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Enhancing Low-Fat Probiotic Yogurt: The Role of Xanthan Gum in Functionality and Microbiological Quality

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Abstract: The objective of this study was to determine the effect of XG addition on low-fat yogurt (LFY) properties. Pasteurized skimmed buffalo milk (SBM) was heated to 95 ± 2 °C for 16 s, cooled to 40 ± 1 °C, and then divided into six treatment lots. The treatments included the following: T1 (control), T2 (0.2% XG), T3 (0.4% XG), T4 (0.6% XG), T5 (0.8% XG), and T6 (1% XG). A proportion of 2% of a mixed starter culture from *Streptococcus thermophilus* (ST), *Lactobacillus bulgaricus* (LB), and *Bifidobacterium bifidum* (BB) in the ratio 1:1:1 was added. Yogurt was manufactured following the standard manufacturing protocol. Chemical composition and texture were determined at fresh time, while water-holding capacity (WHC), viscosity, and syneresis % were determined at 0, 7, 14, and 21 days of storage. Total bacterial counts (TBC), lactobacilli, streptococci, and bifidobacteria counts were determined at 0, 7, 14, and 21 days of storage. Sensory analysis was performed immediately upon the cooling stage (time zero) and then after 14 and 21 days of storage. The experiment was performed in trice. The results obtained showed that the addition of XG in LFY significantly ($p < 0.05$) decreases the pH, total protein (TP), and ash, and significantly ($p < 0.05$) increased the total solids (TS). Additionally, the addition of XG led to a significant ($p < 0.05$) increase in hardness, WHC, and viscosity; however, syneresis significantly ($p < 0.05$) decreased. The addition of higher amounts of XG led to a significant ($p < 0.05$) decrease in the TBC and led to a significant ($p < 0.05$) increase in counts of ST, LB, and BB during the first two weeks of the storage period. Sensory evaluation revealed that increasing the XG concentration up to 0.8% increased the product's acceptability among panelists; however, further increasing the concentration to 1% had a detrimental impact on its acceptability. To conclude, this study showed that XG can be used as a stabilizer in the manufacturing of LFY as well as a prebiotic for starter culture and improve the quality of LFY.

Keywords: xanthan gum (XG); low-fat yogurt (LFY); rheological functions; sensory evaluation; functional properties

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1. Introduction

Xanthan gum (XG), a complex extracellular polysaccharide synthesized by the bacterium Xanthomonas campestris, is renowned for its superior rheological properties [1]. This microbial polysaccharide has gained extensive utilization across various industrial sectors as a thickening, emulsifying, suspending, and stabilizing agent in both food-related and other industrial contexts [2]. The incorporation of stabilizers within food matrices is a well-established practice, dating back over half a century. Recent decades, however, have witnessed the emergence of an array of innovative dairy products that are heavily reliant on the rheological capabilities imparted by such stabilizers [3].

The dairy industry prioritizes the creation of products that not only meet consumer expectations in terms of aesthetics, texture, and taste but also demonstrate enhanced shelf

stability. To achieve this target, there has been a strategic shift towards incorporating stabilizing agents that augment the kinetic stability of food emulsions [4]. Blends of stabilizers such as xanthan gum, galactomannans, carrageenan, guar gum, and locust bean gum have proven to be highly effective in enhancing the quality of a variety of dairy products like ice cream, milkshakes, and ice milk [5]. XG is very important for improving sliceability, firm body, and flavor release of cream cheese. Also, XG serves as a thinker for cottage cheese dressings by improving drainage control [6]. Low-fat yogurt (LFY) is considered the most common fermented dairy product and is consumed by a large group of people as part of a diet or refreshment drink [7].

Yogurt also contains a lot of protein with high biological value, trace amounts of monosaccharides and disaccharides, and a lot of minerals, such as sodium, potassium, calcium, and magnesium. It also contains a large number of other health-promoting substances such as vitamin A, biotin, thiamine, riboflavin, folic acid, niacin, pantothenic acid and ascorbic acid [8]. Yogurt also has a variety of therapeutic effects, such as enhancing digestion and immune function and lowering serum cholesterol levels [9]. Yogurt's viscosity is affected by the homogenization process and thermal treatments. Syneresis is caused by several factors such as elevated temperatures during incubation, low solid-content milk, a disproportionate ratio of whey protein to casein, and mechanical actions of the final product [10]. The main challenge during the processing and storage of yogurt is whey expulsion (syneresis), which is very harmful to the product's integrity [11]. A prevalent solution for this challenge is the utilization of various stabilizing agents. These compounds are integrated into foodstuffs to enhance smoothness and ensure uniformity. Additionally, stabilizers play an important role in maintaining the dispersion of flavor constituents, hence preserving the viscosity of the yogurt [8]. They also interact synergistically with casein molecules to form robust networks, effectively mitigating syneresis and refining the textural attributes of the yogurt [12]. Several types of stabilizers like starch, gelatin, pectin, and hydrocolloid gums like XG are used to enhance the quality of yogurt [13]. However, most of these products have been affected in testing.

The main target of incorporating stabilizers in yogurt is to improve its characteristics, such as appearance, stability, viscosity, and texture. Additionally, the sensorial attributes of yogurt are also positively affected by adding different stabilizers [8]. Gums are considered the most appropriate stabilizer because of their high gelation properties. Commonly used gums as stabilizers include guar gum, xanthan gum, carrageenan, locust bean gum, gum acacia, konjac, and tara gum [6]. Xanthan is quite valuable because it is safe as compared to synthetic stabilizers [1]. Therefore, the objective of this study was to assess the potential of low concentrations of xanthan gum (XG) in enhancing the stability of low-fat yogurt (LFY). Despite previous research on XG, there is a notable gap in the exploration of its effects at minimal levels. Our research seeks to fill this void by investigating the impact of these low concentrations on the chemical, microbiological, rheological, and sensory properties of LFY. Additionally, the literature does not sufficiently cover the role of XG as a prebiotic and its effects on probiotic bacteria within yogurt. This study aims to contribute new insights into the multifaceted role of XG in improving LFY quality, particularly from a probiotic standpoint, which has not been extensively studied before.

2. Materials and Methods

2.1. Manufacturing of Low-Fat Yogurt

Figure 1 shows the process of making LFY according to [14,15], with some modifications. Fresh buffalo's milk (Farm of Faculty of Agriculture, Assiut University, Egypt) was separated at 4 °C to produce SBM. The pasteurized skimmed buffalo milk was heated to 95 ± 2 °C/16 s, cooled to 40 ± 1 °C, and, then divided into 6 treatment lots, as shown in Table 1. Xanthan gum (Loba Chemical Company, Mumbai, India) was added to the SBM as a stabilizer. Then, 2% of mixed starter culture from *Lactobacillus dlebreuckii* ssp., *L. bulgaricus*, *Streptococcus thermophilus*, and *Bifidobacterium bifidum* (Egyptian Microbial Culture Collection: EMCC, Cairo MIRCEN, Faculty of Agriculture, Ain Shams University,

Cairo, Egypt) (1:1:1) was added to SBM. Prepared yogurt samples were kept at incubator temperature (40 ± 2 °C) for 3–4 h until the pH reached 4.6; then, the samples were kept at refrigeration temperature (4 ± 2 °C) for 21 days.

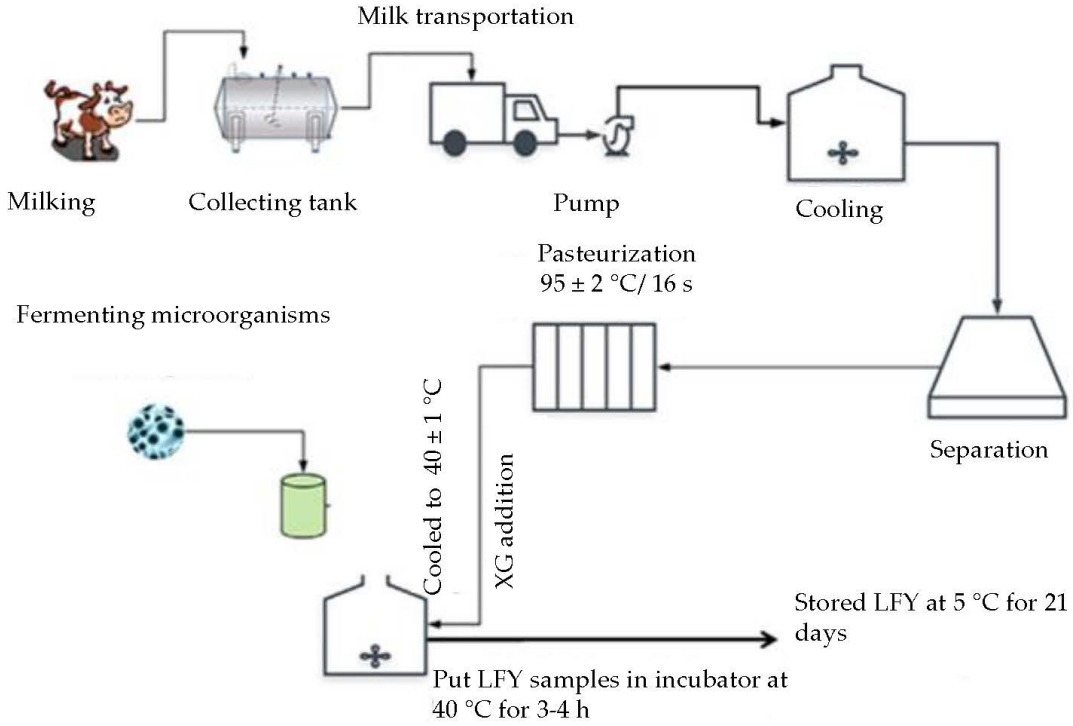

Figure 1. Schematic representation of the manufacturing steps of low-fat yogurt (LFY) [16].

Table 1. Formulations of xanthan gum (XG)-added low-fat yogurt (LFY) samples.

Treatments	XG%
T1	-
T2	0.2
T3	0.4
T4	0.6
T5	0.8
T6	1

2.2. Proximate Composition

All chemicals used for this experiment were obtained from BDH (Mumbai, India), Sigma (New Delhi, India), and Prolabo Chemicals (Mumbai, India) companies. A digital pH meter was used for pH determination of yogurt samples according to the method given in (AOAC 2015). The samples of LFY were analyzed for total protein (TP), TS, and ash content. TS content was determined using a forced-draft oven (AOAC, 2000; method 990.20; 33.2.44). The ash content was estimated using a muffle oven at 550 °C, according to [17]. The TP was determined using the Kjeldahl method (AOAC, 2000; method 991.20; 33.2.11) by utilizing multiple factors of 6.38. The chemical composition was monitored at fresh time.

2.3. Textural Analysis

Textural analysis was performed using a texture analyzer (Stable Micro Systems, Godalming, Surrey, UK) with a back-extrusion plate Probe P-75 (75 mm Dia.), as described by [18]. To run the texture analyzer, Texture Exponent 32 software was used. The compression was performed within the container at a test speed of 0.5 mm/s, holding time for 2 s, and 200 cps rate for data acquisition. Obtained data included the firmness, consistency,

cohesiveness, and adhesiveness of the yogurt to measure the complete textural profile. The textural analysis was monitored at fresh time.

2.4. Viscosity Determination

A Brookfield LVDVE-230 (Cole-Parmer Scientific Experts, East Bunker Ct, Vernon Hills, IL, USA) viscometer was used to estimate the viscosity of the yogurt. Yogurt samples were stirred for 40 s before viscosity determination. Then, viscosity was measured at 15 ± 1 °C using spindle number 4 (10 rpm). The viscometer reading was presented in centipoises (CPS) units. The viscosity was monitored at fresh time.

2.5. Determination of Water-Holding Capacity (WHC)

Water-holding capacity (WHC) was determined by the method as described by [19]. A measure of 20 g of yogurt was centrifuged for 10 min at 669× *g* and 20 °C in a model 3K-30 laboratory centrifuge (Sigma, Darmstadt, Germany). The expelled whey was recovered and weighed. The WHC was determined by using the following formula. The WHC was monitored at 0, 7, 14, and 21 days.

$$WHC(\%) = \frac{Wt.of\ sample\ before\ centrifugation - Wt.after\ centrifugation}{Wt.of\ sample\ before\ centrifugation} \times 100$$

2.6. Syneresis

The syneresis was measured as described by [20]. An LFY sample (30 g) was centrifuged at 230 g for 15 min at 4 °C using a centrifuge (ST Plus series centrifuge, Thermo Fisher, Bremen, Germany). After centrifugation, the clear supernatant was weighed and recorded as percentage of syneresis. The syneresis was monitored at 0, 7, 14, and 21 days.

2.7. Microbiological Analysis

One gram of the LFY samples was weighed under aseptic conditions and transferred into a sterilized jar. Subsequently, 9 mL of a sterile phosphate buffer was added and evenly mixed to attain a 1:10 dilution, which was utilized for preparing the sequence of dilutions [21]. Total bacterial count (TBC) was plated in duplicate on nutrient agar medium, and enumeration was performed using the standard plate count technique [21]. The plates were incubated at 32 °C for 48–72 before microbial enumeration. *Lactobacillus delbrueckii* ssp. *Bulgaricus* counts were determined using the MRS agar medium [22] and plates were incubated at 37 °C for 48 h under anaerobic conditions. *Streptococcus thermophilus* count was enumerated by using M17 agar medium [21]. BB count was enumerated according to [23] using modified MRS agar medium (m-MRS), supplemented with 0.05% L-Cysteine HCl and 0.3% lithium chloride. The plates were anaerobically incubated at 37 °C for 48 h. The small and white colonies were calculated as CFU. The microbiological analyses of LFY prepared using different treatments were performed at 0, 7, 14, and 21 days.

2.8. Sensory Evaluation

The sensory characteristics of the LFY samples were evaluated according to 10–15 trained panelists from the Dairy Science Department, Assiut University. The LFY was examined as described by [16] with some modifications. The samples were evaluated for color and appearance (15 points), flavor (50 points), and body and texture (35 points) for a total of 100 points. The organoleptic characteristics were evaluated weekly when the samples were fresh, and then at 14 and 21 d of storage.

2.9. Statistical Analysis

Data were analyzed by Costat 6.303 software [24]. All data were analyzed by ANOVA using a GLM for each variable to study the effect of treatments and time (storage period) on the characteristics of LFY made with XG. Mean separation was performed using the least significant difference (LSD) comparison test when significant differences were detected at $p \leq 0.05$.

3. Results and Discussion

3.1. Proximate Composition of Low-Fat Yogurt (LFY)

The chemical composition of LFY is presented in Table 2. There was a highly significant difference ($p < 0.05$) between all yogurt treatments in pH, TP, TS, and Ash content. The pH values of LFY ranged from 4.18 for T6 to 4.46 for control. It has been noted that the addition of XG led to a significant decrease ($p < 0.05$) in the pH values, which could be attributed to the fact that XG, considered as a prebiotic, has an activating effect on the growth of probiotic which led to more lactose breaking, directly leading to decreasing pH values [25]. The addition of XG had a significant impact on TP values, which indicated that increasing the addition rate of XG significantly ($p < 0.05$) decreased TP values; this could be due to the fact that XG does not contains any protein [26]. TS values increased with the increase in XG and ranged from 8.58% to 9.67%; this was expected because XG does not contain any moisture. These results were in agreement with those obtained by the authors of [27], who stated that the addition of XG led to a significant increase in the TS values of LFY. Ash values decreased significantly ($p < 0.05$) with the addition of XG, which could be due to the fact that XG does not contain significant amounts of minerals; this led to a decrease in the percentage of minerals in the LFY.

Table 2. Mean ($n = 3$) ± SE proximate composition (%) of low-fat yogurt (LFY).

[1] Treatments	pH	TP	TS	Ash
T1	4.46 [a] ± 0.01	5.47 [a] ± 0.01	8.58 [f] ± 0.05	0.85 [a] ± 0.00
T2	4.40 [b] ± 0.02	5.34 [b] ± 0.01	8.85 [e] ± 0.01	0.81 [b] ± 0.01
T3	4.27 [c] ± 0.01	5.21 [c] ± 0.02	9.08 [d] ± 0.02	0.76 [c] ± 0.02
T4	4.28 [d] ± 0.00	4.94 [d] ± 0.01	9.12 [c] ± 0.02	0.72 [d] ± 0.03
T5	4.25 [e] ± 0.02	4.81 [e] ± 0.03	9.32 [b] ± 0.04	0.68 [e] ± 0.02
T6	4.18 [f] ± 0.01	4.65 [f] ± 0.02	9.67 [a] ± 0.02	0.62 [f] ± 0.01

[a–f] Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of XG).

3.2. Texture Profile Analysis of Low-Fat Yogurt (LFY)

The texture profile analyses of the LFY samples are presented in Table 3. The addition of XG in the manufacturing of LFY significantly influences ($p < 0.05$) its textural properties. The control sample (T1) made without XG exhibited the lowest firmness, consistency, cohesiveness, and adhesiveness as compared to other treatments. As the concentration of XG increased from 0.2% to 1% (T2 to T6), there was a remarkable enhancement in all measured textural parameters. The firmness values especially boosted progressively from 0.63 in the control to 0.94 in the 1% XG sample (T6), indicating a more solid texture. This could be due to XG binding more water, which led to an increase in the firmness of the resulting yogurt. Similar observations obtained by [28]. Consistency showed a more pronounced increase, with values increasing from 17.76 in the control (T1) to 39.21 in T6, which suggesting a more uniform and stable texture [29]. Cohesiveness, which indicates the internal binding of the yogurt, improved steadily with higher XG concentrations, ranging from 0.27 in T1 to 0.48 in T6. This indicates a more cohesive structure in yogurts with higher XG content [30]. Adhesiveness, which reflects the degree to which the yogurt adheres to surfaces, also increased with XG concentration, from 1.86 in T1 to 3.15 in T6 [31]. These findings clearly demonstrate that XG acts effectively as a textural modifier in yogurt, enhancing its firmness, consistency, cohesiveness, and adhesiveness in a concentration-dependent manner.

Table 3. Effect of xanthan gum (XG) on textural profile of low-fat yogurt (LFY).

[1] Treatments	Firmness (g)	Consistency (Pa·s)	Cohesiveness (mj)	Adhesiveness (N·s)
T1	0.63 [f] ± 0.01	17.76 [f] ± 0.00	0.27 [f] ± 0.01	1.86 [f] ± 0.00
T2	0.75 [e] ± 0.02	18.35 [e] ± 0.00	0.34 [e] ± 0.01	1.98 [e] ± 0.00
T3	0.79 [d] ± 0.01	23.87 [d] ± 0.02	0.39 [d] ± 0.00	2.35 [d] ± 0.00
T4	0.85 [c] ± 0.00	28.98 [c] ± 0.01	0.43 [c] ± 0.00	2.56 [c] ± 0.02
T5	0.89 [b] ± 0.02	36.91 [b] ± 0.01	0.47 [b] ± 0.002	2.89 [b] ± 0.03
T6	0.94 [a] ± 0.01	39.21 [a] ± 0.00	0.48 [a] ± 0.00	3.15 [a] ± 0.00

[a–f] Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of XG).

3.3. Water-Holding Capacity of Low-Fat Yogurt (LFY)

Table 4 presented the water-holding capacity (WHC) of LFY treatments over a period of 21 days. The WHC was measured at four time intervals: fresh, 7 days, 14 days, and 21 days. The data revealed that, as the concentration of XG increased, the WHC of the yogurt generally improved. This is evident in the mean WHC values, which increased from 56.68% in the control sample (T1) to 69.88% in the sample with 1% XG (T6). This indicates that XG effectively enhances the moisture retention in LFY during storage time, which could be due to the strong ability of XG to bind water [32]. Regarding the storage time effect, all the treatments showed a significant ($p < 0.05$) decrease in WHC during the 21-day storage period, indicating a natural decline in moisture retention as the yogurt aged [33]. However, the rate of this decline varied among the treatments. The control sample (T1) showed a significant drop from 66.42% to 41.43%, while the 1% XG sample (T6) maintained a higher WHC, dropping less dramatically from 79.80% to 52.40%. This pattern underscores the stabilizing effect of XG in LFY [34]. The mean of WHC also supported the idea that the control sample gained the lowest percentage of WHC (56.68%) and, with the addition of XG, the WHC% increased to range from 57.85%/ T2 to 69.88%/ T6. The obtained data strongly suggest that XG, particularly at higher concentrations, can be an effective ingredient for enhancing the textural properties and longevity of low-fat yogurt.

Table 4. Effect of xanthan gum (XG) on water holding % capacity of low-fat yogurt (LFY).

[1] Treatments	Fresh	7 Days	14 Days	21 Days	Mean
T1	66.42 ± 0.12	66.02 ± 0.01	52.83 ± 0.11	41.43 ± 0.15	56.68 [e]
T2	67.09 ± 0.17	66.73 ± 0.22	57.28 ± 0.41	40.29 ± 0.03	57.85 [d]
T3	65.68 ± 0.23	65.48 ± 0.08	62.01 ± 0.12	45.51 ± 0.34	59.67 [c]
T4	67.68 ± 0.09	67.22 ± 0.01	63.35 ± 0.07	50.09 ± 0.13	62.09 [b]
T5	74.50 ± 0.12	72.30 ± 0.32	57.75 ± 0.09	46.34 ± 0.04	62.72 [b]
T6	79.80 ± 0.06	74.05 ± 0.12	73.25 ± 0.12	52.40 ± 0.06	69.88 [a]
Mean	70.20 [A]	68.63 [B]	61.08 [C]	46.01 [D]	

[a–e,A–D] Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of XG).

3.4. Viscosity of Low-Fat Yogurt (LFY)

Table 5 illustrates the effect of XG addition on the viscosity of LFY samples, which were assessed over a 21-day storage period. The control (T1), manufactured without XG, exhibited a starting viscosity of 2173.80 cp, which steadily decreased over time to 1442.01 cp, indicating a natural decline in viscosity with aging. This could be due to the activity of the starter culture in breaking down the protein matrix, which directly led to a significant ($p < 0.05$) change in viscosity values [16]. Additionally, with the advancement of the storage time, the pH values decreased, which led to an increase in the whey shrinkage in the curd; this could play an important role in decreasing the viscosity values [35]. In contrast, the

XG-added samples (T2–T6) showed a clear trend: an increase in XG concentration resulted in higher initial viscosity values at the highest concentration (1% XG in T6) and ranged from 1896.05 cp for T6 at 21 days of storage to 4124 cp for T6 at the fresh time. For all the XG-added samples, there was a general decrease ($p < 0.05$) in viscosity during the 21 days, but the rate of this decrease was remarkably more gradual in the treatments with higher XG concentrations. For instance, T6 recorded a viscosity of 1896.05 cp at 21 days, which was significantly higher ($p < 0.05$) than the control. It has been noted that there was a positive correlation between higher XG concentrations and higher viscosity values [36]. Regarding the mean of the viscosity values, it has been noted that the control gained the lower value (1840.71 cp) of viscosity; by adding XG, the viscosity significantly ($p < 0.05$) increased to range from (1988.20 cp) for T2 to (3190.90 cp) for T6. This supports the idea that the addition of XG led to an increase in the viscosity of LFY.

Table 5. Effect of xanthan gum (XG) on viscosity (cp) of low-fat yogurt (LFY).

[1] Treatments	Fresh	7 Days	14 Days	21 Days	Mean
T1	2173.80 ± 2.23	1966.50 ± 0.76	1780.51 ± 1.11	1442.01 ± 0.89	1840.71 [f]
T2	3155.00 ± 1.08	1699.00 ± 1.34	1656.80 ± 1.25	1442.01 ± 2.02	1988.20 [e]
T3	3273.80 ± 1.32	2912.00 ± 1.02	2142.50 ± 0.93	1167.00 ± 1.02	2373.83 [d]
T4	3414.60 ± 1.02	3110.00 ± 1.21	2360.20 ± 1.02	1462.00 ± 1.12	2586.70 [c]
T5	3613.60 ± 0.90	3312.01 ± 1.04	2582.20 ± 2.02	1575.03 ± 0.85	2770.71 [b]
T6	4124.30 ± 1.01	3879.23 ± 0.82	2864.02 ± 1.07	1896.05 ± 1.12	3190.90 [a]
Mean	3292.52 [A]	2813.12 [B]	2231.04 [C]	1497.35 [D]	

[a–f,A–D] Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of XG).

3.5. Syneresis%

Syneresis is one of the basic defects of yogurt, which is observed in the form of the accumulation of serum or whey on the yogurt surface. Syneresis occurs due to shrinkage of the three-dimensional (3D) structure of a protein network, which leads to the reduction in the connection power of whey proteins and their exit from the yogurt [37,38]. Table 6 depicts syneresis % in LFY with varying concentrations of XG through a 21-day storage period. There was a significant difference ($p < 0.05$) between the syneresis of treatments. All treatments showed a remarkable increase in syneresis % as storage time progressed. This could be due to decreasing pH levels of LFY during storage, which can be traced back to the starter culture activity in breaking down the lactose into lactic acid. Increasing the acidity led to more curd shrinkage and more expulsion of water [16]. The control sample (T1) showed a progressive increase in syneresis ranging from 44% at fresh time to 58% by the end of the storage period. However, the addition of XG markedly influenced the syneresis values of LFY. It is very clear that increasing XG concentration from 0.2% to 1% (T2 to T6) led to a significant decrease ($p < 0.05$) in syneresis during storage. For instance, T6 gained the lowest syneresis and ranged from 19% at fresh time to 26% at 21 days. The effect of XG in decreasing the syneresis of LFY is mainly a result of the high ability of XG in binding water [39]. The means of the viscosity values indicate that the control gained the higher viscosity value (50.50%); by adding XG, the viscosity significantly ($p < 0.05$) decreased to range from (22.50%) for T6 to (44.25%) for T2. This supports the idea that the addition of XG led to an increase in the viscosity of LFY. Similar results were obtained in [40], where the authors mentioned that increasing XG addition to yogurt from 0.05% to 0.1% led to a significant decrease in syneresis from 44% to 36.5%. The authors of [41] reported that syneresis in yogurt declined with an increase in locust bean gum. In the same trend, the authors of [42] reported that guar gum decreased syneresis in yogurt.

Table 6. Effect of xanthan gum (XG) on syneresis % of low-fat yogurt (LFY).

[1] Treatments	Fresh	7 Days	14 Days	21 Days	Mean
T1	44 ± 0.52	47 ± 0.17	53 ± 0.11	58 ± 0.34	50.50 [a]
T2	37 ± 0.34	41 ± 0.62	48 ± 0.27	51 ± 0.12	44.25 [b]
T3	32 ± 0.24	38 ± 0.88	42 ± 0.77	45 ± 0.28	39.25 [c]
T4	32 ± 0.22	35 ± 0.52	36 ± 0.32	41 ± 0.65	36.00 [d]
T5	24 ± 0.64	27 ± 0.38	32 ± 0.81	36 ± 0.62	29.75 [e]
T6	19 ± 0.12	20 ± 0.31	25 ± 0.25	26 ± 0.92	22.50 [f]
Mean	31.33 [D]	34.67 [C]	39.33 [B]	42.83 [A]	

[a–f,A–D] Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of XG).

3.6. Microbiological Analysis

Table 7 illustrates TBC, *Lactobacillus delbrueckii* ssp. *Bulgaricus (LB)*, *Streptococcus thermophilus (ST)*, and *Bifidobacterium bifidum (BB)*, tracked over a 21-day storage period. Regarding TBC, the control sample (T1), without XG addition, exhibited a moderate bacterial growth trajectory, peaking at 7.89 log CFU/g by day 14, before showing a subsequent decline to 6.98 log CFU/g by the end of the storage period. This pattern, characterized by a growth peak followed by a decline, resonates with the natural life cycle of bacterial colonies in fermented dairy products, influenced by increasing acidity which eventually curtails bacterial viability [43]. Conversely, yogurt samples enriched with XG (T2–T4) displayed a more robust and consistent bacterial count throughout the storage period, peaking at day 14 but maintaining significantly elevated levels even at day 21. This phenomenon suggests that XG, particularly at moderate concentrations, may facilitate a more conducive environment for bacterial growth, possibly through improved texture and nutrient accessibility [28]. XG's role as a polysaccharide, potentially acting as a prebiotic, fostering bacterial growth, is further corroborated by findings in [35,44]. However, the narrative shifts when analyzing samples with higher XG concentrations (0.8% and 1% in T5 and T6), which demonstrated a paradoxical trend of reduced total bacterial count (TBC) over the storage duration. This suggests a potential inhibitory effect of higher XG levels on bacterial proliferation, likely mediated through pH reduction, which unfavorably impacts bacterial growth [38].

Table 7. Total bacterial counts and lactobacilli, streptococci, and bifidobacteria counts of low-fat yogurt (LFY) (log CFU/g) during the storage period.

[1] Treatments	Fresh	7 Days	14 Days	21 Days
Total bacterial counts (log CFU/g)				
T1	7.34 ± 0.06 [Dc]	7.76 ± 0.11 [Db]	7.89 ± 0.01 [Da]	6.98 ± 0.21 [Dd]
T2	7.87 ± 0.13 [Cc]	7.96 ± 0.22 [Cb]	8.05 ± 0.04 [Ca]	7.65 ± 0.02 [Cd]
T3	7.98 ± 0.11 [Bc]	8.13 ± 0.06 [Bb]	8.34 ± 0.14 [Ba]	7.78 ± 0.05 [Bd]
T4	8.15 ± 0.12 [Ac]	8.27 ± 0.16 [Ab]	8.47 ± 0.11 [Aa]	7.59 ± 0.12 [Ad]
T5	6.43 ± 0.09 [Ec]	6.65 ± 0.02 [Eb]	6.71 ± 0.06 [Ea]	6.13 ± 0.22 [Ed]
T6	6.12 ± 0.06 [Fc]	6.34 ± 0.09 [Fb]	6.67 ± 0.08 [Fa]	5.65 ± 0.14 [Fd]
Lactobacillus dlebreuckii ssp. *Bulgaricus* (log CFU/g)				
T1	5.27 ± 0.02 [Fc]	6.85 ± 0.06 [Fa]	5.33 ± 0.03 [Fb]	5.17 ± 0.02 [Fd]
T2	7.80 ± 0.01 [Ec]	8.15 ± 0.03 [Ea]	7.95± 0.02 [Eb]	7.56 ± 0.01 [Ed]
T3	7.91 ± 0.03 [Dc]	8.30 ± 0.02 [Da]	8.14 ± 0.01 [Db]	7.80 ± 0.03 [Dd]
T4	7.98 ± 0.04 [Cc]	8.53 ± 0.01 [Ca]	8.37 ± 0.01 [Cb]	7.91 ± 0.04 [Cd]
T5	8.05 ± 0.02 [Bc]	8.62 ± 0.01 [Ba]	8.42 ± 0.02 [Bb]	8.14 ± 0.03 [Bd]
T6	8.36 ± 0.01 [Ac]	8.73 ± 0.03 [Aa]	8.68 ± 0.07 [Ab]	8.47 ± 0.02 [Ad]

Table 7. *Cont.*

[1] Treatments	Fresh	7 Days	14 Days	21 Days
	Streptococcus thermophilus counts (log CFU)			
T1	6.34 ± 0.05 ^{Cf}	6.77 ± 0.06 ^{Af}	6.11 ± 0.02 ^{Bf}	5.97 ± 0.05 ^{Df}
T2	7.93 ± 0.12 ^{Ce}	8.23 ± 0.02 ^{Ae}	8.03 ± 0.04 ^{Be}	7.54 ± 0.02 ^{De}
T3	8.03 ± 0.03 ^{Cd}	8.38± 0.04 ^{Ad}	8.24± 0.13 ^{Bd}	7.78 ± 0.03 ^{Dd}
T4	8.12 ± 0.01 ^{Cc}	8.61 ± 0.01 ^{Ac}	8.45 ± 0.02 ^{Bc}	7.90 ± 0.06 ^{Dc}
T5	8.18± 0.02 ^{Cb}	8.80 ± 0.04 ^{Ab}	8.54 ± 0.03 ^{Bb}	8.12 ± 0.03 ^{Db}
T6	8.54 ± 0.05 ^{Ca}	8.83 ± 0.02 ^{Aa}	8.74 ± 0.08 ^{Ba}	8.46 ± 0.02 ^{Da}
	Bifidobacterium bifidum counts (log CFU)			
T1	3.67 ± 0.05 ^{Cf}	3.84 ± 0.05 ^{Bf}	4.12 ± 0.01 ^{Af}	3.14 ± 0.01 ^{Df}
T2	6.68 ± 0.01 ^{Cc}	6.92 ± 0.01 ^{Bc}	7.25 ± 0.03 ^{Ac}	6.21 ± 0.03 ^{Dc}
T3	6.95 ± 0.02 ^{Cb}	7.21 ± 0.03 ^{Bb}	7.45 ± 0.01 ^{Ab}	6.32 ± 0.05 ^{Db}
T4	7.03 ± 0.03 ^{Ca}	7.29 ± 0.03 ^{Ba}	7.62 ± 0.01 ^{Aa}	6.38 ± 0.04 ^{Da}
T5	6.45 ± 0.01 ^{Cd}	6.87 ± 0.01 ^{Bd}	7.09 ± 0.00 ^{Ad}	6.04 ± 0.01 ^{Dd}
T6	6.13 ± 0.07 ^{Ce}	6.65 ± 0.02 ^{Be}	6.98 ± 0.01 ^{Ae}	5.88 ± 0.02 ^{De}

$^{a–f,A–F}$ Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of X).

Lactobacillus delbrueckii ssp. *Bulgaricus numbers* (Table 7) showed a pronounced viability enhancement in samples with increased XG content, which was especially notable in T6, which contained 1% XG. The obtained results indicated that, as the concentration of XG in the LFY increased, there was a significant ($p < 0.05$) enhancement in the survival of *Lactobacillus delbrueckii* ssp. *Bulgaricus.* This could be due to the fact that XG, considered to be a polysaccharide, can play a role as a prebiotic substance that can stimulate the vitality of *Lactobacillus delbrueckii* ssp. *Bulgaricus* [45]. Also, XG can binding more water, which can make a more suitable environment for the growth of *Lactobacillus delbrueckii* ssp. *Bulgaricus* [46]. The data also showed a decline in the bacterial counts during the storage period for all XG-added LFYs due to many factors, like nutrient depletion and changes in the storage environment [47,48]. Similarly, the *Streptococcus thermophilus* population (Table 7) demonstrated a consistent pattern of enhanced viability in XG-supplemented samples, reinforcing the notion that XG contributes positively to bacterial stability and longevity during storage.

The numbers of *Bifidobacterium bifidum* (Table 7) in LFY (log CFU/g) during the shelf life indicated that the control sample (T1) had the lowest *Bifidobacteria bifidum* count of 3.67 log CFU/g at fresh time, which peaked at 4.12 log CFU/g by day 14, and then decreased to 3.14 log CFU by the end of the storage time. In contrast, the XG-added samples of the LFY samples (T2–T4) had the highest number of *Bifidobacterium bifidum* and maintained higher numbers of *Bifidobacterium bifidum* during storage as compared to the control; this reflects the idea that XG provides a suitable environment for *Bifidobacterium bifidum* growth [49]. However, higher XG concentrations in T5 and T6 led to a slight decrease in *Bifidobacteria* counts; this can be attributed to the high–low pH levels in these treatments, which directly inhibited the growth of *Bifidobacterium bifidum*. The authors of [50–52] reported that higher acidity and the presence of lactic and acetic acid declined the viable *Bifidobacterium bifidum* counts during the ripening period of dairy products.

3.7. Sensory Analysis

Table 8 provides the sensory properties of low-fat yogurt (LFY) formulations, evaluated across different storage intervals—fresh, 14 days, and 21 days—which indicated the impact of varying concentrations of XG on color and appearance, body and texture, flavor, and overall sensory evaluation. All treatments exhibited relatively similar scores in color and appearance, with T4 and T5, which include 0.6% and 0.8% XG, respectively, scoring slightly

higher, indicating a slight improvement in visual attributes due to XG addition. This trend continues with body and texture, where T4 and T5 significantly outperform the control (T1) and other treatments at the 14th and 21st days, suggesting that the incorporation of XG at these concentrations notably enhances the yogurt's physical consistency over time. The flavor scores illustrate a progressive improvement with increasing XG concentrations, this is especially noticeable in later storage periods. T5 stands out with the highest flavor score at 21 days, implying that optimal XG concentration can significantly enhance the perceived taste of LFY over time. Overall, T5, with 0.8% XG, emerges as the superior formulation, achieving the highest total sensory score of 92 at the end of the 21-day storage period, indicating a well-balanced improvement in color, body, texture, and flavor attributes. Conversely, T6, containing 1% XG, demonstrates a notable decline in sensory properties, particularly in flavor towards the end of the storage period, suggesting that there is an optimal threshold for XG concentration, beyond which sensory properties may deteriorate.

Table 8. Sensory properties of experimented low-fat yogurt (LFY) during the storage period.

	Storage Period/Days											
	Fresh Time				**14**				**21**			
[1] Treatments	**Color and Appearance (15)**	**Body and Texture (35)**	**Flavor (50)**	**Total (100)**	**Color and Appearance (15)**	**Body and Texture (35)**	**Flavor (50)**	**Total (100)**	**Color and Appearance (15)**	**Body and Texture (35)**	**Flavor (50)**	**Total (100)**
T1	14	12	9	35	12	22	24	58	11	28	30	69 [e]
T2	13	12	11	36	13	24	25	62	9	29	37	75 [d]
T3	14	12	10	36	12	25	33	70	10	31	43	84 [c]
T4	15	13	12	40	13	26	34	73	12	30	45	87 [b]
T5	15	13	12	40	13	29	38	80	12	32	48	92 [a]
T6	15	11	11	37	11	23	26	60	11	27	20	58 [f]

[a–f] Means in the same column not sharing a common superscript are different at ($p < 0.05$). [1] Treatments: T1 = control sample (yogurt made without addition of XG), T2 = (yogurt made with addition 0.2% of XG), T3 = (yogurt made with addition 0.4% of XG), T4 = (yogurt made with addition 0.6% of XG), T5 = (yogurt made with addition 0.8% of XG) and T6 = (yogurt made with addition 1% of XG).

4. Conclusions

In summary, our investigation revealed that xanthan gum (XG) serves as an effective stabilizer in low-fat yogurt (LFY) at lower concentrations (0.2–0.4%), improving firmness and overall texture without adversely affecting microbial stability. Notably, a concentration of 0.8% XG optimized sensory attributes, enhancing the yogurt's color, texture, and flavor. This study highlights XG's dual role as both a stabilizer and a potential prebiotic, contributing positively to the yogurt's quality and theories on the viability of the use of probiotic cultures during storage.

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