

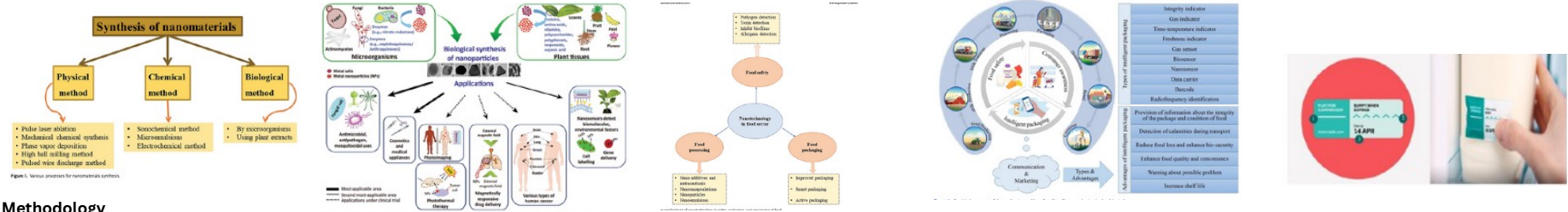
Are Innovations in Food Packaging Technology Sustainable?

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Introduction

Food Packaging is essential to understand food safety and quality. The determination of food contamination and intoxication can be attributed by external factors like moisture content, relative humidity, temperature, dust as well as damaged packaging. Food packaging traditionally used petroleum based plastics, glass, canning materials, metals and cheap paper to process packaging and make it accessible. Plastics like polyethylene and polypropylene have been labelled non biodegradable and purposefully contributes to pollution, microplastic intoxication, and infection. Synthetic chemicals like Bisphenol A (present in Epoxy Resin) and phthalates from plastics disrupt the endocrine system and act mycoestrogenic. Metal packaging like aluminum, tin leeches harmful byproducts into food, possibly causing digestive issues and worsening neurodegenerative conditions. In case of dairy packaging, use of biodegradables like seaweed-based films and corn plastic are ideal for milk sachets, yogurt containers, and cheese wraps. This helps in offering moisture resistance while reducing plastic use. For processed meats, chromatogeny-coated cellulose and recycled fishing net plastics are used. It leads to effective oxygen and moisture barriers. Sometimes Nitrogen flushing is also used to replace oxygen in the meat packaging. Packaging made from cow manure can be used as a renewable alternative for meat or meat analogues. Fresh fruits and vegetables use plantable seed paper along with grass cardboard, which are compostable and increase ecological value. There are 3D-printing and biodegradable packaging to protect material waste. In the bakery industry, FibreForm paper tubes and oyster paper increase shelf life for cookies, pastries, and bakery items. The molded fiber packaging allows for recyclable, custom-printed trays. These reduces carbon footprint and increases shelf life.



Methodology

Use of Bio Polymers in Food Packaging

Cellulose
Cellulose is a naturally occurring, biodegradable biopolymer that is frequently utilised in food packaging due to its superior oxygen barrier qualities. It has strong hydrogen bonding, which limits oxygen permeability, packaged foods have a longer shelf life. However, when exposed to humidity, its hydrophilic nature reduces its ability to withstand moisture, which might result in structural problems. Researchers have improved cellulose films with waterproof coatings or additions like fatty acids and nanoclays to get around this. Cellulose is a crucial component in the transition to environmentally friendly packaging solutions because of advancements like cellulose-based quality indicators and nanocomposite films, which show off its potential in intelligent packaging by providing environmental sustainability recyclability, and even visual spoilage detection.

Chitosan
Derived from the chitin found in crab shells, chitosan is a sustainable biopolymer that is valued for its inherent antibacterial qualities, capacity to form films, and biodegradability. It is perfect for food packaging since it creates flexible, translucent films with superior gas barrier properties. Aromatic oils or nanoparticles can be added to chitosan-based films to increase their antibacterial and antioxidant properties. For instance, chitosan-nisin films containing perilla oil kept fish that were ready to eat for 12 days, and chitosan infused with silver nanoparticles increased the shelf life of strawberries and prevented the formation of bacteria. Chitosan is a great contender for creative, sustainable packaging for food solutions because of its environmentally benign origin, usefulness, and regulatory compliance.

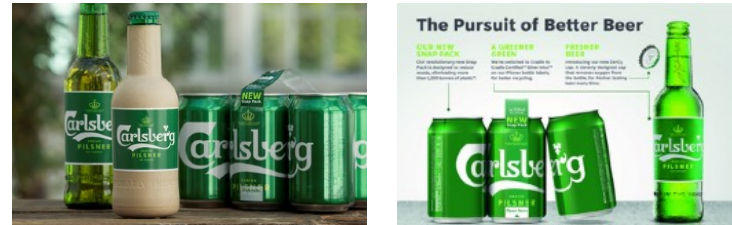
Smart Packaging Technologies

Active packaging is a breakthrough method of food preservation made possible by advancements in edible film production, biopolymers, and nanotechnology. In order to improve safety, preserve sensory quality, and increase shelf life, it incorporates functional elements which interact with food or its surroundings. Nanostructured materials and biophysical components, like nanofibers, essential oils, along with bioactive nanoparticles, allow precise regulation of moisture, gas exchange, and microbial growth. Structures like electrospun cellulose acetate nanofibers (CANFs) loaded with bioactive compounds are examples of how nanotechnology plays a crucial role. When essential oils of clove and cinnamon were added to CANFs, a fibrous matrix with a high porosity and surface area was formed, enabling the controlled release of antimicrobials and antioxidants. These nanofibers showed good resistance to microbial deterioration while maintaining their organoleptic properties. Edible films made of natural polymers like chitosan and pectin serve as removable barriers that have the ability to encapsulate and release beneficial substances like natamycin and epigallocatechin gallate (EGCG). These substances improve the performance of edible film in fruit preservation by providing photoprotection in addition to inhibiting microbial growth. Metal-organic frameworks (MOFs), which have a large surface area and adjustable pore topologies, can also be used to halt fruit ripening after harvest by scavenging ethylene. A higher degree of gas regulation is introduced into the packing matrix by MOFs' capacity to selectively absorb gases. These technologies, which revolutionise food packaging through edible and biodegradable sheets infused with nanoscale bioactive components, are the result of the convergence of biophysics and material engineering.

Carlsberg's "Snap Pack" with Colorimetric Sensor Technology

Carlsberg unveiled the "Snap Pack," a novel packaging idea that uses a glue-based bonding mechanism to replace plastic rings on their beer cans, reducing the amount of plastic used by up to 76%. Carlsberg has collaborated with packaging technology companies to investigate the incorporation of colorimetric freshness sensors, which alter colour in response to temperature and freshness conditions, in addition to minimising plastics. The product's labelling or film contains embedded colorimetric sensors. By changing colour in response to environmental changes like temperature swings that might impact beer quality, these sensors give a visual cue as to if the beer has been subjected to unfavourable storage circumstances. This facilitates real-time product quality monitoring for both customers and retailers. Without changing the recipe or composition of the beer, the Snap Pack principally works on ecological responsibility by drastically lowering the amount of plastic used and improving package transparency. By warning users of possible spoiling or exposure to unfavourable storage circumstances, including temperature violence, which can reduce product quality or raise the danger of microbiological contamination, the incorporation of colorimetric detectors for freshness monitoring provides indirect health advantages to consumers. By reducing the possibility of consuming tainted or spoilt beverages, this technology promotes safer consumption habits and improves product safety in general.

There are still a few potential problems with the Snap Pack's materials. To guarantee food safety and prohibit any hazardous diffusion from packaging into the product, adhesives and sensory components must pass stringent testing. Even though Carlsberg collaborates extensively with regulatory bodies, continuous observation is necessary to completely comprehend long-term impacts. Furthermore, even while the Snap Pack successfully cuts down on plastic waste, it ignores the health hazards that come with alcohol use, like binge drinking. Thus, innovative packaging enhances safety and the environment but has no direct effect on the health effects of alcohol.



Effect of Bio Polymers on Human Health

- Exposure to Chemicals from Additives
Biopolymers such as PLA might have harmful additives (stabilizers, plasticizers, heavy metal catalysts).
These might migrate into food, water, and soil, which could lead to:
Endocrine disruption
Tissue accumulation
Chronic toxicity
- Pesticide and Fertilizer Residues
Feedstock cultivation (e.g., sugarcane, corn) employs intensive agrochemicals.
Air, water, or food exposure may lead to:
Respiratory issues
Neurological and liver damage
Skin irritation
- Occupational Hazards
Manufacturing workers are at risk from:
Sulfuric/phosphoric acid (corrosive)
1-Octanol (systemic toxin)
Heavy metal catalysts (toxic and bioaccumulative)
- Microplastics and Incomplete Degradation
Under real-world conditions (i.e., landfills), such biopolymers as PLA can create biodegradable microplastics.
Such particles can enter the food chain, with unknown long-term health implications.
- Food Security Impacts
Harvesting food crops for bioplastics can increase food prices and decrease availability, leading to malnutrition and food insecurity, particularly in vulnerable areas.

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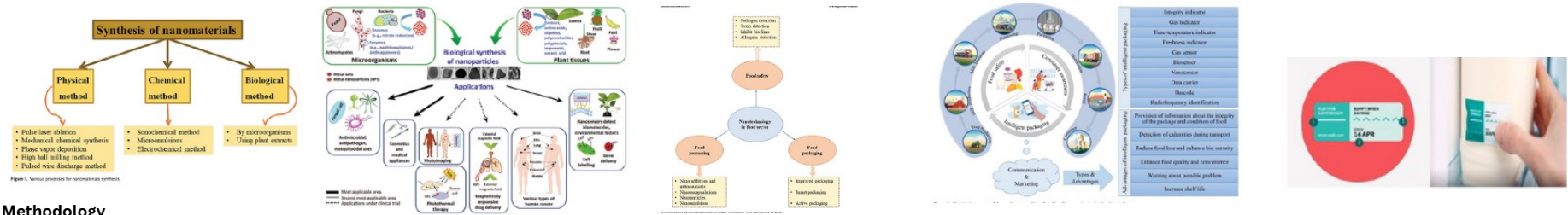
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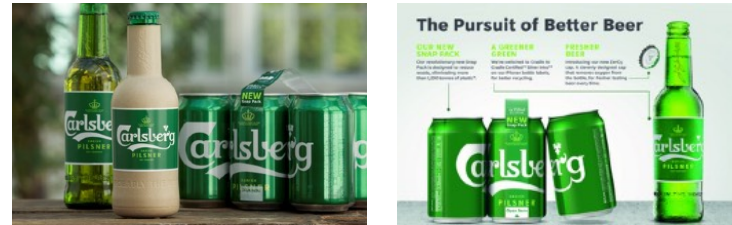
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