Intelligent Packaging Application in Dairy Products

Harsimran Kaur Gill[1], Sivakumar S*[1,2] and Viji P C[1]
[1]College of Dairy and Food Science Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141004 (Punjab),
[2]ICAR-National Academy of Agricultural Research Management, Hyderabad
Corresponding Author: sivakumarshanmugam60@gmail.com

Food safety, nutrition and food security are closely interconnected. The World Health Organization (WHO) plays a leading global role by mobilizing investments and coordinating initiatives at the national level to establish effective food safety systems. Also, WHO provides consumers with the tools they need to make informed decisions regarding the safe consumption of food. However, in the supply chain, food packaging is of paramount importance as it protects the food from contamination; traditionally, packaging materials are used simply to prevent the food from coming in contact with external factors and do not offer information about spoilage. There are many changes that happen to the food during the period of an alteration that are difficult to measure, and this fact makes it necessary to use intelligent packaging systems. This sophisticated packaging technology can identify and monitor product internal and external changes, giving consumers essential information regarding food safety and quality.

Dairy products such as milk, cheese, butter and yogurt are perishable products that need to be managed to prevent spoilage and to provide optimal conditions. The products contain high levels of proteins, fats, vitamins and minerals that are good for consumers. But as well as food going bad, food waste is also caused by its loss of nutrients. Furthermore, it is dangerous to eat the old dairy products. One technological solution to this problem is the use of multilayered packaging to preserve the freshness of milk for longer periods without refrigeration and preservatives. Even with these sophisticated technologies, however, milk can become spoiled because of heat shock or transport injury. When a container of milk is opened by the consumer, he generally only comes to know of its freshness at that time; hence the need for techniques that give an indication of milk quality before the milk is opened. The sensorial characteristics are altered by the spoilage processes and cause relevant economic losses, highlighting the need for improved monitoring and detection approaches in dairy production.

There are three main types of intelligent packaging: indicators, which can improve the convenience and provide quality information; data carriers, which can be used to trace products during the storage and distribution process; and sensors, which can be used for efficient measurement of food products. Indicators are an important subset of intelligent packaging solutions, designed to indicate the shelf life of a product and to convey quality-related information by means of chemical or biological markers contained in the package. These indicators can be distinguished from the inside or outside of a food product and by type of package.

The key technologies utilized in intelligent packaging systems include:

1) Indicators

- Time: Temperature Indicators (TTI): These monitor and report temperature history for all packaged foods from manufacturing to distribution and they may be classified by their mechanism of action as diffusion, microbial, enzyme, polymerization, and light color. TTI's are of special value in monitoring chilled milk, sterilized milk and frozen goods. Studies have shown that TTI's work well with milk.
- Freshness indicators (FI): Continued internal chemical reactions cause changes to occur in the metabolites of fresh food as it is packaged, which can be detected by freshness indicators that can visibly change color or be able to detect the metabolite directly.
- To extend shelf life, gas levels in packages need to be kept constant, which may be affected by fluctuations due to microorganism's respiration or leaks resulting in permeation of materials. Gas indicators measure these changes in the atmosphere which are directly linked to the product deterioration by means of printed elements on films or labels.
- Another type are the pH Indicators based on polyphenols such as anthocyanins for the detection of changes in acidity (Ma *et al*, 2022).

2) Sensors:

- Another important application of gas sensors in the dairy industry is in assessing changes in gas concentrations caused by microbial activity or presence, for example commercial gas sensor arrays have been designed to monitor the growth or presence of antibiotic-resistant bacteria in milk including Serratia spp., Pseudomonas pp., Bacillus spp., *Staphylococcus aureus*, *Candida pseudotropicalis* and *Kluyveromyces lactis*.
- Biosensors are another type of sensor, which features biological receptors such as enzymes or nucleic acids, and are able to detect a contaminant such as the level of urea or the presence of aflatoxin in dairy products. A recent example is an electrochemical biosensor that

is able to detect the level of β-lactoglobulin, a common allergen in milk, with high sensitivity of 0.85 pg/mL (Eissa *et al*, 2012).

- Melamine, a toxic compound illegally added due its nitrogen content can also be detected using modified biosensors employing ionic liquids combined with gold electrodes tailored for milk product analysis. Various electrochemical biosensors have been crafted for lactose quantification utilizing co-immobilized glucose oxidase alongside β-galactosidase enzymes; one example includes LactoSens. VR biosensors used specifically for identifying residual lactose levels in lactose-free dairy items via optimized enzyme configurations immobilized on disposable test strips.
- Nanosensors have gained traction within the dairy industry aimed at detecting pathogens like *Mycobacterium avium* subsp. paratuberculosis using sonicated immunoassays coupled with surface-enhanced Raman scattering techniques along with fluorescent micellar silica nanosensors targeting *Brucella abortus* antibodies found in milk as well as *Escherichia coli* O157:H7 using gold nanoparticle-modified screen-printed carbon electrodes.

3) Data Carriers

Data carriers streamline informational flow throughout the supply chain but do not actively monitor product quality, they instead ensure traceability while combating theft or counterfeit issues.

4) Barcodes

Cost-effective tools widely used for inventory management available in one-dimensional and two-dimensional formats differing significantly in storage capacity.

5) RFID Tags

More sophisticated than barcodes with capabilities up to 1 MB data storage enabling real-time data collection without line-of-sight limitations offering advantages across traceability measures within supply chains enhancing overall efficiency alongside promoting product safety standards.

Conclusion

Intelligent packaging is not only intended to provide important information about the quality of the packed food, but has the additional capacity of enabling the consumer to monitor characteristics of the packed food during the transport/storage phases that could cause spoilage before the indicated date to reduce the risk of foodborne illness, as well as characteristics such as temperature or microbial growth, integrity or physical damage, which all lend themselves to ensuring the freshness of the packed food, and which represent significant commercial opportunities for reducing the incidence of food waste and allergic reactions.

References

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