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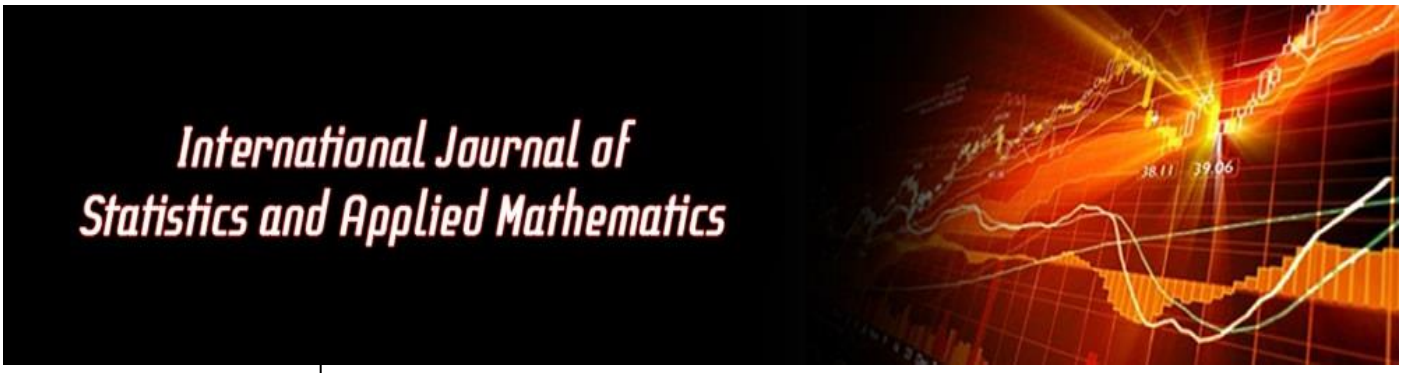

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Kumari M
Teaching Associate, Dairy Engineering, CoDS&T, RAJUVAS, Bikaner, Rajasthan, India

Vinchurkar RV
Ph.D Scholar, Dairy Microbiology, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Somveer
Ph.D Scholar, Dairy Engineering, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Deshmukh RR
Ph.D Scholar, Dairy Microbiology, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Corresponding Author:
Kumari M
Teaching Associate, Dairy Engineering, CoDS & T, RAJUVAS, Bikaner, Rajasthan, India

Mathematical model-based comparative storage study of dahi at refrigeration and room conditions

Kumari M, Vinchurkar RV, Somveer and Deshmukh RR

Abstract
Dahi, a traditional Indian fermented dairy product with significant nutritional and sensory attributes, undergoes changes in its shelf-life under varying environmental conditions. This study aimed to assess the impact of different temperatures levels on the shelf-life of *dahi* and influences its properties such as pH of *dahi* both at room temperature and under refrigeration. The research involved systematic experimentation, wherein *dahi* samples were subjected to controlled environments mimicking diverse temperature and humidity scenarios. In this trial, 20 distinct *dahi* samples were prepared and subsequently stored at varying temperatures: room temperature (37 °C) and refrigeration (4 °C). *Dahi* remained consumable for approximately 10 to 12 h when stored at room temperature, whereas when refrigerated, it maintained its suitability for consumption for about 3 to 5 days. Storing *dahi* at 37°C instead of 4 °C led to a 6% average pH increase. The developed mathematical model demonstrated a pH decline over storage time, in line with experimental results, with a strong correlation (R^2>0.97). Further research is warranted to explore preservation techniques and packaging solutions to extend the shelf-life of *dahi* under different environmental conditions.

Keywords: Mathematical models, *dahi*, shelf-life

1. Introduction
Dahi is a popular dairy product known for its nutritional value and distinct taste. In this study, *dahi* samples were subjected to different temperature environments, simulating storage conditions, to analyse their impact on the pH levels and overall quality of the product. The pH levels were measured over time to understand the extent of acidity or alkalinity changes, which directly relate to the microbial stability and sensory attributes of *dahi* (Chandan and Shahani, 1995) [1]. Additionally, the relative properties of *dahi*, encompassing texture, flavour, and visual appearance, were assessed to comprehend the comprehensive effect of temperature on its quality. The findings of this study contribute to a better understanding of shelf life of *dahi* and its sensitivity to temperature variations, thereby aiding in the development of guidelines for optimal storage and distribution practices to maintain its quality for consumer satisfaction.
The evaluation of the shelf life of perishable food products holds paramount importance in ensuring consumer safety and satisfaction. Temperature plays a pivotal role in influencing the microbial activity and chemical reactions that govern the quality and shelf life of *dahi* (Gemechu, 2015) [2]. The pH level of *dahi* serves as a crucial indicator of its quality, as it directly influences taste, texture, and microbial stability. The delicate balance between acidity and alkalinity significantly impacts the sensory attributes and overall consumer acceptability of *dahi*. The effect of temperature on the pH of *dahi* becomes particularly significant due to its potential to alter the metabolic activity of microorganisms present in the product. Consequently, a comprehensive exploration of the relationship between different temperature conditions and the pH of *dahi* is essential to ensure its optimal quality and extend its shelf life (Tamime, 2002) [3]. In this context, this study aims to delve into the multifaceted aspects of the shelf life of *dahi.* By subjecting *dahi* samples to a range of temperature conditions simulating storage and distribution scenarios, we seek to elucidate the intricate relationship between temperature, pH variations, and the relative properties of *dahi.*

2. Methodology

2.1 Preparation of *dahi*

The preparation of *dahi* begins with our carefully selected local milk, gently heated to 90 °C for 10 min. Next, a 100 mL milk sample is inoculated with 1.5, 2, and 2.5 mL of back slopping culture. The incubation for 10 h at 37 °C was done to activate the culture and to get the *dahi*.

2.2 Storage of *dahi* at different conditions

After *dahi* preparation, it was stored at room temperature and refrigeration temperature to examine the effect of temperature over the pH values of *dahi*. The pH values of dahi samples were checked after interval of every 2 h for 24 h storage study. All other storage parameters were kept constant. The comparative analysis was done to evaluate the effect of storage temperature over shelf-life of *dahi.*

2.3 Mathematical models

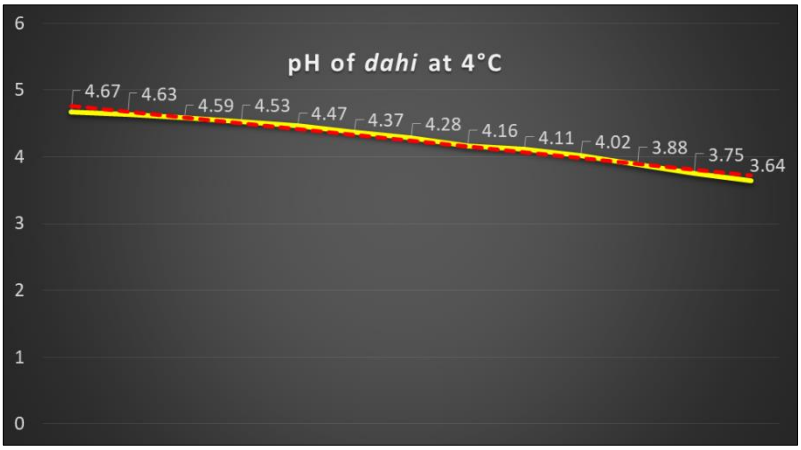
After analysis of pH development of *dahi* over 24 h storage period, Microsoft Excel software was used to formulate the mathematical models to predict the trend in pH values of *dahi* samples.

3. Results

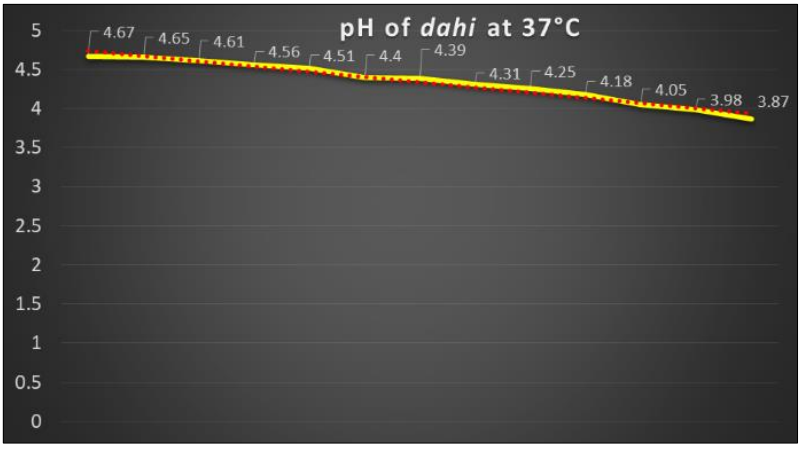
The pH of *dahi* is a critical indicator of its freshness, taste, and microbial stability. The study investigated pH variations under different temperature conditions. In this study it was observed that pH levels decreased over time in all samples at room temperature due to natural acidification whereas refrigerated *dahi* samples exhibited a slower decrease in pH, suggesting a controlled acid development process. In contrast, *dahi* stored at higher temperatures experienced faster pH reduction, which could be attributed to accelerated bacterial activity. In this case refrigerated *dahi* maintained its desired creamy texture for an extended period, while *dahi* exposed to elevated temperatures displayed signs of textural deterioration, such as increased separation of whey and curd. Similarly, the refrigerated *dahi* retained its characteristic tangy odour, while *dahi* stored at elevated temperatures exhibited a more pronounced sourness, possibly due to intensified bacterial metabolism. Visual assessments revealed that refrigerated *dahi* retained its smooth and uniform appearance, whereas *dahi* stored at higher temperatures exhibited uneven consistency and potential signs of whey separation.

Table 1: Rise in pH of *dahi* during 24 h storage study at different temperatures

Time (h)	pH (37 °C)	pH (4 °C)
0	4.67±0.03	4.67±0.03
2	4.63±0.03	4.65±0.03
4	4.59±0.03	4.61±0.03
6	4.53±0.03	4.56±0.03
8	4.47±0.03	4.51±0.03
10	4.37±0.03	4.46±0.03
12	4.28±0.03	4.39±0.03
14	4.16±0.03	4.31±0.03
16	4.11±0.03	4.25±0.03
18	4.02±0.03	4.18±0.03
20	3.88±0.03	4.05±0.03
22	3.75±0.03	3.98±0.03
24	3.64±0.03	3.87±0.03



A): pH of stored *dahi* at 4 °C



B): pH of stored *dahi* at 37 °C

Fig 1: Development of pH of *dahi*; (a) storage at 4°C, and (b) storage at 37 °C

$y = -0.0873x + 4.8492$ $R^2 = 0.9783$ (1)

Equation (1) represents the mathematical model for prediction of developed pH values during storage of *dahi* at 4 °C.

$y = -0.0667x + 4.8077$ $R^2 = 0.9751$ (2)

Whereas, equation (2) represents the mathematical model for prediction of pH values during storage of *dahi* at 37 °C.

Discussion

The results underscore the critical influence of temperature on shelf life of *dahi*, pH dynamics, and overall quality. Refrigeration emerged as the optimal storage condition, preserving microbiological stability, sensory attributes, and pH levels. Elevated temperatures accelerated microbial activity, leading to shortened shelf life, alterations in pH, and deterioration of texture, flavour, and visual appearance. The average increase in pH was 6% when *dahi* was stored at 37 °C rather than 4 °C. The obtained results were in good alignment with the findings of other researchers (Yadav *et al.*, 2007 and Dey *et al.*, 2011) [4, 5] These findings emphasize the necessity of proper temperature management during *dahi* production, distribution, and storage to ensure consumer satisfaction and product quality. The formulated mathematical showed decreasing trend in pH values when storage period stretches, which was confirmed with the experimentally obtained results. These models showed very high degree of correlation as the value of R^2 was too close to 1 (R^2>0.97).

Conclusion

This study provides valuable insights into the interaction between temperature conditions and the shelf life of dahi, shedding light on the multifaceted impact of temperature on pH dynamics and relative attributes. The outcomes highlight how temperature significantly affects the changes, and overall quality of *dahi*. Optimal storage, achieved through refrigeration, maintains microbiological stability, sensory qualities, and pH levels. Higher temperatures speed up microbial activity, reducing shelf life, altering pH, and degrading texture, flavour, and appearance. Storing *dahi* at 37°C instead of 4°C led to a 6% average pH increase. The developed mathematical model demonstrated a pH decline over storage time, in line with experimental results, with a strong correlation (R^2>0.97). These findings stress the importance of precise temperature control in *dahi* production, distribution, and storage for superior product quality and consumer satisfaction.

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