Evaluation of the Quality and Safety of Yogurt Enriched with Aloe vera Gel

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Abstract

This study Was aimed to utilize the known biological properties of Aloe vera gel within the global trend towards developing healthy functional foods. This was achieved by preparing and evaluating yogurt fortified with different concentrations (1.5%, 3%, and 6%) of fresh, natural Aloe vera gel extracted from the aloe plant and comparing it to commercially prepared Aloe vera gel during a refrigerated storage period of 0, 7, 14, and 21 days. The results showed the overall excelled of the natural gel over its commercial counterpart. The natural gel, particularly at the highest concentration (6%), significantly improved the physicochemical properties of the yogurt, including a marked increase in water retention, a reduction in whey separation and a significant slowdown in pH decrease and acid buildup. Oxidative indicators (peroxide value and lipid pH) also confirmed enhanced fat stability. These advantages were associated with the rich chemical profile of the natural gel, revealed by high-performance liquid chromatography (HPLC) analysis and antioxidant activity measurements, which showed a higher content of phenolic compounds. The natural gel exhibited stronger antioxidant activity (lower IC_{50}) compared to commercial gels. Microbiologically, the natural gel proved more effective in inhibiting microbial growth, reflected in reduced total bacterial counts, coliform bacteria, yeasts, molds, and chemo-regulation bacteria during storage. Finally, yogurt enriched with the natural gel, particularly at a 6% concentration, maintained the highest sensory acceptability (especially taste and texture) throughout the study period compared to the control (C) and commercial gel samples. This study concludes that natural, rather than commercially processed, Aloe vera gel is a promising functional additive for improving overall quality and extending shelf life of yogurt, achieving its highest effectiveness at a 6% addition concentration.

Keywords: Functional yogurt, Natural Aloe vera gel, Antioxidant, Microbiological quality, Refrigerated storage.

Introduction

Yogurt is one of the most widely consumed fermented dairy products globally, due to its high nutritional value and beneficial health properties. This is primarily attributed to the presence of lactic acid bacteria, which contribute to improved digestive health and enhanced immunity [1]. Recently, the food industry has witnessed a growing trend towards developing functional foods fortified with natural ingredients to enhance the product's health value and meet the demands of consumers seeking healthier foods. [2] Among these natural ingredients, Aloe vera has emerged as a promising candidate due to its historical reputation in traditional medicine and its rich chemical composition. The inner gel of the Aloe vera plant is a storehouse of a range of bioactive compounds such as polysaccharides (especially asmanan), vitamins, enzymes, and minerals, which give it antioxidant, antimicrobial, and anti-inflammatory properties [3]. These properties open the door to the possibility of using Aloe vera gel as a natural additive in dairy products to improve their quality and safety. Despite these possibilities, the form in which the gel is added, whether fresh or processed, remains a concern. Whether natural or commercially processed, the difference between natural and commercially processed Aloe vera gels is of paramount importance. Natural gels retain many of their thermoactive compounds but

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may be unstable.In contrast, most commercially processed gels undergo heat treatment and refining processes that can degrade sensitive compounds such as polysaccharides, potentially reducing their functional efficacy [4]. Therefore, evaluating the differences between the effects of natural and commercial gels on the final product is a crucial step in determining the optimal formulation for industrial application. The significance of this research lies in its systematic scientific comparison between the use of natural and commercial Aloe vera gels in the production of functional yogurt. This will help determine which type is more effective in improving the sensory and physicochemical properties of yogurt, enhancing antioxidant activity, extending shelf life through natural preservative properties, and maintaining the viability of lactic acid bacteria. This research aims to study and evaluate the effect of fortifying milk intended for yogurt production with fresh natural Aloe vera gel compared to commercial Aloe vera gel at three concentrations (1.5%, 3%, and 6%) on the physicochemical, microbiological, and sensory quality properties of the product, in addition to assessing the effectiveness of these additives in improving oxidative stability and antioxidant activity during a refrigerated storage period of 21 days.

Materials and Methods

Materials: Fresh whole cow's yogurt, a commercial starter culture (*Lactobacillus bulgaricus and Streptococcus thermophilus*), fresh Aloe vera leaves, and commercial Aloe vera gel.

Extraction of Natural Aloe vera Gel

The gel was extracted from fresh, mature Aloe vera leaves (800 g) according to method [5] with some modifications. The leaves were washed and their surface sterilized with 70% ethanol. The inner gel was then carefully separated, avoiding the yellow layer (*aloin*). The extracted gel weighed 480 g (60% extraction rate). The gel was then mixed and centrifuged for purification, and stored in tightly sealed, opaque containers at 4°C until use within 24 hours. This quantity provided the study's requirements for preparing all concentrations (1.5%, 3%, and 6%) for the replicates across the four storage periods (0, 7, 14, and 21 days).

Yogurt Production and Treatment Preparation: Milk was heated at 85°C for 30 minutes, cooled to 43°C, gels were added at the specified concentrations, a 3% starter culture was added, and the mixture was incubated until pH 4.6, then cooled to 4°C. Seven treatments were conducted: a control treatment (C) (without additives), three treatments fortified with natural gels (N1, N2, N3), and three treatments fortified with commercial gels (S1, S2, S3). The treatments were stored at 4°C for 21 days, and analyses were performed on days 0, 7, 14, and 21.

Chemical Tests: Chromatographic Analysis using HPLC of Natural and Commercial Aloe vera Gel: The active compounds of natural and commercial Aloe vera gels were analyzed using a SYKAM HPLC system according to a modified method [6]. A C18-ODS column measuring 25 cm × 8.46 mm was used, along with a mobile phase of methanol: water:formic acid (70:25:5) at a flow rate of 1 mL/min. Detection was performed at a wavelength of 280 nm, and the compounds were identified by comparing their retention times with those of the standard. The following equation was used to calculate the concentration of the compounds:

Concentration of compound = Concentration of standard x Sample area / Sample area x Dilution / Weight of sample.

Antioxidant activity and total phenolic content of natural and commercial Aloe vera gel were determined. Antioxidant activity was estimated using the DPPH assay, following the method described in [7], by mixing different concentrations of the samples (0–250 µg/mL) with a DPPH solution and incubating for 30 minutes at 25°C. The absorbance was

measured at 517 nm. The total phenolic content was determined using Folin-Ciocalto reagent, incubated for 60 minutes, and the absorbance was measured at 765 nm. The inhibition percentage and IC_{50} value were calculated from the relationship between concentration and inhibition percentage.

Physicochemical analyses included the pH, which was measured using a pH-meter after titration with standard solutions [8], the peroxide value, which was estimated according to the method [9] by extracting the fat and titrating it with potassium hydroxide, the fat acidity (ADV), which was estimated according to the method [10] by extracting the fat with an ether mixture and then titrating it with KOH, the acidity ratio, which was estimated by titrating with 0.1N (NaOH) using phenolphthalein indicator [11], the water retention capacity, which was estimated by the weight of the precipitate after centrifugation (3000 rpm, 60 minutes, 10°C) [12], and finally, the spontaneous oozing of whey, which was estimated by measuring the volume of serum released from a 50 g sample after two hours at 4°C [13].

Microbiological Analyses

These included total bacterial counts on Nutrient Agar and incubation for 24–48 hours at 37°C [14], coliform bacteria on MacConkey Agar and incubation for 24–48 hours at 37°C [15], yeast and mold on Potato Dextrose Agar and incubation for 5 days at 25°C [16], and chemoreceptor bacteria on Nutrient Agar and incubation for 7–12 days at 4°C [14].

Sensory Evaluation

The sensory characteristics of the samples were evaluated according to the method described by [17]. A committee of 15 panelists, comprised of faculty members specializing in food science at the College of Agricultural Engineering Sciences, University of Baghdad, with extensive experience in sensory evaluation, was formed. A 9-point Hedonic scale questionnaire was used to evaluate the sensory qualities of taste and flavor, texture and consistency, acidity, appearance, and overall acceptability. The following scores represent the tasters' levels of satisfaction:

9: Very satisfied • 8: Very satisfied • 7: Moderately satisfied • 6: Lightly satisfied • 5: Disliked • 4: Lightly disliked • 3: Moderately disliked • 2: Very disliked • 1: Disliked not at all

Samples were randomly presented to the evaluators under neutral and well-lit conditions, with water provided between samples to ensure the neutrality of the evaluation, as shown in Table 1.

Statistical Analysis

Data were analyzed using the SAS statistical software [18] to compare means using the least significant difference (LSD) test.

Results and Discussion

Extraction of Natural Gel from Aloe vera Leaves

The gel was successfully extracted from mature leaves with an efficiency of 60% of the total weight, consistent with the range (50-70%) reported in previous studies [19]. The extraction process followed a strict sterilization protocol using 70% ethanol, with careful separation of the gel from the yellow layer (Aloe vera) to avoid a bitter taste. This was followed by mixing and centrifugation to obtain a homogeneous, impurity-free consistency. The gel was then stored in opaque, airtight containers at 4°C until use.

Characterization of Natural and Commercial Gels by HPLC: The HPLC analysis in figures 1 and 2 revealed clear differences between the natural and commercial gels. The natural gels exhibited four major peaks with large areas,

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reflecting high concentrations of phenolic compounds, flavonoids, and anthraquinones [4]. In contrast, the commercial gels showed only two peaks with smaller areas and no characteristic peaks, reflecting the loss of active compounds due to heat treatment [20]. The delayed appearance of the peaks is partly attributed to the effect of methanol on the separation efficiency [21]. These results are consistent with the study [22], which confirmed that natural extracts retain a higher concentration of active compounds, and are further supported by the study [23], which demonstrated a decrease in the anthraquinone and phenolic compound content in commercial products as a result of manufacturing processes.

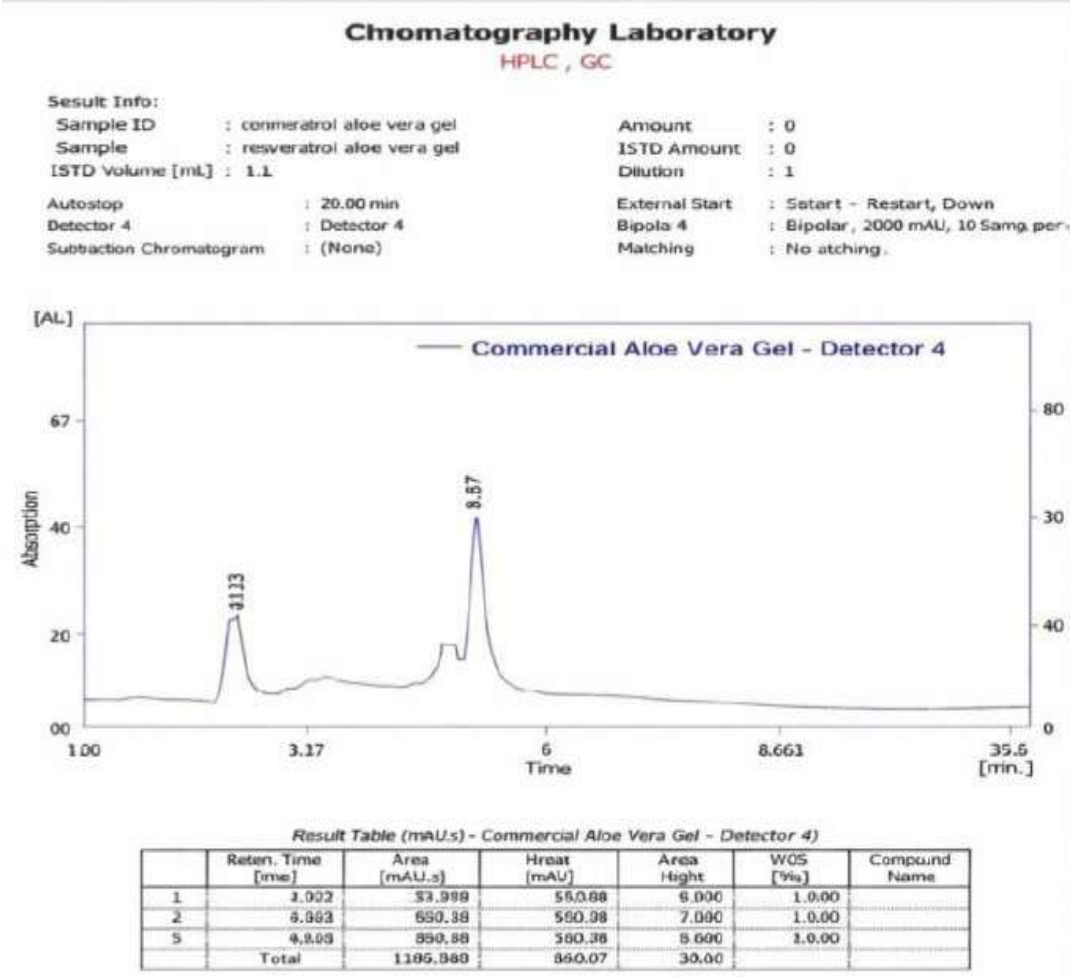

Figure (1): illustrates the analysis using high-performance liquid chromatography (HPLC) of a sample of natural Aloe vera gel.

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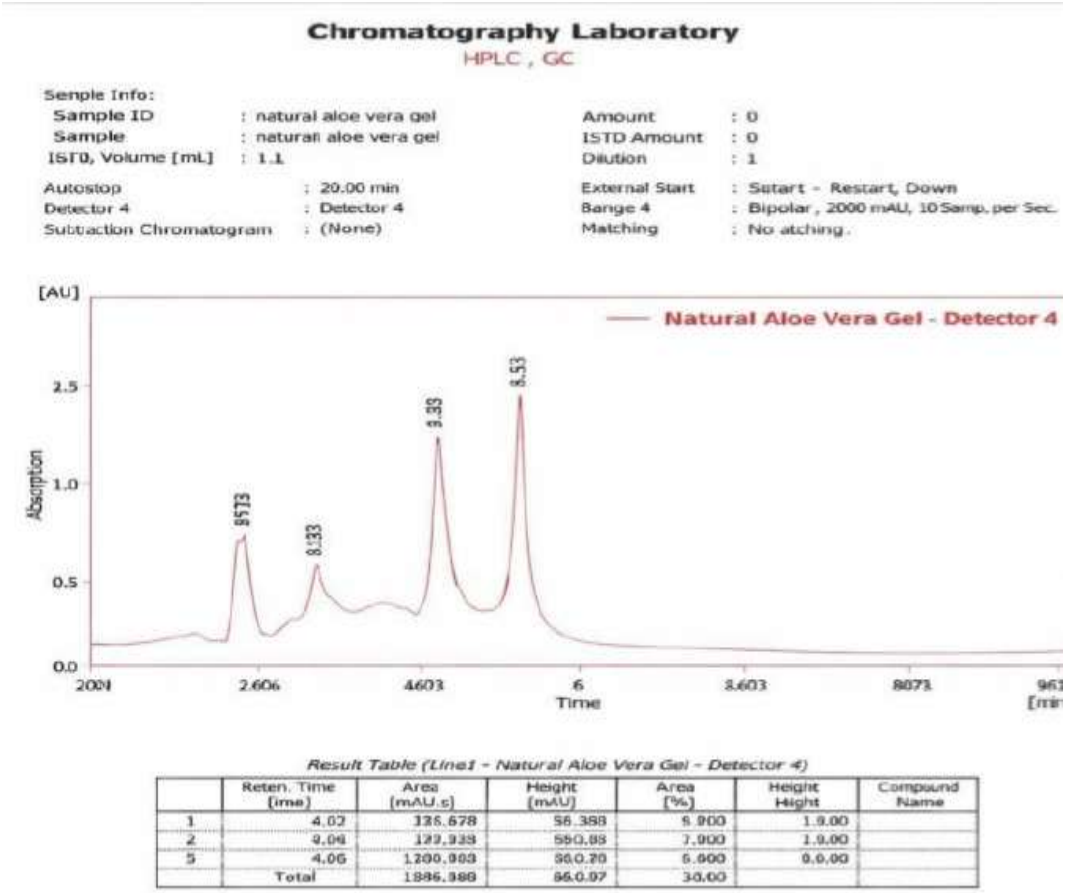

Figure (2) illustrates the analysis using High-Efficiency Liquid Chromatography (HPLC)of a commercial Aloe vera gel sample

Antioxidant Activity and Total Phenolic Content of Natural and Commercial Aloe vera Gel

The results of the antioxidant activity and total phenolic content analysis, shown in Table (1), indicate a significant advantage for the natural gel over the commercial gel at all studied concentrations. The natural gel exhibited higher inhibition rates of DPPH isoforms at all concentrations (78.6-25.1%) compared to the commercial gel (64.1-18.3%), with a lower IC_{50} value (128.6 µg/ml) compared to 172.4 µg/ml for the commercial gel. The natural gel also had a higher total phenolic content, reaching 45.7 mg GAE/g compared to 28.3 mg GAE/g for the commercial gel, representing a relative increase of 61.5%. Compared to gallic acid as a reference, it exhibited the highest inhibition rates across all concentrations (95.1–68.4%) and the lowest IC_{50} value (62.3 µg/ml), confirming the effectiveness of the evaluation methodology [22]. The excelled of natural Aloe vera gel is attributed to its retention of active phenolic compounds that were not subjected to heat treatment during extraction, whereas commercial manufacturing processes lead to partial loss of these compounds [20]. These results are consistent with the findings of a study [23] which indicated that natural Aloe vera extracts retain higher antioxidant activity compared to commercial products.

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Table 1: Antioxidant activity and phenolic content of natural and commercial Aloe vera gel compared to gallic acid.

Concentration (µg/ml)	Gallic acid (inhibition %)	Natural aloe vera gel (inhibition%)	Commercial aloe vera gel (inhibition%)
50	68.4	25.1	18.3
100	79.6	41.7	29.5
150	87.2	58.9	43.2
200	92.5	70.3	55.8
250	95.1	78.6	64.1
IC_{50} (µg/ml(	62.3	128.6	172.4
Total phenolic content (mg/g GAE(	–	45.7	28.3
LSD	8.902*	6.741*	14.58*
(P≤0.05) *			

Physicochemical analyses of different yogurt treatments during storage periods (0, 7, 14, and 21 days).

Water holding capacity

The water holding capacity results in Table (2) showed a gradual decrease in water retention capacity for all treatments during storage, with a significant advantage (P≤0.05)* for natural gels over commercial ones. Treatment N3 (6% natural) recorded the highest values throughout the storage period (57.0-65.5%), followed by N2 (3% natural) and then N1 (1.5% natural). This is attributed to the richness of natural gels in polysaccharides, which strengthen the protein network and increase its ability to bind water by interfering with yogurt proteins [24]. Treatment S3 (6% commercial) was the best among the commercial treatments, but it remained lower than its natural counterpart N3, due to the loss of some effective colloidal compounds during manufacturing [25]. The control treatment (C) had the lowest water retention capacity across all periods. The natural gel treatments, especially N3, the rate of decrease in water retention compared to the control treatment (C), confirms its role in improving product stability and extending its shelf life.

Table (2): Effect of adding natural and commercial Aloe vera gel in different concentrations on the water retention capacity (%) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatment	Water holding capacity(%)			
	Storage period (day)			
	0	7	14	21
C (Control)	52.0	48.5	45.0	41.0
N1 Yogurt + Natural Jelly 1.5%	56.0	53.5	50.5	47.0
N2 Yogurt + Natural Jelly 3%	60.5	58.0	55.0	52.0

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N3 Yogurt + Natural Jelly 6%	65.5	62.5	60.0	57.0
S1 Yogurt + Commercial Jelly 1.5%	54.0	51.5	48.5	45.5
S2 Yogurt + Commercial Jelly 3%	58.0	55.5	52.5	49.5
S3 Yogurt + Commercial Jelly 6%	62.0	59.5	56.5	53.5
LSD	6.20*	5.94*	5.68*	4.94*
(P≤0.05) *.				

Spontaneous whey separation

All The results of spontaneous whey separation in Table (3) showed significant differences (P≤0.05) * among treatments throughout all storage periods, as the control treatment (C) recorded the highest values for whey separation (4.5-9.0 mL/50 g), reflecting the weak structural integrity of the curd in the absence of texture-enhancing agents. This result is consistent with study [26], which indicated that whey separation increases with the weakening of the protein network during storage.

In contrast, natural gel treatments recorded the lowest values for whey separation (P≤0.05)*, with N3 (6% natural) being the best (1.5-6.0 mL/50 g), outperforming N2 and N1. This is attributed to the interaction of polysaccharides with milk proteins, forming a more cohesive gel network that enhances water retention capacity. This result is consistent with study [27], which confirmed that polysaccharides in natural Aloe vera gel strengthen the protein network and reduce whey separation.

Commercial gel treatments showed a gradual decrease in whey separation with increasing concentration, with S3 (6% commercial) recording the lowest values (3.0-7.5 mL/50 g), though it remained higher than natural gel treatments due to the loss of active compounds during manufacturing. This result is consistent with study [27], which demonstrated that heat treatments lead to the loss of effective colloidal compounds.

A gradual and significant increase (P≤0.05)* in whey separation values was observed for all treatments as storage progressed, which is attributed to the weakening of the protein network alongside increasing acidity [13].

Table (3): Effect of adding natural and commercial Aloe vera gel in different concentrations on the spontaneous whey separation of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

treatments	Spontaneous whey separation (mL/50 g)			
	Storage period (day)			
	0	7	14	21
C (Control)	4.5	6.0	7.5	9.0
N1 Yogurt + Natural Jelly 1.5%	4.0	5.5	7.0	8.5
N2 Yogurt + Natural Jelly 3%	3.5	5.0	6.5	8.0
N3 Yogurt + Natural Jelly 6%	3.0	4.5	6.0	7.5
S1 Yogurt + Commercial Jelly 1.5%	2.5	4.0	5.5	7.0
S2 Yogurt + Commercial Jelly 3%	2.0	3.5	5.0	6.5
S3 Yogurt + Commercial Jelly 6%	1.5	3.0	4.5	6.0
LSD	0.90*	1.10*	1.30*	1.50*
(P≤0.05) *.				

pH

The pH results in Table (4) show a gradual decrease in all treatments during storage due to the continued activity of lactic acid bacteria. Treatment N3 (6% normal) recorded the highest values throughout the storage period (4.72-4.32), followed by N2 (4.26-4.68), and then N1 (4.20-4.65). The commercial gel treatments, in order, showed S3 (4.23-4.69), followed by S2 (4.20-4.66), and then S1 (4.16-4.64), while the control treatment (C) had the lowest pH (4.62-4.10). The differences between treatments were not statistically significant (NS) at any of the storage periods. This indicates that the addition of natural and commercial gelling agents did not significantly affect the metabolic activity of lactic acid bacteria, and that the effect of the gelling agents is primarily focused on improving the structural and physical properties rather than on the acidity of the product [28, 29].

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Table (4): Effect of adding natural and commercial Aloe vera gel in different concentrations on the pH values of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	pH value			
	Storage period (day)			
	0	7	14	21
C (Control)	4.62	4.45	4.28	4.10
N1 Yogurt + Natural Jelly 1.5%	4.65	4.50	4.35	4.20
N2 Yogurt + Natural Jelly 3%	4.68	4.54	4.40	4.26
N3 Yogurt + Natural Jelly 6%	4.72	4.58	4.45	4.32
S1 Yogurt + Commercial Jelly 1.5%	4.64	4.48	4.32	4.16
S2 Yogurt + Commercial Jelly 3%	4.66	4.50	4.35	4.20
S3 Yogurt + Commercial Jelly 6%	4.69	4.53	4.38	4.23
LSD	0.389	0.296	0.307	0.322
NS.				

Peroxide Value (POV)

The peroxide value results in Table (5) showed that all treatments adhered to the permissible limit of 1.3 mEq/kg of fat, as per ISO 3976 [30]. All treatments recorded a gradual increase in values during storage, with a statistically significant ($P \leq 0.05$) difference (NS) between the natural gel treatment and the control treatment (C) on days 7 and 14. The differences were not statistically significant (NS) on days 0 and 21.

N3 (6% natural) recorded the lowest values throughout the storage period (0.7–1.0), followed by N2 (1.1–0.8) and then N1 (-0.8–1.2). The commercial gel treatments gave the following results: S3 (1.1–0.8), followed by S2 (0.8–1.2, then S1 (0.8–1.3), while the control treatment (C) had the highest results (0.9–1.3). The superiority of natural gel is due to its richness in antioxidant compounds that inhibit lipid peroxidation [24, 31].

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Table (5): Effect of adding natural and commercial Aloe vera gel in different concentrations on the peroxide value (POV) (mEq/100g fat) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	peroxide value (POV) /(meq/100g fat)			
	Storage period (day)			
	0	7	14	21
C (Control)	0.9	1.1	1.2	1.3
N1 Yogurt + Natural Jelly 1.5%	0.8	0.9	1.0	1.2
N2 Yogurt + Natural Jelly 3%	0.8	0.9	1.0	1.1
N3 Yogurt + Natural Jelly 6%	0.7	0.8	0.9	1.0
S1 Yogurt + Commercial Jelly 1.5%	0.8	1.0	1.2	1.3
S2 Yogurt + Commercial Jelly 3%	0.8	0.9	1.1	1.2
S3 Yogurt + Commercial Jelly 6%	0.8	0.9	1.0	1.1
LSD	0.218 NS	0.266	0.292	0.287 NS
(P≤0.05) *.				

Acid degree value (ADV)

The Acid degree value results in Table (6) showed a gradual increase in all treatments during storage, reflecting the continued enzymatic activity and lipolysis over time [32]. The control treatment (C) recorded the highest values throughout the storage period (1.20–3.40) (meq/100g fat), while the natural gel treatments significantly outperformed the other treatments in reducing ADV values (P≤0.05)*. Treatment N3 (6% natural) showed the lowest ADV values throughout the storage period (0.95–2.05), followed by N2 (2.30–1.00) and then N1 (2.75–1.10) (meq/100g fat).

The results for Acid degree value in Table (6) show a gradual increase in all treatments during storage, reflecting the continued enzymatic activity and lipolysis over time [32]. The commercial gel treatments were as follows: S3 (2.20–1.00), followed by S2 (2.55–1.05), and then S1 (2.95–1.15) (meq/100g fat). The superiority of the natural gel is attributed to the ability of its phenolic compounds to inhibit lipolytic enzymes [33, 34]. The differences between the treatments were significant at all storage periods.

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Table (6): Effect of adding natural and commercial Aloe vera gel in different concentrations on the acid degree value (mEq/100g fat) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	(ADV) values (meq/100g fat)			
	Storage period (day)			
	0	7	14	21
C (Control)	1.20	1.85	2.60	3.40
N1 Yogurt + Natural Jelly 1.5%	1.10	1.60	2.10	2.75
N2 Yogurt + Natural Jelly 3%	1.00	1.45	1.85	2.30
N3 Yogurt + Natural Jelly 6%	0.95	1.30	1.65	2.05
S1 Yogurt + Commercial Jelly 1.5%	1.15	1.70	2.25	2.95
S2 Yogurt + Commercial Jelly 3%	1.05	1.55	2.00	2.55
S3 Yogurt + Commercial Jelly 6%	1.00	1.40	1.180	2.20
LSD	0.250*	0.276*	0.495*	0.362*
(P≤0.05) *.				

Total acidity %

The acidity levels in Table (7) showed a gradual increase in all treatments during the four storage periods, resulting from the continued activity of lactic acid bacteria and the conversion of lactose to lactic acid [35]. The control treatment (C) recorded the highest values in all periods (0.73-1.15%), while treatment 6 (N3% normal) had the lowest (0.95-0.67%), followed by N2 (0.69-1.00%) and then N1 (0.70-1.05%). The commercial gel treatments were, in order: S3 (0.69-1.03%), followed by S2 (0.70-1.06%), and then S1 (0.71-1.10%).The differences between all treatments were not statistically significant (NS) in any of the storage periods.This indicates that the addition of natural and commercial gel did not significantly affect the metabolic activity of lactic acid bacteria, and that the gel effect was more pronounced in structural properties than in acidity development [36, 37].

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Table (7): Effect of adding natural and commercial Aloe vera gel in different concentrations on the total acidity (%) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	Total acidity %			
	Storage period (day)			
	0	7	14	21
C (Control)	0.73	0.86	1.00	1.15
N1 Yogurt + Natural Jelly 1.5%	0.70	0.82	0.94	1.05
N2 Yogurt + Natural Jelly 3%	0.69	0.79	0.90	1.00
N3 Yogurt + Natural Jelly 6%	0.67	0.76	0.86	0.95
S1 Yogurt + Commercial Jelly 1.5%	0.71	0.84	0.97	1.10
S2 Yogurt + Commercial Jelly 3%	0.70	0.82	0.95	1.06
S3 Yogurt + Commercial Jelly 6%	0.69	0.80	0.92	1.03
LSD	0.196 NS	0.192 NS	0.187 NS	0.208 NS
NS				

Microbiological analyses

Total bacterial count

The results of the total bacterial count in Table (8) showed no significant differences (NS) among treatments on day 0, as all treatments recorded equal counts (0.0 log CFU/g), indicating that the heat treatment was sufficient to eliminate bacteria at the beginning of storage. This result is consistent with study [38], which confirmed that proper heat treatment reduces bacterial counts to low levels at the start of storage.

As storage progressed, significant differences ($P \leq 0.05$)* appeared among treatments on days 7, 14, and 21. The control treatment (C) recorded the highest bacterial counts (3.5-6.5 log CFU/g), reflecting the absence of inhibitory factors and the presence of post-heat treatment contamination. This result is consistent with study [38].

In contrast, natural gel treatments recorded the lowest bacterial counts, with N3 (6% natural) being the best (0.5-3.5 log CFU/g), due to its content of active compounds that inhibit bacterial growth. This result is consistent with study [39].

Commercial gel treatments showed a gradual decrease in counts with increasing concentration, with S3 (6% commercial) recording the lowest among them (2.0-5.0 log CFU/g), but it remained higher than natural gel treatments due to the loss of active compounds during manufacturing. This result is consistent with study [23].

A gradual increase in bacterial counts was also observed as storage progressed due to bacterial growth under refrigeration conditions. This result is consistent with study [40].

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Table (8): Effect of adding natural and commercial Aloe vera gel in different concentrations on the total bacterial count (log CFU/g) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	Total bacterial count (log CFU/g)			
	Storage time (day)			
	0	7	14	21
C (Control)	-	3.5	5.0	6.5
N1 Yogurt + Natural Jelly 1.5%	-	3.0	4.5	6.0
N2 Yogurt + Natural Jelly 3%	-	2.5	4.0	5.5
N3 Yogurt + Natural Jelly 6%	-	2.0	3.5	5.0
S1 Yogurt + Commercial Jelly 1.5%	-	1.5	3.0	4.5
S2 Yogurt + Commercial Jelly 3%	-	1.0	2.5	4.0
S3 Yogurt + Commercial Jelly 6%	-	0.5	2.0	3.5
LSD	-	0.45*	0.60*	0.75*
(P≤0.05) *.				

Total Coliform Count

The results of the coliform count in Table (9) showed no significant differences (NS) among treatments on day 0, as all treatments recorded similar counts with no statistical differences, indicating that the heat treatment was sufficient to reduce the counts to comparable levels at the beginning of storage.

As storage progressed, significant differences (P≤0.05)* appeared among treatments on days 7, 14, and 21. The control treatment (C) recorded the highest counts (1.8-2.5 log CFU/g), reflecting the absence of inhibitory factors and the presence of post-heat treatment contamination. This result is consistent with study [41].

In contrast, natural gel treatments recorded the lowest counts, with N3 (6% natural) being the best (0.0-0.5 log CFU/g), due to their content of anthraquinone compounds that inhibit coliform bacteria. This result is consistent with study [42].

Commercial gel treatments showed a gradual decrease in counts with increasing concentration, with S3 (6% commercial) recording the lowest among them (0.3-1.0 log CFU/g), but it remained higher than natural gel treatments due to the loss of active compounds during manufacturing. This result is consistent with study [23].

A gradual increase in counts was observed until day 14, followed by a decrease on day 21 under the influence of increased acidity. This result is consistent with study [40].

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Table (9): Effect of adding natural and commercial Aloe vera gel in different concentrations on the total coliform count (log CFU/g) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	Total coliform bacteria count (log CFU/g)			
	Storage period (day)			
	0	7	14	21
C (Control)	-	1.2	1.8	2.5
N1 Yogurt + Natural Jelly 1.5%	-	0.9	1.4	2.0
N2 Yogurt + Natural Jelly 3%	-	0.6	1.0	1.5
N3 Yogurt + Natural Jelly 6%	-	0.3	0.6	1.0
S1 Yogurt + Commercial Jelly 1.5%	-	0.2	0.5	0.8
S2 Yogurt + Commercial Jelly 3%	-	0.1	0.3	0.5
S3 Yogurt + Commercial Jelly 6%	-	0.0	0.1	0.3
LSD	-	0.25*****	0.30*****	0.30*****
(P≤0.05) *.				

Yeast and Mold:

The results of yeast and mold count in Table (10) showed significant differences (P≤0.05)* among treatments during storage, while the differences were not significant (NS) on day 0. The control treatment (C) recorded the highest counts (1.40-1.80 log CFU/g), reflecting the absence of inhibitory factors and the presence of post-heat treatment contamination. This result is consistent with study [43], which indicated that the presence of yeast and mold during storage reflects inadequate sanitary conditions during manufacturing.

In contrast, natural gel treatments recorded the lowest counts, with N3 (6% natural) being the best (0.10-0.50 log CFU/g), and all were free on day 0 (0.0 log CFU/g), due to their content of phenolic compounds that inhibit fungal spore reproduction. This result is consistent with study [44], which demonstrated that phenolic compounds and anthraquinones in natural Aloe vera gel inhibit fungal growth.

Commercial gel treatments showed a gradual decrease in counts with increasing concentration, with S3 (6% commercial) recording the lowest among them (0.20-0.80 log CFU/g), but it remained higher than natural gel treatments due to the loss of active compounds during manufacturing.

A gradual increase in counts was observed until day 14, followed by a decrease on day 21 under the influence of increased acidity. This result is consistent with study [40], which stated that microbial growth is affected by increased acidity as storage progresses.

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Table (10): Effect of adding natural and commercial Aloe vera gel in different concentrations on the yeast and mold count (log CFU/g) of yogurt samples during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	Yeast and mold count (log CFU/g)			
	Storage period (day)			
	0	**7**	**14**	**21**
C (Control)	-	1.40	1.80	1.30
N1 Yogurt + Natural Jelly 1.5%	-	0.10	1.50	1.00
N2 Yogurt + Natural Jelly 3%	-	0.70	1.10	0.60
N3 Yogurt + Natural Jelly 6%	-	0.40	0.80	0.20
S1 Yogurt + Commercial Jelly 1.5%	-	0.80	1.20	0.70
S2 Yogurt + Commercial Jelly 3%	-	0.50	0.80	0.30
S3 Yogurt + Commercial Jelly 6%	-	0.20	0.50	0.10
LSD	-	0.28*	0.30*	0.25*
(P≤0.05) *.				

Psychrotrophic bacteria count

The results of the psychrotrophic bacterial count in Table (11) showed no significant differences (NS) among treatments on day 0, as all treatments recorded equal counts (CFU/g 0.0 $\times 10^2$), indicating that the heat treatment was sufficient to eliminate these bacteria at the beginning of storage. As storage progressed, significant differences *($P \leq 0.05$) appeared among treatments on days 7, 14, and 21.

The control treatment (C) recorded the highest counts (CFU/g 3.2-7.5 $\times 10^2$), reflecting the absence of inhibitory factors and the presence of post-heat treatment contamination. This result is consistent with study [45], which confirmed that psychrotrophic bacteria grow at low temperatures in the absence of inhibitors. Natural gel treatments recorded the lowest counts, with N3 (6% natural) being the best (CFU/g 0.3-1.2 $\times 10^2$), due to their content of active compounds that inhibit psychrotrophic bacteria. This result is consistent with study [46], which demonstrated that the active compounds in natural Aloe vera gel maintain their stability at low temperatures and hinder bacterial growth.

Commercial gel treatments showed a gradual decrease in counts with increasing concentration, with S3 (6% commercial) recording the lowest among them (CFU/g1.2-3.5 $\times 10^2$), but it remained higher than natural gel treatments due to the loss of active compounds during manufacturing.

A gradual increase in counts was also observed as storage progressed, due to the ability of these bacteria to grow at low temperatures. This result is consistent with study [45].

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Table 11: Effect of adding natural and commercial Aloe vera gel in different concentrations on the count of psychrotrophic bacteria (CFU/g ×10²) of different yogurt treatments during storage periods (0, 7, 14, and 21 days) at a temperature of 5 ± 1°C.

Treatments	Psychrotrophic bacteria count			
	Storage time (day)			
	0	**7**	**14**	**21**
C (Control)	-	3.2	5.0	7.5
N1 Yogurt + Natural Jelly 1.5%	-	0.8	1.5	2.5
N2 Yogurt + Natural Jelly 3%	-	0.5	1.0	1.8
N3 Yogurt + Natural Jelly 6%	-	0.3	0.7	1.2
S1 Yogurt + Commercial Jelly 1.5%	-	2.5	4.0	6.2
S2 Yogurt + Commercial Jelly 3%	-	1.8	3.0	4.8
S3 Yogurt + Commercial Jelly 6%	-	1.2	2.2	3.5
LSD	-	0.60*	0.90*	1.20*
(P≤0.05) *.				

Sensory Evaluation

The sensory evaluation results in Table (13) showed a significant superiority (P≤0.05) of the natural gel treatments over the control treatment (C) and the commercial gel in all sensory attributes (taste and flavor, texture and consistency, acidity, appearance, and overall acceptability) throughout the storage period. All treatments showed a gradual decrease in sensory scores with the progression of storage, but at varying rates. Treatment N3 (6% natural) was the best overall, maintaining the highest score in overall acceptability (36.8-42.5) throughout the storage period. It was followed by Treatment N2 (34.0-41.0), and then Treatment N1 (31.0-39.2). This excelled is due to the role of polysaccharides in improving texture and curd cohesion and reducing water separation [28].

The commercial gelling treatments were ranked as follows: S3 (6%) (commercial) (28.6–37.5), followed by S2 (30.1–38.6), then S1 (29.1–37.6), while the control treatment (C) recorded the lowest scores across all periods (28.1–37.6).The improvement in sensory characteristics in the treatments enriched with natural gelling is attributed to its effective role in improving texture and reducing water separation. This positively impacted the product's appearance and overall acceptability, especially at higher concentrations. The balanced taste and appropriate acidity also contributed to increased consumer preference for these treatments [47].

Table 12: Effect of adding natural and commercial gelling at different concentrations on the sensory evaluation of yogurt treatments during successive storage periods (0, 7, 14, and 21 days at 5 ± 1°C).

Treatment	Storage period (day)	sensory properties					
		Taste and aroma	Texture Total	Acidity	Appearance	General acceptability	total
C (control)	0	7.6	7.4	7.5	7.6	7.5	37.6
	7	7.0	6.9	6.8	7.0	6.9	34.6
	14	6.4	6.3	6.2	6.4	6.3	31.6
	21	5.7	5.6	5.5	5.7	5.6	28.1
N1	0	7.8	7.9	7.8	7.9	7.8	39.2
	7	7.3	7.4	7.2	7.3	7.3	36.5
	14	6.8	6.9	6.7	6.8	6.8	34.0
	21	6.2	6.3	6.1	6.2	6.2	31.0
N2	0	8.2	8.3	8.1	8.2	8.2	41.0
	7	7.8	7.9	7.7	7.8	7.8	39.0
	14	7.4	7.5	7.3	7.4	7.4	37.0
	21	6.8	6.9	6.7	6.8	6.8	34.0
N3	0	8.5	8.6	8.4	8.5	8.5	42.5
	7	8.2	8.3	8.0	8.1	8.2	40.8
	14	7.9	8.0	7.7	7.8	7.9	39.3
	21	7.4	7.5	7.2	7.3	7.4	36.8
S1	0	7.5	7.6	7.4	7.6	7.5	37.6
	7	7.1	7.0	6.9	7.1	7.0	35.1
	14	6.6	6.5	6.4	6.6	6.5	32.6
	21	5.9	5.8	5.7	5.9	5.8	29.1
S2	0	7.7	7.8	7.6	7.8	7.7	38.6
	7	7.3	7.2	7.1	7.3	7.2	36.1

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	14	6.9	6.8	6.7	6.9	6.8	34.1
	21	6.1	6.0	5.9	6.1	6.0	30.1
S3	0	7.4	8.0	7.2	7.5	7.4	37.5
	7	6.9	7.4	6.7	6.9	6.9	34.8
	14	6.3	7.0	6.1	6.4	6.4	32.2
	21	5.6	6.2	5.4	5.7	5.7	28.6
LSD value		2.067	1.771	2.184	1.905	1.822	5.807*
(P≤0.05) *.							

Conclusions

This study demonstrates that adding 6% fresh natural Aloe vera gel (Treatment N3) is an effective strategy for improving the overall quality of yogurt and enhancing its functional properties. The natural gel showed significant superiority over its commercial counterpart in all studied attributes, including improved physicochemical properties (increased water retention, reduced whey seepage, and maintained fat stability), enhanced antioxidant activity, reduced microbial load, and improved sensory acceptability during storage. This superiority is attributed to the natural gel's richness in phenolic compounds and active polysaccharides, which are partially lost during commercial manufacturing processes. These results support the trend toward using natural additives in the functional food industry, and the study recommends using 6% fresh natural gel in yogurt production to improve quality and extend shelf life.

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