International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2023; SP-8(4): 71-76

www.veterinarypaper.com
Received: 07-04-2023
Accepted: 11-05-2023

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Computational models for predicting the physico-chemical properties of *dahi* based on its sensory attributes

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Abstract
Dahi, a known dairy delight, emerges from milk's elegant transformation through lactic acid fermentation. The pH of milk, typically at 6.7, transforms to 3.6-4.5 during fermentation. This shift encourages casein, a milk protein, to coagulate, creating a solid curd. In the dairy industry, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* are the predominant bacteria. The quality of *dahi* is usually judged by 9-point hedonic scale based sensory score cards. The physico-chemical attributes of *dahi* generally are checked manually, which is a time-and resource-consuming process. So, this study aimed at development of computational models to predict the pH, titratable acidity (% LA) and density (kg/m^3) of *dahi*. The predictive models showed good agreements with the experimental results. For example, the computational model for pH prediction had 0.79 level of correlation.

Keywords: Dahi, fermentation, titratable acidity, computational models, level of correlation

1. Introduction
Dahi, a renowned dairy product, results from milk undergoing lactic acid fermentation. Enjoyed in its natural state alongside meals, it transforms into refreshing raita when blended with ingredients like cucumber, boiled potato, or crispy gram flour batter. *Dahi*, the result of milk undergoing lactic acid fermentation, serves as a natural way to preserve milk in tropical conditions. This process not only halts spoilage but also imparts a pleasantly tangy aroma, especially revitalizing in hot climates. The ancients recognized fermentation's unique therapeutic benefits, absent in raw milk. For those sensitive to regular milk, *dahi* often proves suitable. Furthermore, curd consumption aids digestibility by partially breaking down constituents. Ingesting curds stimulates coliform organisms in rat intestines to produce thiamine, countering inhibitory effects of substances like sulphaguanidine on vitamin biosynthesis. Curd, also known as *Dahi*, delights as a sweet or savory lassi, or as a dessert with sugar, diced fruits such as banana, orange, and seasonal mango (Samanta *et al.*, 2015) [9].
Fermented foods, made from plant or animal materials, form a significant part of human diets globally. Enjoyed for centuries, these products are vital to various cuisines. Among them, *dahi* stands as one of the earliest known fermented milk items. Microorganisms, particularly lactic acid bacteria, play a key role in milk fermentation, turning lactose into lactic acid (Kagan, 1985) [3]. Currently, *dahi* is typically made using specific lactic acid-producing bacteria or by directly adding acid to milk. The delicious quality of *dahi* hinges on the balance between two key bacterial types: *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. Various factors like heat treatment, incubation temperature, culture amount, and incubation duration influence *dahi* quality (Paskov *et al.*, 2010) [7]. Milk has a pH around 6.7, which drops to 3.6-4.5 during fermentation under various conditions. This lowered pH prompts milk proteins like casein to coagulate, forming a solid curd. *Lactobacillus bulgaricus* and *Streptococcus thermophilus* are the predominant bacteria in the milk industry (Oladimeji *et al.*, 2016) [6].
This article delves into the profound impact of LAB on *dahi* flavour. It explores how microorganism-mediated glycolysis, proteolysis, and lipolysis contribute to flavour and off-flavour production. The study investigates the influence of diverse starter cultures on *dahi* taste, and it delves into the cutting-edge field of metabolic engineering for bolstering flavour.

Additionally, the article examines contemporary research on directing and managing flavour creation through LAB (Chen *et al.*, 2017) [2].

2. Methodology

2.1 Preparation of *dahi*

Local market-sourced milk was acquired and heated at 90 °C for 10 min. A 100 mL milk sample was then blended with 1.5, 2, and 2.5 mL of back culture. Incubation at 37 °C for 10 h followed to activate the culture and to set the *dahi*.

2.2 Sensory analysis

Experienced individuals who regularly consume *dahi* evaluated its body, colour, texture, appearance, flavour, and taste. The score card for panel test is shown in table 1.

2.3 Physico-chemical analysis

Different physico-chemical parameters such as density, titratable acidity and pH of *dahi* samples were determined.

1. The titratable acidity of *dahi* was determined by using phenolphthalein as indicator by titration of 0.1 N NaOH.
2. The pH of *dahi* sample was determined by dissolving yoghurt sample in water and using an electrode (pH meter).
3. The density of different *dahi* samples were determined by using equation 1.

Density (kg/m3) = Mass/Volume (1)

Table 1: Quantitative descriptive sensory analysis card for *dahi*

Quantitative Descriptive Sensory Analysis Card

Product: _____ **Panelist:** _____

Sample Codes: _____ **Date:** _____

Characteristics	**Low End**	**0 1 2 3 4 5 6 7 8 9 10**	**High End**
Appearance			
Surface	Cracked		Smooth
Colour	Off white		White
Colour consistency	Un even		Consistent
Free whey	Nil		Pronounced
Flavour			
Acidic	Nil		Pronounced
Salty	Nil		Pronounced
Sweet	Nil		Pronounced
Bitter	Nil		Pronounced
Un natural	Nil		Pronounced
Texture			
Gel strength	Weak		Strong
Ropiness	Nil		Pronounced
Granularity	Nil		Pronounced
Overall Acceptability	Not Acceptable		Highly Pronounced

Remarks, if any: _____

Name and Signature of panelist: _____

3. Result and discussion

The prepared *dahi* samples with 1.5, 2.0 2.5% concentrations of cultures were analysed for sensory evaluation, and chemical properties like pH, titratable acidity (% LA) and density. The obtained score card for colour and appearance, flavour and taste, body and texture are given in table 2.

Table 2: Sensory score of *dahi* prepared from mixed culture of previous day

Concentration (%)	Colour and appearance	Flavour and taste	Body and texture	Overall acceptability
1.5%	7.2±1.30	6.0±0.70	7.3±0.43	8.0±0.29
1.5%	7.4±0.31	6.0±0.75	6.0±1.02	7.0±0.60
1.5%	7.0±0.91	6.0±1.15	6.0±0.85	7.0±0.89
2.0%	9.0±0.47	8.0±0.25	9.0±0.60	9.0±1.20
2.0%	8.6±0.36	7.6±0.31	8.0±0.85	9.0±0.60
2.0%	8.6±0.75	7.6±0.80	8.3±0.68	8.3±0.85
2.5%	8.5±0.80	7.5±0.35	8.2±0.65	8.1±0.55
2.5%	8.0±0.85	7.3±0.25	8.0±0.65	8.0±0.75
2.5%	8.0±0.75	6.0±0.86	6.0±0.30	7.0±0.75

3.1 Colour and appearance

The colour and appearance evaluations for various *dahi* samples can be found in table 2. Significantly diverse outcomes emerged among the samples in terms of colour and appearance. The most impressive score was achieved by *dahi* with a 2.0% culture addition, whereas the lowest score was observed in *dahi* with a 1.5% culture addition. The average colour and appearance scores for *dahi* with 1.5, 2.0 and 2.5% culture additions were 7.1, 8.73 and 8.17, which showed significant difference among them. The experiment revealed that concentration of culture significantly impacted colour and appearance scores.

3.2 Flavour and taste

Dahi achieved its highest score with a 2.0% culture concentration, while the lowest was seen with 1.5% addition. The average flavour and taste ratings for 1.5, 2.0, and 2.5% culture addition were 6.0, 7.73, and 6.93, respectively, revealing significant differences. The study highlighted the pivotal role of culture concentration in influencing flavour and taste scores.

3.3 Body and texture

The table 2 presents the body and texture assessments of different *dahi* samples, yielding notably diverse results. Optimal scoring was achieved by *dahi* with a 2.0% culture addition, while the lowest score emerged from *dahi* with a 1.5% culture addition. The average body and texture scores for 1.5%, 2.0%, and 2.5% culture additions were 7.1, 8.73, and 8.17, respectively, highlighting significant differences among them. This experiment underscores the substantial influence of culture concentration on body and texture scores.

3.4 Overall acceptability

The highest overall acceptability scores (9.0±1.20, 9.0±0.60 and 8.3±0.85) were obtained for *dahi* samples which were inoculated with 2.0% concentration of culture. These results coincide with findings of some researchers (Salvador and Fiszman, 2004) [8] that highlighting that dahi prepared from whole milk showed superior colour, appearance, flavour, taste, body and texture ratings in comparison to other samples. The Microsoft excel software was used to generate the graphical representation for various sensory parameters (Figures 1, 2 and 3).

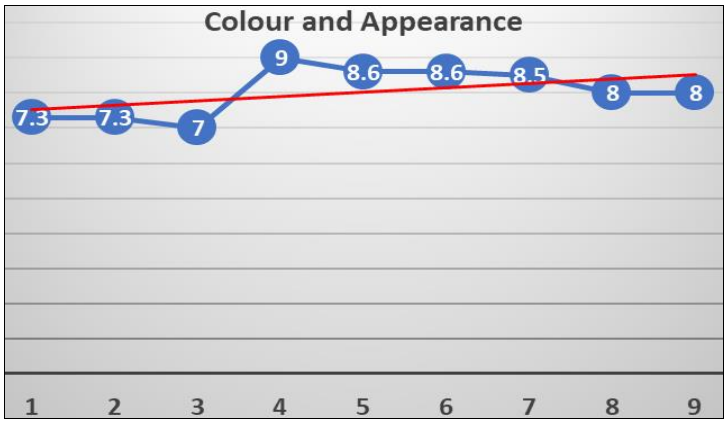

Fig 1: Graphical representation of colour and appearance score card for *dahi*

Fig 2: Graphical representation of flavour and taste score card for *dahi*

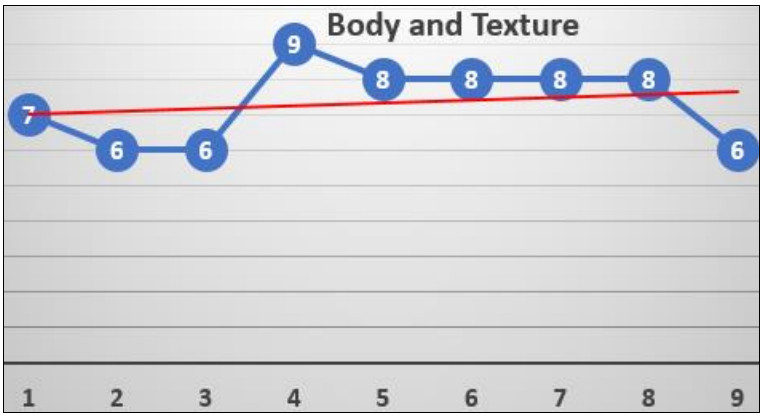

Fig 3: Graphical representation of body and texture score card for dahi

The formulation of computational models for predicting the sensory parameters of dahi was done by using Microsoft excel software and shown in table 3.

Table 3: Computational models to predict the score card for sensory parameters of *dahi*

Sensory parameters (x is % concentration of culture)	Computational model	Eq.
Colour and appearance	y = 0.125x + 7.4083	2
Flavour and taste	y = 0.0667x + 6.3333	3
Body and texture	y = 0.0833x + 6.9167	4

The physico-chemical properties of *dahi* were determined by using the methods (2.4.i to 2.4.iii) and the obtained values are presented in table 4.

Table 4: Physico-chemical attributes of *dahi* prepared by mixed culture

Concentration (%)	pH	Titratable acidity (%LA)	Density (kg/m^3)
2.5%	4.12±0.01	0.74±0.04	1026.98±0.01
2.5%	4.05±0.01	0.71±0.01	1026.76±0.05
2.5%	4.26±0.01	0.72±0.12	1027.03±0.01
2.0%	4.31±0.02	0.62±0.06	1027.18±0.05
2.0%	4.33±0.02	0.70±0.01	1027.39±0.02
2.0%	4.28±0.01	0.65±0.05	1027.09±0.07
1.5%	4.50±0.03	0.64±0.01	1028.34±0.04
1.5%	4.82±0.01	0.63±0.05	1029.74±0.01
1.5%	4.62±0.02	0.68±0.04	1028.71±0.03

From the results presented in table 4, it can be interpreted that with increase in % culture concentration, there was increase in pH, density whereas decrease in titratable acidity (%). The lowest and highest pH values were noted for 1.5 and 2.5% concentration of culture, respectively. The average pH values for 2.5, 2.0 and 1.5% culture concentrations were 4.14, 4.30 and 4.64%, respectively. The titratability acidity (% LA) values showed decreasing trend with increase in concentration of culture (%), whereas the obtained density values were in direct relation with concentration (%) of culture. The obtained results are in good relation with the findings of some authors (Lee and Lucey, 2010) [4], as the authors concluded that increasing the concentration of culture (%) drastically increased the pH values while titratable acidity values showed inverse trend the experimental findings were supported by the results of previous studies (Abrahamsen and Rysstad, 1991; Nighswonger, 1996) [1, 5].

Fig 4: Graphical representation of pH for *dahi*

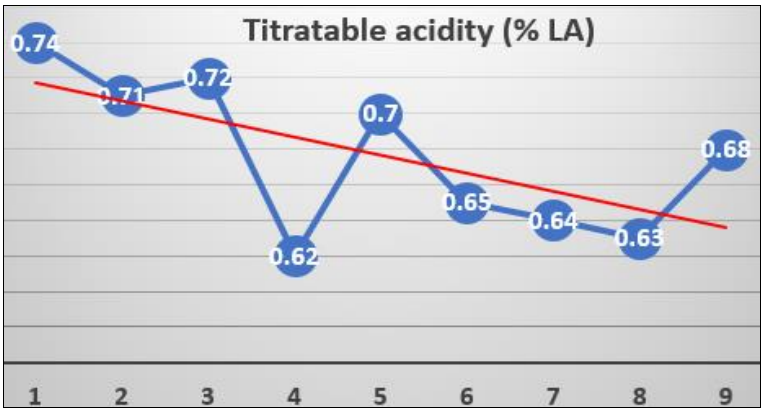

Fig 5: Graphical representation of titratable acidity (% LA) for *dahi*

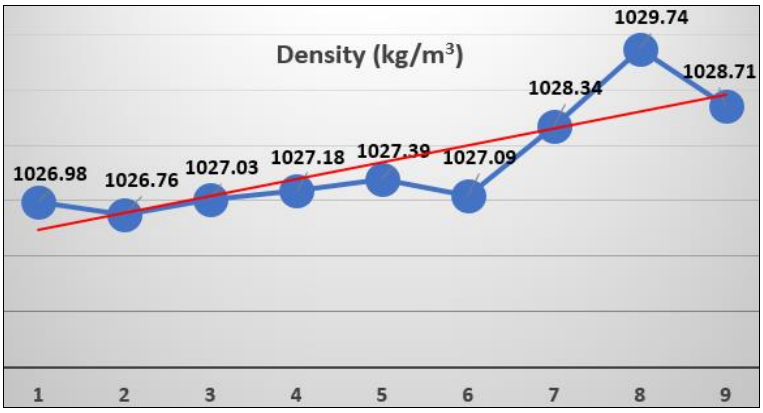

Fig 6: Graphical representation of density (kg/m3) for dahi

The formulation of computational models for predicting the sensory parameters was done by using Microsoft excel software and shown in table 5.

Table 5: Computational models for predicting the physico-chemical attributes of *dahi*

Physico-chemical attributes (x is % concentration of culture)	Computational model	Eq.
pH	$y = 0.08x + 3.9556$ $R^2 = 0.7963$	5
Titratable acidity (% LA)	$y = -0.0102x + 0.7275$ $R^2 = 0.4134$	6
Density (kg/m^3)	$y = 0.3065x + 1026.2$ $R^2 = 0.6891$	7

The model for pH prediction had 0.79 level of correlation and it interprets that pH decreases with increase in the value of x (% concentration of culture). On the other hand, the titratable acidity (% LA) showed direct or increasing trend with the value of x. The predictive models showed good agreements with the experimental results as the value of R^2 was higher than 0.6 except for titratable acidity.

4. Conclusion

The experiment clearly demonstrates the substantial impact of culture levels on *dahi* sensory score and chemical properties. The optimum sensory score was obtained for 2.0% concentration of culture. The average scores obtained for colour and appearance, flavour and taste, body and texture and overall acceptability at 2.0% concentration of culture were 8.66, 7.33, 8.44 and 8.76, respectively. Various computational models (Eq. 2, 3 and 4) were formulated for the sensory parameters and it was obtained that all sensory attributes have direct relation with the concentration of culture (%) to be added in milk, which were confirmed with the experimental findings.

Standard methods were adopted to find out the chemical properties of *dahi* like pH, titratable acidity (% LA) and density (kg/m^3). At optimum concentration of 2.0% in milk, the obtained average values of pH, titratable acidity (% LA) and density were 4.31, 0.66% LA and 1027.22 kg/m^3, respectively. Computational models were developed to predict the effect of culture concentration (%) on the chemical properties of *dahi*. It was concluded that pH and density (kg/m^3) showed an inverse relation with the concentration (%) of culture, whereas the titratable acidity (% LA) showed increasing trend with concentration of culture. The experimentally obtained results were in good alignment with the predicted results from computational models.

5. References

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