World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(Research Article)

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Investigation of the effects of homogenisation and gelling agents on the physicochemical, textural, and sensory properties of Yoghurt

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World Journal of Biology Pharmacy and Health Sciences, 2025, 22(03), 277-282

Publication history: Received on 05 May 2025; revised on 12 June 2025; accepted on 14 June 2025

Article DOI: https://doi.org/10.30574/wjbphs.2025.22.3.0600

Abstract

Yoghurt, a fermented dairy product, is valued globally for its nutritional benefits and unique sensory properties. Optimizing its texture, stability, and shelf life remains essential for commercial success. This study investigated the combined effects of milk homogenization and the incorporation of gelling agents—pectin and gelatin—on the physicochemical and sensory quality of yoghurt. A 10% skimmed milk powder solution was prepared, pasteurized, and split into two batches: homogenized (140 bar at 60°C) and non-homogenized. Each batch was further subdivided for the addition of pectin or gelatin, followed by inoculation with a 2% lactic acid bacteria starter culture. Samples were incubated at 43°C until pH 4.4 was reached. Physicochemical parameters such as pH, viscosity, syneresis, and texture were analyzed, alongside sensory evaluation by a semi-trained panel. Homogenization improved texture, gloss, and viscosity while reducing syneresis. Pectin significantly reduced whey separation, while gelatin enhanced creaminess and set firmness. The combination of homogenization and appropriate gelling agents resulted in yoghurt with improved consumer acceptability and shelf stability. These findings demonstrate the critical role of processing techniques and additives in tailoring yoghurt characteristics to market preferences.

Keywords: Yoghurt; Homogenisation; Gelling Agents; Pectin; Gelatin; Syneresis; Viscosity; Sensory Analysis

1. Introduction

Yoghurt is a widely consumed dairy product known for its nutritional value, probiotic benefits, and desirable sensory characteristics. It is produced through the fermentation of milk by lactic acid bacteria, primarily *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. The fermentation process results in the acidification of milk, leading to protein coagulation and gel formation (Tamime and Robinson, 2007). These transformations not only influence the microbiological safety of yoghurt but also its texture, flavor, and shelf stability—parameters critical to consumer acceptance and market success.

In contemporary dairy processing, technological interventions such as homogenization and the use of gelling agents play significant roles in enhancing yoghurt quality. Homogenization, a mechanical process that disrupts fat globules under high pressure, has been demonstrated to improve the uniformity of the fat distribution, enhance mouthfeel, and reduce creaming in dairy products (Skriver et al., 1999; McClements, 2005). By producing a more stable emulsion,

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homogenization contributes to improved product consistency and viscosity, both of which are vital for consumer satisfaction.

In parallel, gelling agents such as pectin and gelatin are commonly employed to reinforce the gel matrix and reduce syneresis—the separation of whey from the yoghurt matrix. Pectin, a plant-derived polysaccharide, functions by interacting with calcium ions and milk proteins to form a stable network that retains moisture (Thakur et al., 1997; Rolin, 1993). Gelatin, a collagen-derived protein, contributes to firmness and elasticity in dairy gels, forming a thermo-reversible structure upon cooling (Kavoosi et al., 2013).

The stability and texture of yoghurt are directly influenced by interactions among milk proteins, fat globules, bacterial metabolites, and added stabilizers. Studies have shown that optimizing these interactions through controlled processing conditions and the use of functional additives can significantly enhance product quality (Sodini et al., 2004; Aryana and McGrew, 2007). For instance, homogenized milk tends to exhibit improved gel strength and water-holding capacity due to finer dispersion of fat and protein components (Lee and Lucey, 2004). Additionally, the addition of gelling agents can mitigate post-acidification effects and contribute to the extended shelf life of the product (Ozturkoglu-Budak et al., 2016).

Despite extensive research on yoghurt formulation, the combined effects of milk homogenization and gelling agents on yoghurt quality are yet to be fully understood in practical manufacturing settings, especially in emerging markets. This study aims to fill that gap by systematically evaluating how homogenization and the incorporation of either pectin or gelatin influence the physicochemical, textural, and sensory characteristics of yoghurt. Through a structured experimental design involving standardized processing parameters, we investigate the synergetic or antagonistic interactions of these variables to identify optimal formulation strategies.

The findings from this study are expected to provide valuable insights for yoghurt manufacturers seeking to enhance product consistency, consumer satisfaction, and shelf-life without compromising nutritional or sensory quality. Moreover, understanding these interactions could enable greater control over product differentiation in a competitive dairy market.

2. Materials and Methods

2.1. Materials

Commercial skimmed milk powder (SMP), pectin, and gelatin were procured from certified food-grade suppliers. The starter culture used for fermentation consisted of a standardized blend of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. Distilled water was used for all dilutions and hydration procedures. All equipment used—such as homogenizer (GEA PandaPLUS 2000), pH meter (Hanna Instruments), viscometer, incubator, and texture analyzer (TA.XTplus)—were calibrated and operated according to the manufacturers' instructions.

2.2. Preparation of Skimmed Milk Solution

A 10% (w/v) skimmed milk solution was prepared by reconstituting skimmed milk powder in warm distilled water (90% v/v) at 40°C. The mixture was stirred continuously for 5 minutes to ensure complete hydration and uniform dispersion of milk solids. The hydrated milk was then heated to 60°C to prepare it for homogenization and gelling agent incorporation.

2.3. Experimental Design and Sample Grouping

The milk mixture was divided into two main batches

- Batch A: Homogenized milk
- Batch B: Non-homogenized milk

Each batch was further subdivided into three treatment groups, as follows

- Control (no gelling agent)
- Pectin-treated sample
- Gelatin-treated sample

This yielded a total of five yoghurt variants

- Homogenized with no gelling agent (Control A)
- Non-homogenized with no gelling agent (Control B)
- Homogenized with pectin
- Homogenized with gelatin
- Non-homogenized with pectin
- Non-homogenized with gelatin

2.4. Homogenization Process

Batch A was subjected to mechanical homogenization at 140 bar (approximately 2000 psi) using the GEA PandaPLUS 2000 homogenizer. The temperature during homogenization was maintained at 60°C. The process was aimed at reducing fat globule size to enhance product texture and uniformity.

2.5. Addition of Gelling Agents

Pectin and gelatin were each dissolved in distilled water (1.5% w/v) and preheated to 60°C for complete hydration. The hydrated solutions were added to respective milk batches immediately after homogenization (for homogenized samples) or after heating (for non-homogenized samples). Each gelling agent was added at a final concentration of 0.5% w/v.

2.6. Pasteurization and Cooling

All milk samples were heat-treated at 85°C for 15 minutes to eliminate microbial contaminants and denature whey proteins, thereby improving the texture and water-holding capacity of the final product. Samples were then cooled to 44°C to prepare for starter culture inoculation.

2.7. Inoculation and Incubation

Each sample was inoculated with 2% (v/v) of the prepared starter culture. The inoculated mixtures were mixed thoroughly and poured into sterile, pre-labeled containers. Incubation was conducted at 43°C until the pH of the yoghurt samples reached 4.4, marking the endpoint of fermentation. The fermentation time was recorded for each sample.

2.8. Storage Conditions

Post-fermentation, all samples were immediately cooled to 4°C and stored under refrigeration. pH and syneresis were measured at day 0 (post-incubation) and again after 7 days of storage.

2.9. Physicochemical Analyses

- pH Measurement: Conducted using a calibrated digital pH meter.
- Viscosity: Measured using a Brookfield viscometer (Model DV-E), with spindle No. 4 at 50 rpm at 10°C.
- Syneresis: Quantified using the gravimetric method. Samples were centrifuged at 3000 rpm for 10 minutes and the volume of separated whey was measured.
- Texture Profile Analysis (TPA): Performed with a TA.XTplus texture analyzer. Parameters such as peak entry force and suction force were recorded.

2.10. Sensory Evaluation

A panel of 12 semi-trained individuals (ages 20–45) evaluated the yoghurt samples for gloss, whiteness, syneresis, texture, smell (bitter, cheesy, creamy), viscosity, acidity, creaminess, and cheesiness. A structured 7-point hedonic scale was employed where 1 represented the least desirable and 7 the most desirable attribute (Meilgaard et al., 2016). Sensory sessions were conducted under consistent lighting and temperature in individual booths to minimize bias.

2.11. Statistical Analysis

Data were analyzed using SPSS version 25. Descriptive statistics (mean ± standard deviation) were calculated for all parameters. One-way ANOVA was used to determine significant differences ($p < 0.05$) among the treatments. Post-hoc comparisons were performed using Tukey's HSD test where applicable.

3. Results

pH Changes During Fermentation and Storage A general reduction in pH values was observed in all yoghurt samples post-fermentation, indicating successful microbial activity. Homogenised samples exhibited more significant pH reduction, reaching 3.97 after 7 days, compared to 4.00 in non-homogenised samples. Pectin-treated samples maintained higher pH values, suggesting potential buffering effects.

Viscosity Homogenised samples showed significantly higher viscosity ($p < 0.05$) than non-homogenised ones. Gelatin-treated samples displayed the highest viscosity among all, reflecting their structural reinforcement capability. In contrast, pectin-treated samples had reduced viscosity, possibly due to less effective integration into the protein matrix.

Syneresis Syneresis analysis revealed minimal whey separation in pectin-treated samples (0.20%), highlighting superior water-binding capacity. Non-homogenised and gelatin-treated samples had greater whey separation (7.37% and 6.59%, respectively), indicating weaker gel matrices.

Texture Profile Analysis TPA results showed that non-homogenised yoghurt had the highest peak force, indicating a firmer texture. Pectin-treated yoghurt was the softest, with low hardness and suction force. Gelatin and homogenisation together produced yoghurt with moderate hardness and good cohesiveness, desirable for consumer acceptance.

Sensory Evaluation Homogenised yoghurt scored higher in gloss and creaminess. Gelatin-treated samples were preferred for their mouthfeel and texture. Pectin-treated samples were visually whiter and had minimal syneresis but were rated lower in viscosity and smoothness.

4. Discussion

Influence of Homogenisation on Physicochemical Properties Homogenisation disrupted fat globules and enhanced emulsion stability, resulting in higher viscosity and lower syneresis. These outcomes agree with recent reports by Patel et al. (2022) and Kaur et al. (2021), which found improved structural integrity and microbial activity in homogenised milk.

Role of Gelling Agents Gelatin's protein-based matrix improved yoghurt's cohesiveness and viscosity. Similar results were found by Peighambardoust et al. (2021). Pectin, though effective in syneresis control, resulted in lower viscosity, supporting findings by Nogueira et al. (2021) and Winuprasith et al. (2023).

Synergistic Effects The combination of homogenisation and gelatin yielded the most favorable results in terms of sensory perception, viscosity, and overall texture, consistent with findings by Mousavi et al. (2024) and Tang et al. (2020).

5. Conclusion

Homogenisation significantly improved yoghurt's physicochemical and sensory quality by enhancing fermentation kinetics, reducing syneresis, and increasing viscosity. Gelatin emerged as a superior gelling agent for creaminess and structure, while pectin excelled in moisture retention but compromised texture.

Recommendations

- Dairy producers should adopt homogenisation to improve product consistency.
- Gelatin is recommended for enhancing sensory attributes in premium yoghurt.
- Pectin use should be optimized in combination with other stabilisers.
- Further research should explore plant-based alternatives and long-term shelf stability.

Compliance with ethical standards

Disclosure of conflict of interest

All authors declare No conflict of interest.

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