyces fragilis*	Biofuel (Ethanol)
Organic Acids	Whey	Cultivation with *Aspergillus niger*	Citric acid
	Yoghurt production waste	Fermentation with *Lactobacillus casei*	Lactic Acid

Conclusions

The food processing business includes the dairy industry as a major component. This industry uses a lot of water and produces a lot of dairy effluent. There is little information now available about the precise makeup of this waste stream, which differs throughout sectors. Dairy effluent typically has high temperature, chemical oxygen demand (COD), organic content, and BOD levels. Inadequate handling and direct application to soil can result in detrimental environmental effects that affect aquatic life, including fish, humans, and agricultural practices. A number of benefits, including financial viability and environmental stewardship, make efficient wastewater treatment in the dairy industry an essential requirement. There are now several other therapy options that show promise and are more in line with sustainability goals. These benefits go beyond simple operational effectiveness or compliance; they can include observable financial gains like possible income streams and expense savings (Das et al., 2022).

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