Article- Recent Technological Advancements for Novel and Sustainable Packaging of Dairy Food Products

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Abstract:
Food packaging is crucial for protecting products, ensuring safety, and facilitating consumption. Important phases comprise manufacturing, wrapping, delivery, and preservation. The primary goal of food packaging is to maintain the quality of products throughout this process.
Packaging fulfills multiple functions, including storing items, shielding them, offering convenience, and conveying messages. The packaging process is crucial in preserving the quality of food products, particularly dairy items, which are susceptible to biological, physical, and chemical changes that can compromise their quality within a short period of time. Innovations in food packaging are driven by consumer demands and industry trends. Therefore, employing innovative methods like nanotechnology, modified atmosphere packaging, active packaging, and intelligent/smart packaging is essential within the dairy sector..

The dairy packaging market is witnessing significant growth, driven by increasing consumption of milk and milk-based products, alongside rising health concerns. Intelligent packaging solutions, including indicators, data carriers, and sensors, are being developed to preserve dairy products and provide consumers with essential information.

Despite advancements, challenges persist in dairy packaging, such as ensuring economical, hygienic, safe, and environmentally friendly packaging. Secondary packaging, including cartons, boxes, and wraps, is gaining importance in ensuring food safety and extending shelf life.Sustainable packaging innovations are emerging to meet consumer preferences while addressing environmental challenges. These innovations include biodegradable materials and improved design processes. This review paper examines recent technological advancements in the realm of sustainable packaging for dairy food products. As sustainability becomes more important globally, the dairy industry must adopt eco-friendly packaging solutions while maintaining product safety. This paper explores innovative packaging materials, designs, and technologies that offer novel approaches to address these challenges.

Keywords: Dairy food products, Packaging techniques, Sustainability, Novel.

INTRODUCTION:

Food packaging refers to containers or cases made of materials like metal, glass, or plastic that protect food products from external factors. It also helps with the marketing and consumption of these productsThe steps involving packaging, transportation, and storage play a vital role in maintaining food safety, much like the production process itself. The primary goal of food packaging is to uphold the food's quality from its creation to its consumption, thereby guaranteeing food safety.**[1]**

Packaging can be defined in three ways, as stated by [2]

1. Organized arrangement of a product for shipping, distribution, storage, sale, and eventual consumption.
2. Ensuring the secure and economical transportation of goods to the final consumers.
3. Utilizing technology and economic strategies to reduce shipping expenses while increasing sales and profitability.

Food packaging is constantly adapting to meet consumer demands and keep up with the latest trends in the food industry. When creating a food package, it's essential to consider four key roles: storage, safeguarding, ease of use, and communication. This entails designing packaging that effectively shields the product from external elements like moisture, gases, odors, bacteria, dust, and pressure.. Furthermore, food packages should contain detailed information about the product, and they should be regularly improved to adapt to different living conditions[2]

The packaging of milk is crucial for preserving its nutritional value, preventing wastage, and ensuring better marketability. This is particularly crucial because milk and dairy items are susceptible to rapid physical, chemical, and biological alterations. Packaging advancements have been consistently evolving to prolong the shelf life of these products.. In milk production, both processing and packaging are equally important operational phases, with packaging being the last but no less important phase.
The packaging sector faces the task of providing consumers with nutritious milk in a package that is cost-effective, hygienic, safe, and eco-friendly.
The following novel methods are used in packaging technology[3]
Nanotechnology, altered atmospheric packaging, active packaging, and intelligent/smart packaging.

The choice of packaging material for dairy products is crucial, as it can greatly impact the quality, safety, cost, and marketing of these products to the consumers. Recently, the focus has shifted towards innovative packaging solutions such as smart or intelligent packaging, modified atmosphere and active packaging, and sustainable packaging. This article provides an overview of the latest trends and applications in dairy product packaging, including evaporated, sweetened condensed, and powdered milks, ice cream, butter, acidified dairy products, and cheeses[6]

The dairy packaging industry is continuously developing innovative packaging solutions to cater to the convenience and preferences of 21st-century consumers.
The market is witnessing consistent growth, driven by rising consumption of milk and milk-derived items like ice cream, cheese, yogurt, milkshakes, and similar products. There's also a growing demand for processed dairy goods. Additionally, increasing health concerns among children and the elderly contribute to the expansion of the dairy packaging sector

Dairy products are known to contain a high amount of nutrients that support the growth of spoilage and pathogenic microorganisms. This presents a notable threat to the quality and safety of the products. It has been demonstrated that packaging plays a crucial role in safeguarding dairy products post-manufacturing and prolonging their shelf life. Intelligent packaging, in particular, can be used as a powerful tool for preserving dairy products and keeping users informed about the product's history. This can be achieved through the use of indicators such as time, temperature, gas, and freshness, as well as data carriers such as RFID and barcodes, and sensors. In this review, we will discuss the various attempts made to develop intelligent packaging for dairy products[7].
Dairy packaging is constantly evolving, with stand-up pouches and pressure-sensitive labels featuring QR codes driving innovation in the industry. The use of new materials and technologies makes dairy products more appealing and attractive to consumers. The need for sustainability is one of the main drivers of this innovation, but the perishable nature of dairy products also plays a significant role.

Current Challenges in Dairy Packaging:
One of the major challenges for the dairy packaging industry is to ensure that milk is delivered to consumers in an economical, hygienic, safe, and environmentally friendly manner. Due to the long shelf life requirements for UHT milks, multiple laminates are used, such as a triple layer of high-density polyethylene.

It is common for secondary packaging to have negative impacts on the environment from the extraction of raw materials to its disposal. To reduce these impacts, it's important to identify and quantify them. Life Cycle Assessment is a useful tool for achieving this goal and meeting the objectives of this study[4].

Technological Innovations in Sustainable Packaging:
This paper is dedicated to explore recent technological advancements in sustainable packaging for dairy products. It covers various innovations related to packaging, such as the creation of biodegradable and compostable materials, active and intelligent packaging solutions, and the improvement of packaging design and manufacturing processes. The focus of each innovation is on the benefits it can provide for sustainability, product protection, and consumer appeal.
Packaging of dried milk powder is a critical factor that affects quality, safety, consumer acceptance, and marketing. Milk powder contains fat and has a tendency to undergo lipid oxidation due to its hygroscopic nature. Therefore, milk powders need to be packaged in a way that prevents exposure to moisture, light, and oxygen to maintain their quality and freshness[5].

The significance of secondary packaging cannot be overlooked when it comes to safeguarding dairy products. Processors utilize this packaging to transport and store the primary packaging that directly touches the product. Secondary packaging choices encompass folding cartons, corrugated boxes, plastic crates, wraps, and films. Their demand is increasing as they play an essential role in ensuring food safety and facilitating supply chain operations.
According to Technavio - a global technology research and advisory company based in Elmhurst, Illinois - the secondary packaging market is expected to grow by $72.19 billion between 2023 and 2027. The market is projected to experience a 4% compound annual growth rate. Technavio

attributes this growth to factors such as rising demand for sustainable packaging, heightened interest in packaged and processed foods, and the growing e-commerce industry[8,9].

New secondary packaging solutions, driven by innovative packaging materials and design, are increasingly being used to ensure product safety and extend shelf life, according to Technavio[10]. Some Packaging of dairy food products depicts in table 1.

Table 1. Packaging of dairy food products

Sl.No.	Dairy product	Packaging material	Image
1.	Fluid Milk	Flexible packages like cartons, bags, pouches, cans, plastic bottles, plastic packages, jars etc.	
2.	Cream	Glass bottle, paper carton, low density polyethylene sachet, plastic bottles, etc.	

3.	**Yogurt**	**Glass ceramic packaging,Plastic Packaging, Composite material packaging, Ecolean Packaging, Metal packaging,**	
4.	**Curd**	**LDPE, HDPE or PP, Polystyrene, etc.**	
5.	**Butter**	**Butter Paper or Parchment Paper, Cellophane, Plastic, Aluminum Foil Laminate, Aluminum Foil Laminate, Plastic, etc.**	
6.	**Cheese**	**Pukka film, Unibloc system, Storpac, Vacuum pouch, Heat-shrink bags.**	

7.	**Ice Cream**	**Bulk Container, LDPE, HDPE, Cone Sleeves, Glass Bottles / jars, Corrugated paper box, Wrapper, Steel / Tin Cans:**	
8.	**Milk Powder**	**Bulk Bin, Tote Bin, Big Bag/Bag in Box, Can Packaging, Jar Packaging, Flexible Packaging, Carton Packaging,**	

Future Directions and Challenges:

The paper concludes by discussing directions and remaining challenges in the field of sustainable packaging for dairy products. This paper delves into the cutting-edge technologies and research domains that hold the potential for future innovations, including nanotechnology, bioplastics, and blockchain-enabled traceability systems. In addition to highlighting these promising areas, it addresses the ongoing challenges related to scalability, cost-effectiveness, and regulatory compliance[11,12].

As industries progress and grow, it becomes more important to explore emerging technologies and research areas. Identifying and delving into these domains enables businesses and academics to stay at the forefront and maintain competitiveness within their fields..

For example, nanotechnology entails manipulating materials at the atomic and molecular levels, with uses spanning from medicine to electronics.. Bioplastics, on the other hand, offer a more sustainable alternative to traditional plastics, and blockchain-enabled traceability systems can enhance supply chain transparency and accountability[13].

Although these technologies offer potential advantages, there are still obstacles to their widespread implementation. Issues related to scalability, cost-effectiveness, and regulatory compliance must be addressed to ensure their successful integration into existing systems. Nevertheless, by staying informed and engaged with these emerging technologies and research

areas, businesses and academics can position themselves to capitalize on future opportunities and drive innovation in their respective fields[14,15].

CONCLUSION:

The conclusion summarizes the key findings of the review, highlighting the significance of recent technological advancements for sustainable packaging in the dairy industry. Continued innovation and collaboration are crucial in driving progress towards eco-friendly packaging solutions.. Finally, it calls for concerted efforts from stakeholders across the dairy supply chain to accelerate the adoption of sustainable packaging practices.

Overall Impression:

This review paper presents a comprehensive overview of recent technological advancements in sustainable packaging for dairy food products. It effectively synthesizes current research and industry developments, offering valuable insights into the challenges, opportunities, and future directions of the field. The paper serves as a valuable resource for researchers, industry professionals, and policymakers interested in advancing sustainability in the dairy packaging sector, with its thorough analysis and well-structured presentation. The dairy packaging industry is evolving to meet the demands of the 21st century, with a focus on safety, sustainability, and consumer appeal. Continued innovation in packaging materials and design will play a vital role in ensuring the quality and longevity of dairy products while minimizing environmental impact. The paper provides a useful guide for those interested in staying up-to-date with the latest advancements in sustainable packaging for dairy products.

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