Exploring Innovative Techniques to Predict and Extend the Shelf-Life of *Dahi*

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Millions of people around the nation regularly eat *dahi*, which is a popular dairy product. It is a common ingredient in many recipes due to its creamy consistency, tangy flavour, and various health advantages. *Dahi* does have a shelf life, though, just like any perishable food item. It is essential to assure its freshness and quality that you are aware of the elements that affect its shelf life and that you are using correct estimating techniques. Predicting shelf life involves developing methods or techniques to determine the quality and remaining shelf life of *dahi*. This can be achieved through various means such as sensory evaluation, microbial analysis, chemical analysis, and advanced analytical techniques.

By accurately predicting the freshness of *dahi*, producers can ensure that consumers are provided with high-quality products and minimize wastage. Prolonging the freshness of *dahi* refers to employing innovative approaches to extend its shelf life. This can involve the use of different preservation methods, including physical techniques (e.g., refrigeration, modified atmosphere packaging) and chemical methods (e.g., food additives, antimicrobial agents). Additionally, advancements in packaging materials and technologies can help maintain the quality and freshness of *dahi* for a longer duration. The shelf life of *dahi* has recently been extended by the application of mathematical models and the creation of bionanocomposites, with promising results.

Factors Affecting the Shelf Life of *Dahi*

Microbial contamination

Dahi can become contaminated by microorganisms such bacteria, yeast, and mould, which causes spoiling. The fermentation process used to make *dahi* is carried out by lactic acid bacteria, which are essential in controlling the growth of dangerous bacteria. *Dahi*'s shelf life can be shortened by incorrect handling, unsanitary circumstances, or storage at high temperatures, which can promote the growth of spoiling microorganisms.

pH level

The microbiological stability and shelf life of *dahi* are influenced by its acidity, which is dictated by its pH level. Most bacteria cannot grow at *dahi*'s low pH, which normally ranges from 4.0 to 4.6. It's essential to maintain the proper pH levels during production and storage to stop the growth of spoiling microorganisms.

Temperature

Dahi's shelf life is significantly influenced by temperature. Microbial growth is accelerated by high temperatures and slowed by cold temperatures. *Dahi* benefits from storage at frigid temperatures (4°C) since it keeps its quality and shelf life longer. However, exposure to temperature variations or storage at a higher temperature than is advised might cause food to spoil.

Oxygen exposure

The shelf life of *dahi* can be harmed by oxygen exposure. It can trigger oxidative reactions that result in off flavours and a reduction in product quality as well as encourage the growth of aerobic spoilage bacteria. *Dahi* needs to be protected from these negative effects by using proper packaging that reduces oxygen permeability.

Ingredients and additives

The methodology and quality of ingredients used in *dahi* manufacture have a big impact on the duration it will preserve. The product's overall freshness and durability are influenced by premium milk, starter cultures, and stabilisers. Additionally, by preventing the growth of bacteria that cause deterioration, preservatives and antimicrobial compounds can increase the shelf life of *dahi.*

Estimation Methods for Predicting the Shelf Life of *Dahi*

Sensory Evaluation

The sensory evaluation of *dahi* comprises trained panellists rating its sensory qualities, including flavour, texture, aroma, and appearance. Experts can estimate a product's shelf life and predict the period when it stops meeting up to consumer expectations by tracking changes in sensory properties over time.

Chemical and Microbiological Analysis

Chemical analysis is used to track particular substances or changes in *dahi*'s composition over time. This technique offers information on the product's stability and freshness while assisting in the identification of chemical reactions that take place over time. Quantifying the bacteria load in *dahi* samples is part of the microbiological analysis process. Experts can determine the shelf life of a product based on the microbial count and the storage circumstances by monitoring the growth of microorganisms, particularly spoilage bacteria.

Accelerated shelf-life (ASL) testing

In order to imitate the consequences of prolonged storage over a shorter period of time, accelerated shelf-life testing involves testing *dahi* samples to accelerated storage conditions, such as increased temperatures. Experts can calculate the product's shelf life under normal storage settings by observing changes in quality features, as shown in Table 1 (Leahy *et al*., 2014).

Table 1. Stability study conditions, temperature, and storage intervals

Stability study conditions	Storage intervals (days)	Storage temperature (°C)
Shelf storage conditions	90, 180, 270 and 360	20-25
Accelerated shelf life conditions[1]	30	40-54
Accelerated shelf life conditions[2]	14	54±2

Mathematical Models for Shelf-life Prediction

Arrhenius equation

The correlation between temperature and the rate of chemical reactions is described by the Arrhenius equation. The Arrhenius equation can be used to calculate the rate of chemical or microbiological reactions that impact product quality in the context of predicting the shelf-life of *dahi* (Eq. 1). Experts can extrapolate the shelf life under varied storage situations by applying the equation to various temperature environments.

$$k=k_o \exp\left(-\frac{Ea}{RT}\right) \qquad (1)$$

where,

K_o = Constant
Ea = Activation Energy
R = Gas constant
T = Absolute temperature

Arrhenius method was used by Zhi *et al.* (2018) to predict the shelf life of *dahi* samples. Based on the results, sample 1 and sample 2 had a shelf-life prediction of 15.5 and 18.5 days, respectively, at 5°C. It was interpreted from the study that Arrhenius model is an effective method in predicting the shelf-life and to improve the quality parameters of *dahi*. Due to popularity of Arrhenius model, it is been used as an alternate of ASL test.

Zero-order kinetics

In zero-order kinetics, the response rate is assumed to be constant over time. This model can be used to calculate the degradation of particular *dahi* ingredients, like vitamins or flavours, and to forecast the time when their concentrations will decline below safe levels (Eq. 2).

$$[A]=[A]_o\text{-}kt \qquad (2)$$

where,

N_o	=	Initial log number of cells
N	=	Log number of cells
k	=	Rate of reaction
t	=	Time

Weibull distribution

In reliability engineering, the Weibull distribution is frequently used to simulate how quickly things degrade. By taking into account the likelihood of product failure owing to microbial spoilage, changes in sensory characteristics, or chemical degradation, it can also be used to estimate the shelf life of *dahi*.

This model considers variables including temperature, pH, and storage conditions as well as the likelihood of failure or spoiling over time (Eq. 3). It offers a more thorough understanding of the ageing and degradation processes that *dahi* goes through.

$$\text{Log}(N)=\text{Log}(No)\text{-}\left(\frac{t}{\text{delta}}\right)^p \qquad (3)$$

where,

N	=	Log number of cells
N_o	=	Initial log number of cells
T	=	Time
delta	=	Time for the first decimal reduction
p	=	Shape, p=1, log-linear p>1, concave downward curve p<1, concave upward curve

Another common model used for shelf-life prediction of *dahi* is the modified Gompertz model. This model takes into consideration the microbial growth of *dahi* during storage, as well as the decline in pH and sensorial qualities. It can provide an estimate of the time it takes for the *dahi* to reach a certain level of spoilage based on these factors.

Techniques for Extending the Shelf Life of *Dahi*

Packaging plays a crucial role in preserving the freshness of *dahi*. Innovations in packaging materials and technologies, such as oxygen and moisture barrier films, active and intelligent packaging systems, and modified atmosphere packaging, can help create a protective environment and inhibit the growth of spoilage microorganisms. Active packaging is an innovative technique used to extend the shelf life of *dahi* by incorporating functional elements into the packaging material, which actively interact with the *dahi* to improve its quality and freshness throughout its storage period.

Additionally, the compatibility of the functional components with the dahi, sensory consequences, and regulatory compliance must all be carefully taken into account when designing active packaging for *dahi*. The active packaging components and additives utilised must be secure, efficient, and permitted for interaction with food, as defined by manufacturers.

Bionanocomposites-based packaging

Definition and properties

Nanoscale fillers, such as nanoparticles or nanofibers, are combined with a biopolymer matrix to create bionanocomposites (Fig. 2). High mechanical strength, barrier qualities, and antibacterial activity are just a few of these materials' special qualities (Basavegowda and Baek, 2021).

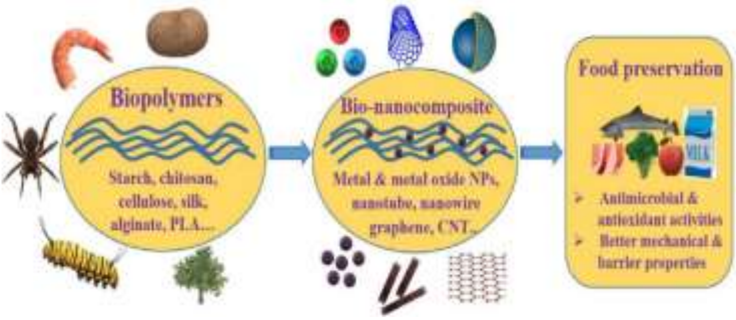

Fig. 2: Bionanocomposites for food preservation

Dahi packaging made with bionanocomposites can provide better defence against microbiological contamination, moisture loss, and oxygen permeation.

Methods of Incorporation in *dahi* packaging

Researchers have looked into a number of ways to include bionanocomposites into the materials used to package *dahi*. These consist of electrospinning, solvent casting, and melt mixing. Each technique seeks to achieve the necessary characteristics and usefulness by maximising the dispersion of nanofillers inside the polymer matrix.

Benefits of using Bionanocomposites

Dahi packaging made from bionanocomposites has several benefits. The product's shelf life is first extended by improving the barrier qualities, and preventing oxygen entry and moisture loss. The growth of spoilage bacteria is efficiently inhibited by the antimicrobial characteristics of bionanocomposites, lowering the risk of contamination. They offer mechanical reinforcement, enhancing the robustness and integrity of the packing.

Comparison Between Traditional and Novel Packaging Techniques

Each packaging technique contains its own pros and cons, although the choice of packaging depends on the storage conditions and specific application. The Table 2 contains benefits of using bionanocomposite-based packaging, polypropylene (PP) cup packaging and polyethylene (PE) pouch packaging for *dahi.*

Table 2. Comparison between traditional and novel packaging techniques

Bionanocomposite-based packaging	PP cup packaging	PE pouch packaging
Antimicrobial Properties	Convenient and lightweight	Compact and lightweight
Enhanced Barrier Properties	Cost-effective	Flexible and versatile
Enhanced Shelf Appeal	Durability and recyclability	Convenience and portability
Sustainability and customizability	Good for marketing opportunities	Product visibility and efficient space utilization

Conclusion and Future Scope

To preserve *dahi*'s quality and freshness, it is essential to comprehend methods to extend its shelf life. The shelf life of *dahi* is greatly influenced by elements such microbial contamination, pH levels, temperature, oxygen exposure, and additives. The correct prediction of shelf life is made possible by estimation techniques such sensory evaluation, microbiological analysis, chemical analysis, and accelerated shelf-life testing. The Arrhenius equation, zero-order kinetics, and the Weibull distribution are a few examples of mathematical models that can be used to estimate shelf life based on temperature, chemical processes, and the likelihood that a product would fail.

Moreover, the use of bionanocomposites in *dahi* packaging offers a variety of benefits, including as enhanced barrier capabilities, antibacterial activity, and mechanical reinforcement. The shelf life of *dahi* could be further improved through ongoing research in bionanocomposites, assuring consumers receive fresh and high-quality goods. The field of dahi packaging continues to evolve, driven by technological advancements and consumer demands. Future trends in dahi packaging include smart packaging with integrated sensors for real-time monitoring, sustainable packaging innovations, and further optimization of barrier properties. By staying informed about emerging trends, manufacturers can stay ahead of the competition and meet evolving consumer needs.

References

Basavegowda, N., and Baek, K. H. (2021). Advances in functional biopolymer-based nanocomposites for active food packaging applications. *Polymers*, *13*(23), 4198.

Leahy, J., Mendelsohn, M., Kough, J., Jones, R., and Berckes, N. (2014). Biopesticide oversight and registration at the US Environmental Protection Agency. *Biopesticides: state of the art and future opportunities*, 3-18.

Rhim, J. W., Park, H. M., and Ha, C. S. (2013). Bio-nanocomposites for food packaging applications. *Progress in polymer science*, *38*(10-11), 1629-1652.

Sofu, A., and Ekinci, F. Y. (2007). Estimation of storage time of dahi with artificial neural network modeling. *Journal of Dairy Science*, *90*(7), 3118-3125.

Yang, S. Y., and Yoon, K. S. (2022). Quantitative Microbial Risk Assessment of Listeria monocytogenes and Enterohemorrhagic Escherichia coli in Dahi. Foods, 11(7), 971.

Zhi, N. N., Zong, K., Thakur, K., Qu, J., Shi, J. J., Yang, J. L., Yao, J., and Wei, Z. J. (2018). Development of a dynamic prediction model for shelf-life evaluation of dahi by using physicochemical, microbiological and sensory parameters. *CyTA-Journal of Food*, *16*(1), 42-49.

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