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Valorisation of Dairy Processing Wastes for Sustainable Industrial Practises

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Milk and dairy products play a vital role in the global diet by providing essential proteins and minerals needed for human growth and maintenance. Efficiently and effectively converting milk into dairy products and ingredients requires a comprehensive approach, as food loss and waste have far-reaching effects, including impacts on food security, the environment, and economic losses for individuals and businesses. Due to the increase in dairy industrial activities, waste generation has also risen and needs to be managed properly. On a global scale, the annual quantity of dairy waste residue, comprising solid waste and effluents, is approximated to range from 4-11 million tonnes. Waste management is a critical global issue that prompts discussions on how to handle waste. Effluent from food processing wastewater is also a major concern due to high water usage and waste products from the production process, which are the main source of wastewater in many countries. A rising worry surrounds the impact of food production on the environment, fuelled by the push for sustainable products, regulations, and corporate collaborations. Regarding this topic, the dairy industry must contribute to global food security by adopting sustainable practices.

Dairy products frequently go to waste because of the rapid growth of spoilage-causing microbes in items such as cheese, cultured products, and fluid milk. Martin et al. (2021) explored different approaches to reduce food spoilage in the industrial setting. These methods involve minimizing the growth of harmful microbes, treating products to reduce microbial content, implementing natural control methods, handling spoilage organisms in raw materials, and employing data-driven technologies to improve quality and reduce spoilage. Waste production and product wastage can occur due to various factors such as leakage, overflow, lack of careful control, and other forms of wastage during the processing stages. The formation of sludge is a consequence of the waste generated from various activities such as processing, cleaning, and sanitation, as well as from treatment processes.

Sustainability should be deeply ingrained within corporate operations, not just an optional feature or separate strategy. It's essential to integrate sustainability practices into dairy industries because of the substantial pollution they produce, aiming to enhance operational efficiency (Feil et al., 2020). Utilizing waste from the dairy industry can lead to the development of sought-after by-products for various uses such as single-cell protein production, biofuel production, bioplastics, biosurfactants, biohydrogen, whey, and other by-products utilized for product preparations.

Value-added products from dairy waste

Single-cell protein

Microbial protein, also referred to as single-cell protein, demonstrates promise as a protein source for human consumption and could function as an alternative to conventional protein sources. Dairy waste can serve as a valuable reservoir of *Rhizobia*, which has shown to be effective in protein synthesis and can be utilized as a source of single-cell proteins. Derived from dairy waste, this resource is available year-round and remains unaffected by weather conditions.

Biopolymers and plastics

Several research projects have focused on creating biopolymers from dairy waste with properties such as high viscosity and increased molar mass. Bioplastics such as Poly-3-hydroxybutyrate (PHB) can be produced from dairy waste using specific microbial strains like *Bacillus subtilis, Ralstonia eutropha,* and *Azohydromonas australica*. Because of their delicate and easily affected by heat nature, their use in large-scale applications is still restricted.

Biosurfactants

Various microorganisms such as bacteria, fungi, and yeast can produce biosurfactants, which are also called surface-active agents, that can serve as alternatives to conventional organic surfactants. These

biosurfactants can be derived from dairy processing waste and are used for membrane cleaning purposes.

Biohydrogen

Sludge generated from dairy waste has been utilized in the production of biofuel as it can be a great source of hydrogen and methane. Hydrogen's lack of emissions has led to its recognition as a clean and environmentally friendly energy source, with water being its sole by-product when combusted. Dark fermentation is the preferred method for biohydrogen production because it efficiently converts by-products like volatile fatty acids into biohydrogen through photofermentation. Utilizing suitable microorganisms to digest the effluent slurry has also been shown to be effective in creating extinguishing agents (Tani et al., 2006).

Biofuel

With their superior emission characteristics, capacity to decompose naturally, and overall positive impact on sustainability, biofuels have become a popular substitute for non-renewable energy sources. By using yeast such as *Kluyveromyces marxianus*, it is possible to convert dairy waste into ethanol. Obtaining bio-oils from microalgae cultivated on dairy wastewater can produce approximately 1.12 × 109 Gigajoules of energy each year when paired with other energy extraction techniques. Hence, it is safe to say that creating biofuel from microbial cultivation on dairy waste is a feasible approach. It is crucial to investigate the effects of temperature, pH, lipid production, and other treatments on the biomass (Usmani et al., 2022).

Whey and by-product utilization

Whey and other by-products like buttermilk are generally regarded as major by-products of the milk processing industry and can be utilized for product preparations like ready-to-serve beverages and sports nutrition-based products. They also find their application in encapsulation matrices due to their high emulsion stability. Separating milk micronutrients and components can be a useful method for reducing processing waste. One potential opportunity involves producing D-lactic acid from cheese whey powder (Liu et al., 2018). Additional organic acids such as Succinic acid, Propionic acid, Acetic acid, and Lactobionic acid have been effectively derived from cheese whey. Creating edible film from whey has been a topic of interest because of its antibacterial properties and easy access to raw materials.

Conclusion

Food loss and wastage are major concerns, and dairy products are frequently among the items that are lost and thrown away. Dealing with the increasing amount of dairy waste is a major global challenge, primarily because of its high organic content. Disposing of this material correctly is now a critical issue because of strict waste discharge regulations and the urgent requirement for environmental conservation. These waste materials can be utilized as a basis for the widespread production of biomass, biopolymers, and energy generation by combining different technologies. Dairy waste has shown its value in different industries like food, agriculture, petroleum, cosmetics, and pharmaceuticals, playing a role in sustainable development. It is crucial to extract value-added products from dairy waste by adjusting process parameters, whether through independent or integrated procedures. Utilizing this method can greatly increase the production of bio-based products and help reduce the environmental hazards linked to waste disposal. Utilizing waste biorefinery in this specific context is essential for achieving sustainability by extracting resources from waste generated by the dairy industry. Establishing a viable circular bioeconomy concept contributes to economic prosperity, environmental quality, and social equality for both current and future generations.

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