Wiley
Journal of Food Quality
Volume 2026, Article ID 6206693, 12 pages
https://doi.org/10.1155/jfq/6206693

WILEY

Research Article

Incorporation of *Adiantum capillus-veneris* L. Extract as a Functional Ingredient to Enhance the Quality Characteristics of Yogurt

Kimia Khaki[1,2], **Samar Mansouripour**[1,2] and **Mansooreh Sadat Mojani-Qomi**[1,2]

[1]*Department of Food Science and Technology, TeMS.C., Islamic Azad University, Tehran, Iran*
[2]*Nutrition and Food Sciences Research Center, TeMS.C., Islamic Azad University, Tehran, Iran*

Correspondence should be addressed to Samar Mansouripour; sa.mansouripour@iau.ac.ir; s_mansouripour@yahoo.com

Received 29 April 2025; Revised 30 November 2025; Accepted 17 December 2025

Academic Editor: Meriam Tir

Copyright © 2026 Kimia Khaki et al. Journal of Food Quality published by John Wiley & Sons Ltd. This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Adiantum capillus-veneris L. is known for its bioactive compounds and health benefits. In this study, the physicochemical, functional, and sensory properties of set-type yogurt fortified with *Adiantum capillus-veneris* L. extract (ACVE) were evaluated during 21 days of storage. Higher pH values and lower acidity were observed in yogurts containing 0.25% and 0.5% ACVE on Day 21 of storage. ACVE enhanced water holding capacity (WHC), a^* and b^* values, total phenolic content (TPC), antioxidant activity, and α-amylase inhibition (by more than three times). Additionally, the yogurts containing 0.25% and 0.5% ACVE showed a higher storage modulus, complex viscosity, and a more compact microstructure. Moreover, ACVE reduced syneresis and the L^* value of yogurt ($p < 0.05$). The addition of 0.25% and 0.5% ACVE in yogurt significantly reduced the LAB on the first day of storage. However, ACVE-fortified yogurts exhibited significantly higher LAB counts at the end of the storage ($p < 0.05$). An increase in acidity and a decrease in pH were observed with prolonged storage, except in yogurt with 0.5% ACVE. The TPC, antioxidant activity, WHC, and LAB counts of fortified yogurts were enhanced during storage, whereas syneresis and α-amylase inhibition were reduced ($p < 0.05$). Sensory evaluation indicated that all yogurts were acceptable, and no significant difference in overall acceptance was observed between yogurts containing 0.1% and 0.25% ACVE and the control ($p > 0.05$). Therefore, ACVE (particularly at levels up to 0.25%) can be used as a novel functional additive to enhance the quality characteristics of yogurt.

Keywords: α-amylase inhibition; *Adiantum capillus-veneris* L.; antioxidant activity; functional yogurt; rheological properties

1. Introduction

Yogurt is the most popular fermented dairy food product prepared through lactic acid fermentation by *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* [1, 2]. This product is nutritious due to its milk composition and the metabolic products produced by starter culture bacteria [3]. However, its phenolic content and antioxidant capacity are limited. Therefore, incorporating bioactive compounds from natural plant sources is an effective approach to enhancing the functional properties and health benefits of yogurt [4, 5]. In recent years, the addition of various plant-origin extracts such as olive leaf [6], chrysanthemum [2], germinated black cumin seed [7], *Siraitia grosvenorii* fruit [8], rose flower [9], moringa leaves [10], and argel (*Solenostemma argel* Hayne) [11] has improved the nutritional quality of yogurt.

Adiantum capillus-veneris (ACV) (Maidenhair Fern) is a perennial plant from the Pteridaceae family. It is widely distributed worldwide [12] and grows in humid regions with high organic materials [13]. This plant is rich in phytochemical components, such as flavonoids, tannins, phenolics, triterpenoids, sterols, carotenoids, and chlorophyll [14–16], and its leaf is safe for human consumption [14]. It is utilized both as an ornamental and medicinal plant [17]. In traditional medicine, ACV has been used to treat various

diseases, including colds, cough, bronchitis, fever, skin diseases, and tumors of the spleen and liver, as well as hair tonic, diuretic, and antidysentery [18–20]. Additionally, this plant has been reported to exhibit antioxidant, antimicrobial, anti-inflammatory, antidiabetic, anticancerous, wound-healing, and analgesic characteristics [16, 21, 22]. The results of Hashemi et al. [17] showed that incorporating *Adiantum capillus-veneris* extract (ACVE) into an edible starch film enhanced the antioxidant properties and shelf life of fresh-cut pears. Despite the great potential of ACV as a functional ingredient, to the best of our knowledge, it has not yet been used in the formulation of food products. The aim of this study was to evaluate the functional properties (phenolic compounds, antioxidant capacity, and α-amylase inhibition) as well as physicochemical, rheological, microstructural, microbiological, and sensory characteristics of yogurt fortified with ACVE.

2. Materials and Methods

2.1. Materials. Dried ACV leaves were purchased from a medicinal plant store in Tehran, Iran. The plant was authenticated by the Herbarium of the Faculty of Pharmacy, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran, and was assigned the voucher number 208-1-PMP/A. Raw cow milk, skim milk powder (Pegah Dairy Co. in Tehran, Iran), and lyophilized starter cultures containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* (5×10^{10} CFU/g, YC 350, Yo-Flex, Chr. Hansen, Hørsholm, Denmark) were used for yogurt preparation. All the chemicals (analytical grade) were provided by Merck Company (Darmstadt, Germany). 2,2-Diphenyl-1-picrylhydrazyl (DPPH), α-amylase enzyme, and dinitrosalicylic acid (DNS) were supplied by Sigma-Aldrich (USA).

2.2. Extraction of ACV and Determination of Total Phenolics and Antioxidant Activity. The extract of ACV leaves was prepared according to the method described by Waszkowiak and Gliszczyńska-Świgło [23], with some modifications. The leaves were manually separated from the other parts of the plant. The cleaned leaves were ground into a fine powder and passed through a 60-mesh sieve. Then, 200 g of ACV leaf powder was extracted for 24 h in 2000 mL of ethanol : water (20 : 80, v/v) with stirring at 25°C. The obtained extract was filtered by Whatman No. 42 filter paper and centrifuged for 15 min at 9072 × *g* (Hettich, Germany). The supernatant was filtered again and concentrated using a rotary evaporator (Heidolph Laborota 4003, Germany) under vacuum at 45°C. Then, the hydroalcoholic extract was freeze-dried (Christ alpha 1-2D plus), placed in a dark glass, and kept in the refrigerator.

The total phenolic content (TPC) of ACVE was measured based on the Folin–Ciocalteu method [24]. First, 100 μL of the extract was mixed with 100 μL of Folin–Ciocalteu reagent. After 5 min, 300 μL of sodium carbonate 7.5% (w/v) was added, and the mixture was incubated in the dark for 30 min. Then, the absorption was recorded using an ultraviolet-visible spectrophotometer (SU-6100-Philler Scientific, USA) at 725 nm.

The DPPH free radical scavenging method was used to determine antioxidant activity [25]. One milliliter of extract and 2 mL of DPPH methanolic solution (0.1 mM) were mixed. After incubation in the dark for 30 min, the absorbance was measured at 515 nm.

2.3. Yogurt Production. The raw cow milk was heat-treated at 50°C, and 2.0% of skim milk powder was added (at 60°C) after the fat content was standardized to 3.0% by a separator. Then, the milk was heated to 90°C for 5 min, cooled to 44°C, and inoculated with 3% v/v yogurt starter culture. The ACV extracts were added at three concentrations (0.1%, 0.25%, and 0.5% w/w) and mixed with the inoculated milk portions. All prepared mixtures, along with the control (without extract), were poured into plastic cups (200 mL) and incubated at 42°C until the pH reached 4.6. The yogurt treatments were then refrigerated for 21 days [26].

2.4. Determination of Physicochemical Properties. A digital pH meter (86502 AZ, Taiwan) and alkali titration with 0.1 N NaOH were used to determine the pH and titratable acidity of the yogurts, respectively [27]. To measure the syneresis, 25 g of yogurt was poured on filter paper and placed on the top of a funnel. The whey separated at refrigerator temperature for 2 h was weighed. The percentage of the drained whey to the initial yogurt was calculated and expressed as syneresis content [28]. The water holding capacity (WHC) was determined by the centrifuge method [29]. First, 5 g of yogurt was centrifuged at 2268 × *g* for 30 min at 10°C. The collected supernatant was then weighed and WHC was calculated using equation (1), where W was the weight of the supernatant and W' was the initial weight of the sample:

$$\mathrm{WHC}(\%) = \left(1 - \frac{W}{W'}\right) \times 100. \quad (1)$$

2.5. Color Measurement. The changes in color indices of yogurt treatments, including L^* (brightness, 0 = black, 100 = white), a^* (+: red, −: green), and b^* (+: yellow, −: blue), were evaluated using a CR-400 Minolta colorimeter (Konica Minolta, Japan) after 7 days of storage.

The total color difference with control (ΔE) was also calculated according to the following equation [30]:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}. \quad (2)$$

2.6. Yogurt Extract Preparation and Determination of TPC, Antioxidant Activity, and α-Amylase Inhibition. First, the method described by Qiu et al. [9] was applied to yogurt extract preparation, with some modifications. After combining 20 mL of 80% methanol with 2 g of yogurt using a magnetic stirrer for 20 min, the mixture was centrifuged at 2268 × *g* for 10 min. The supernatant was collected, and the TPC and antioxidant activity were measured as described in Section 2.2.

The α-amylase inhibition assay was performed on the first and 21st days after production, based on the method reported by Nazari et al. [7], with minor modifications. A mixture containing 0.1 mL of α-amylase (1 unit/mL), 0.1 mL of yogurt extract, and 0.2 mL of 1% starch solution was incubated at 37°C for 20 min. Then, 0.2 mL of DNS reagent was added, followed by heating in a water bath at 100°C for 15 min. After dilution with 5 mL of distilled water, the absorbance was measured at 540 nm.

2.7. Microbial Analysis. The lactic acid bacteria (LAB) count in yogurt treatments was assessed on the first and 21st days of storage. The 10-fold serial dilutions were prepared for each sample, and the pour plate method on MRS agar (Q Lab, USA) was used for the enumeration [31]. The Petri dishes were incubated at 37°C for 48 h, and the results were reported as the log CFU/g.

2.8. Rheological Properties. The rheological properties of the yogurt treatments were measured using a rheometer (Physica Anton Paar, MCR 301, Austria) equipped with a parallel plate geometry (25 mm diameter) and a gap distance of 1 mm. The dynamic oscillatory test was conducted after 7 days of production according to Liu et al. [32] with slight modifications. The frequency sweep was carried out within the linear viscoelastic region over a frequency range of 0.1–100 rad/s at 0.1% strain, as determined by the amplitude sweep test. The rheological parameters, including the G′ (elastic modulus), G″ (loss modulus), Tan δ (loss factor), and complex viscosity (η^*), were evaluated.

2.9. Microstructure. A scanning electron microscope (SEM) (TESCAN VEGA3, Czech Republic) was used to evaluate the microstructure of yogurt treatments 1 week after yogurt production [33]. The freeze-dried samples were coated with a thin layer of gold-palladium, and the images were obtained at an accelerating voltage of 30 kV and a magnification of 10000×.

2.10. Sensory Evaluation. The 9-point hedonic scale from 1 (strong dislike) to 9 (extremely like) scores was used to evaluate the taste, odor, color, texture, and overall acceptability [11]. The evaluation was conducted by thirteen semitrained panelists from the Food Analysis Laboratory at Tehran Medical Sciences, Islamic Azad University (Tehran, Iran). The yogurt treatments, labeled with three-digit codes, were randomly presented to the panelists after being removed from the refrigerator. The panelists rinsed their mouths with water between samples.

2.11. Statistical Analysis. All experiments were conducted in triplicate, and the data were expressed as mean ± standard deviation. The statistical analysis of the results was performed using MINITAB 22 software. The significant differences between the data were determined by analysis of variance (ANOVA), and Tukey's test at a significance level of $p < 0.05$ was used to compare the means.

3. Results and Discussion

3.1. Physicochemical Properties of Yogurt. The results of the physicochemical properties of yogurt treatments are shown in Table 1. The decreasing and increasing trends in pH and acidity were observed with ACVE on the first and 7th days of storage, respectively ($p < 0.05$). These changes could be attributed to the acidic nature of ACVE due to the presence of phenolic acids [34]. At the end of the storage period, the pH and acidity of the control reached 4.08% and 1.14%, respectively, whereas the yogurts containing 0.25% and 0.5% of ACVE exhibited higher pH values (4.21 and 4.25) compared to the other treatments and the lowest acidity (1.01% and 0.99%), respectively ($p < 0.05$). The addition of higher concentrations of ACVE in yogurt probably increased the buffering effect due to the additional proteins and delayed postacidification as a result of its polysaccharides [35]. The results are consistent with previous studies on yogurts containing purslane [36] and rose flower [9] extracts. The continued lactose fermentation and increased lactate production by LAB resulted in a rise in acidity and a decline in pH with prolonged storage, except for the yogurt with 0.5% extract. Nevertheless, the pH of all yogurt samples (4.02–4.30) remained below 4.6 throughout the whole storage period, in accordance with FDA recommendations [37]. Furthermore, the acidity values (0.85%–1.14%) were within the standard range (0.6%–1.5%) stated by the Codex Alimentarius Commission [3].

The addition of ACVE significantly affected the WHC and syneresis of yogurt treatments ($p < 0.05$) (Table 1). The WHC increased with the elevation of ACVE concentration; using 0.5% ACVE resulted in the highest WHC compared to other treatments ($p < 0.05$). Furthermore, yogurts with ACVE demonstrated lower syneresis after 21 days than the control. Syneresis is a phenomenon that occurs due to the weakening of the three-dimensional gel network in yogurt and the inability to retain the whey. An improvement in the WHC of yogurt causes more resistance to syneresis [26]. The enhanced WHC and reduced syneresis in ACVE-fortified yogurts may be attributed to the interaction between polyphenols and yogurt proteins. This interaction could strengthen the yogurt gel network and promote higher serum retention [38]. Similar findings have been reported in yogurts supplemented with mulberry fruit [4], *Ferulago angulata* [39], and moringa leaf [10] extracts. Additionally, since ACVE contains various sugars and mucilage [40, 41], its polysaccharides may interact with casein micelles, leading to an improvement in WHC [34]. As storage time progressed, syneresis significantly decreased in all treatments, while WHC improved ($p < 0.05$). The enhanced stability of casein networks may improve the retention of the aqueous phase during storage by forming stable complexes and reducing syneresis. Therefore, incorporation of ACVE in yogurt could strengthen the yogurt gel matrix and improve the serum phase maintenance.

Table 1: The effect of ACVE (0%, 0.1%, 0.25%, and 0.5%) on the physicochemical properties of yogurt treatments during storage.

Parameter	Treatment	Storage time (days)			
		1	7	14	21
pH	Control	4.30 ± 0.01^{aA}	4.08 ± 0.03^{aB}	4.07 ± 0.01^{bB}	4.08 ± 0.00^{cB}
	0.1% ACVE	4.22 ± 0.005^{bA}	4.08 ± 0.005^{aC}	4.13 ± 0.02^{aB}	4.07 ± 0.005^{cC}
	0.25% ACVE	4.21 ± 0.00^{bA}	4.02 ± 0.01^{bC}	4.12 ± 0.00^{aB}	4.21 ± 0.00^{bA}
	0.5% ACVE	4.21 ± 0.01^{bB}	4.04 ± 0.01^{abD}	4.14 ± 0.005^{aC}	4.25 ± 0.005^{aA}
Acidity (%)	Control	0.85 ± 0.03^{bC}	1.01 ± 0.005^{bB}	1.05 ± 0.01^{abB}	1.14 ± 0.02^{aA}
	0.1% ACVE	0.98 ± 0.01^{aBC}	1.01 ± 0.005^{bB}	0.93 ± 0.03^{cC}	1.07 ± 0.005^{bA}
	0.25% ACVE	0.98 ± 0.01^{aC}	1.08 ± 0.005^{aA}	1.01 ± 0.00^{bB}	1.01 ± 0.00^{cB}
	0.5% ACVE	1.02 ± 0.01^{aB}	1.08 ± 0.005^{aA}	1.08 ± 0.00^{aA}	0.99 ± 0.005^{cC}
Syneresis (%)	Control	32.85 ± 0.35^{aA}	31.94 ± 0.01^{aA}	30.64 ± 0.57^{aB}	29.72 ± 0.26^{aB}
	0.1% ACVE	32.59 ± 0.38^{aA}	31.33 ± 0.12^{bB}	30.09 ± 0.63^{aC}	28.98 ± 0.24^{bD}
	0.25% ACVE	32.36 ± 0.35^{aA}	31.10 ± 0.12^{bB}	29.73 ± 0.73^{aC}	28.60 ± 0.14^{bcD}
	0.5% ACVE	32.00 ± 0.24^{aA}	30.39 ± 0.09^{cB}	29.36 ± 0.63^{aC}	28.09 ± 0.11^{cD}
WHC (%)	Control	37.66 ± 0.26^{dD}	38.80 ± 0.14^{dC}	39.71 ± 0.07^{dB}	40.68 ± 0.16^{dA}
	0.1% ACVE	38.14 ± 0.06^{cD}	39.59 ± 0.14^{cC}	40.99 ± 0.02^{cB}	41.41 ± 0.21^{cA}
	0.25% ACVE	39.70 ± 0.08^{bD}	41.83 ± 0.08^{bC}	42.51 ± 0.13^{bB}	42.99 ± 0.01^{bA}
	0.5% ACVE	40.81 ± 0.04^{aD}	42.37 ± 0.03^{aC}	43.68 ± 0.17^{aB}	44.06 ± 0.05^{aA}

Note: Results are presented as a mean value ± SD. The different superscript lowercase (a–d) and uppercase (A–D) letters are significant ($p < 0.05$) in each identical column and row, respectively.

3.2. Color Values. The changes in the color values of yogurt treatments are listed in Table 2. The addition of ACVE significantly decreased the L^* value while increasing the a^*, b^*, and ΔE (color difference compared to the control) values. The presence of various pigments, such as carotenoids, pheophytin, and chlorophylls in ACV leaves [20], could affect the color values of the yogurts. Therefore, yogurt with the highest concentration of ACVE (0.5%) exhibited the most change in color values compared to the control. The lower brightness (L^*) observed in yogurts containing ACVE compared to the control could be due to the higher WHC, as a higher L^* in yogurt is associated with more serum phase on the surface [11]. Additionally, the use of ACVE significantly decreased the greenness in yogurt treatments. This is likely due to the higher release of riboflavin, the green compound, which is associated with greater syneresis in the control, leading to a decrease in the a^* value [42]. Similarly, the a^* value of yogurts with green tea and mint extracts was higher than that of the control after 7 days of storage [43]. In another study, using olive leaf extract in yogurt decreased the L^* value and increased both the a^* and b^* values [6].

3.3. TPC and Antioxidant Properties. The phenolic compounds and antioxidant activity of the ACVE used in the present study were obtained at 8.48 mg GAL/mL and 31.19%, respectively. The ACVE caused a significant enhancement of TPC in fortified yogurts during the whole storage time ($p < 0.05$), as indicated in Figure 1(a). The TPC of the fortified yogurts ranged from 4.02 to 6.14 mg GAE/g, compared to 3.35–4.12 mg GAE/g in the control during storage. This increase is due to the presence of various phenolic compounds in ACVE, such as chlorogenic acid, gallic acid, rutin, kaempferol, kaempferol-3-sulfate, kaempferol-3-glucuronide, and isoquercetin [34]. Additionally, on the first day of storage, a significant increase in antioxidant activity was observed, with a rise from 44.92% in the control to 51.50%–64.70% in fortified yogurts ($p < 0.05$) (Figure 1(b)). After 21 days of storage, the yogurt containing only 0.1% ACVE exhibited a 1.42-fold increase in antioxidant activity compared to the control. Moreover, using 0.25% and 0.5% ACVE led to 1.67-fold and 1.87-fold enhancement, respectively. According to the results of Hashemi et al. [17], incorporation of ACVE into edible starch film enhanced the TPC and antioxidant activity of coated fresh-cut pears. The results of the present study demonstrated for the first time that incorporating ACVE into a food product formulation has the potential to enhance phenolic content and antioxidant activity. The TPC and DPPH radical scavenging activity were enhanced in all yogurt treatments with increasing storage time. Similarly, Akan et al. [44] reported an increase in TPC and antioxidant activity in yogurts containing aqueous extracts of medicinal plants (garlic, oregano, rosemary, basil, and peppermint) during storage. Moreover, according to Cai et al. [4], the TPC and antioxidant activity of probiotic yogurt containing mulberry fruit extract were enhanced over the 28 days of storage. In contrast, some previous studies have reported a decline in TPC and DPPH radical scavenging activity in yogurt during the storage period [2, 26]. An increase in polyphenols during storage may occur if the release of these compounds exceeds their degradation [4]. This increase may be related to the breakdown of phenolic compounds by LAB, leading to the release of compounds with additional antioxidant activity or the activation of previously bound or inactive substances [6]. Additionally, peptides with antioxidant properties may be produced due to the breakdown of proteins by LAB [45]. According to Guemidi et al. [1], consuming yogurt within 10 days after production is recommended because of a decline in antioxidant activity during storage. However, the results of the present study suggest that consumption within the stated period may not be necessary, as the antioxidant properties are enhanced during storage.

Table 2: The color values of yogurt treatments fortified with ACVE (0%, 0.1%, 0.25%, and 0.5%).

Treatment	L^*	a^*	b^*	ΔE
Control	89.41 ± 0.005^{a}	-1.28 ± 0.005^{d}	9.22 ± 0.01^{d}	—
0.1% ACVE	88.53 ± 0.01^{b}	-1.08 ± 0.005^{c}	10.43 ± 0.00^{c}	1.50 ± 0.01^{c}
0.25% ACVE	85.84 ± 0.005^{c}	-0.80 ± 0.005^{b}	11.94 ± 0.005^{b}	4.51 ± 0.01^{b}
0.5% ACVE	84.59 ± 0.00^{d}	-0.46 ± 0.005^{a}	13.74 ± 0.01^{a}	6.66 ± 0.004^{a}

Note: Results are presented as a mean value ± SD. The different superscript letters are significant ($p < 0.05$) in the same column.

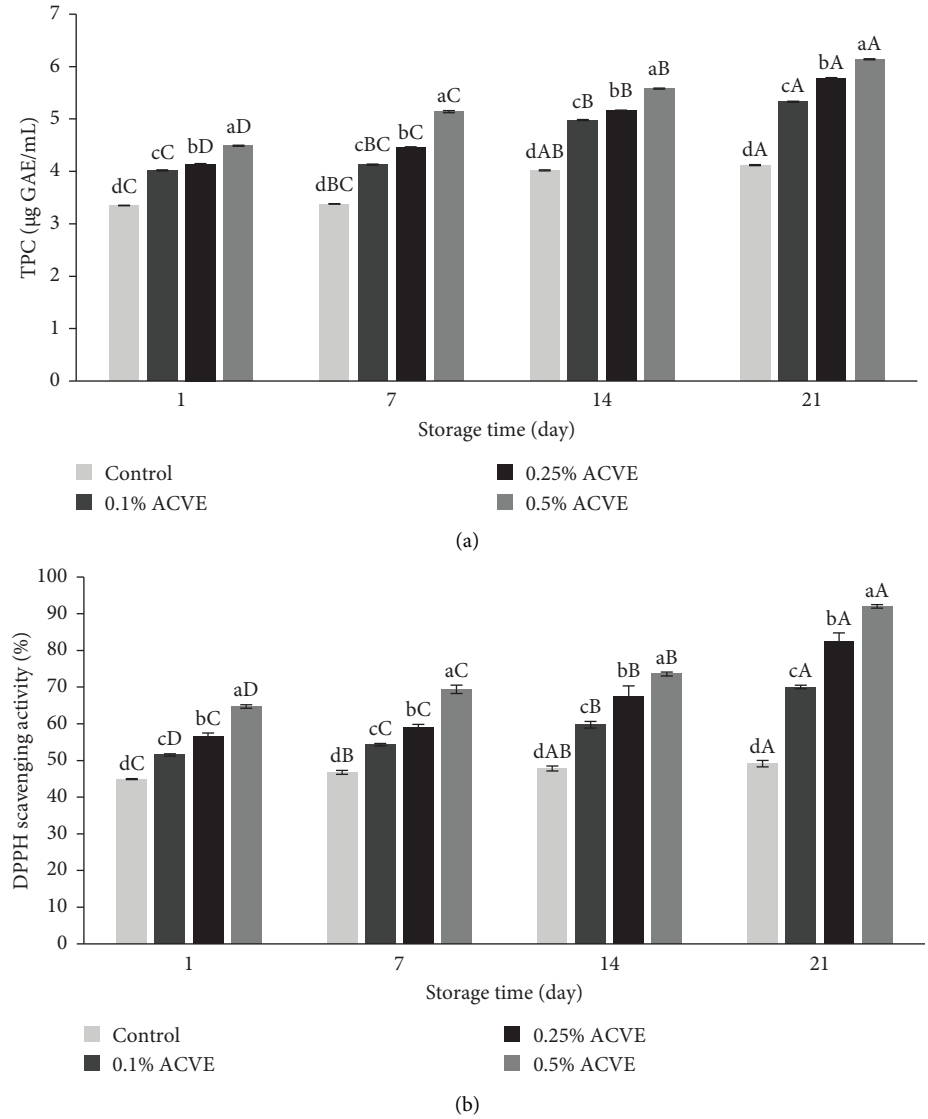


Figure 1: Results of total phenolic content (a) and antioxidant activity (b) of yogurt treatments fortified with ACVE (0%, 0.1%, 0.25%, and 0.5%) during storage. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) on the same day and during the storage period, respectively.

3.4. α-Amylase Inhibition. The ACVE-fortified yogurts exhibited higher α-amylase inhibition than the control on the first and 21st days after production ($p < 0.05$) (Figure 2). On Day 1 of storage, the α-amylase inhibitory activity in the treatments containing ACVE (41.97%–48.84%) was more than three times higher than that of the control (13.83%). The main source of blood sugar is dietary starch, which is hydrolyzed into glucose. The glucose is absorbed by the small intestine, leading to an increase in blood glucose. The retardation of absorbing glucose in the digestive tract by inhibiting the carbohydrate-hydrolyzing enzymes such as α-amylase could be used for the management of Type II

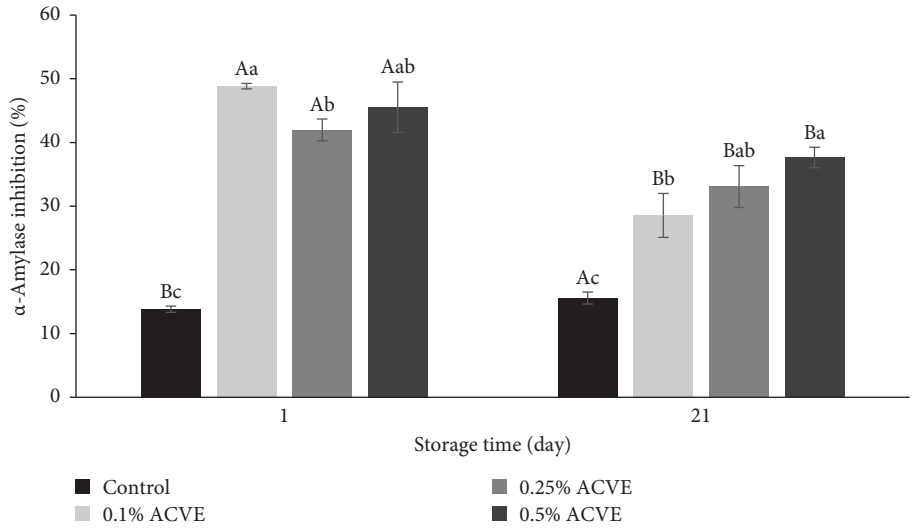


Figure 2: α-Amylase inhibition of yogurt treatments fortified with ACVE (0%, 0.1%, 0.25%, and 0.5%) on the 1st and 21st days of storage. The different superscript lowercase and uppercase letters are significant ($p < 0.05$) on the same day and during the storage period, respectively.

diabetes [45]. However, the drugs with α-amylase and α-glucosidase inhibitory properties that are prescribed for the treatment of Type II diabetes have several side effects, such as diarrhea and bloating. Therefore, using natural sources with inhibitory properties against these enzymes instead of drugs could be valuable [7]. According to previous research, ACV showed antidiabetic properties, which may be related to phenolic compounds such as flavonoids and tannins [46]. The effects of ACVE on reducing starch digestion (by inhibiting enzymes involved in carbohydrate digestion) have been previously reported by Kasabri et al. [47]. The α-amylase inhibitory activity of this plant is mainly attributed to chlorogenic acid [47], which was identified in the ACVE used in the present study based on the chromatography results (data not shown). In addition to polyphenols, the bioactive peptides generated through the proteolysis of proteins in yogurt may exert inhibitory activity [44]. Similar findings have been reported by Nazari et al. [7] regarding the enhancement of α-amylase inhibition in yogurt using germinated black cumin seed extract. Moreover, Herrera et al. [48] stated that the incorporation of strawberry tree and hawthorn extracts in yogurts caused higher inhibition of α-amylase compared to the control. The α-amylase inhibitory activity of treatments decreased during storage. The decrease may be due to the degradation of the polyphenols with inhibitory activity against α-amylase. Furthermore, the balance between the formation of bioactive peptides and further degradation into inactive peptides and amino acids is crucial for enzyme inhibition [45]. In this regard, the results of Shori [49] indicated that the α-amylase inhibitory activity in yogurt fortified with rosemary, dill, oregano, and ginger extracts declined after 14 days of storage. Despite the reduction in inhibitory properties, ACVE-fortified yogurts exhibited approximately twofold or greater α-amylase inhibitory activity (28.55%–37.64%) compared to the control (15.58%).

3.5. LAB Count. The changes in LAB counts of the yogurt treatments are indicated in Table 3. There were no significant differences between the control and yogurt containing 0.1% ACVE on the first day of storage ($p > 0.05$). However, using 0.25% and 0.5% of ACVE in yogurt significantly reduced the LAB counts from 7.07 log CFU/g in the control to 6.77 log CFU/g and 6.74 log CFU/g, respectively ($p < 0.05$). The decrease could be due to phenolic compounds with antimicrobial properties in ACVE [50]. Similarly, Hamed et al. [51] reported a reduction of viable starter culture in yogurt by increasing the concentration of peanut skin extract from 50 to 200 mg/L. Notably, there was an increasing trend in LAB count during storage ($p < 0.05$). In addition, on the 21st day of storage, a significantly higher number of LAB was observed in ACVE-fortified yogurts (7.52–7.57 log CFU/g) compared to the control (7.49 log CFU/g) ($p < 0.05$). Although phenolic compounds in plant extracts possess antimicrobial properties, they can also promote LAB growth [11]. Moreover, LAB may release simpler phenolic compounds by breaking down polyphenols during storage, which likely stimulates their growth. The microbial results are correlated with the TPC enhancement in ACEV-fortified yogurts during storage. In agreement with our findings, Zhang et al. [10] reported that the incorporation of moringa leaf extract in yogurt enhanced LAB proliferation. Furthermore, Paul et al. [52] stated that yogurt fortified with peanut extract showed significantly higher total viable counts and total lactobacillus counts than the control. After 21 days of storage, the LAB counts remained above the minimum Codex standard for yogurt (7 log CFU/g).

3.6. Rheological Properties. Changes in the viscoelastic properties of yogurt treatments are presented in Figure 3. In each oscillation cycle, the energy retained by the food is defined as the storage modulus (G′), whereas the energy

Table 3: LAB counts (log CFU/g) of yogurt treatments fortified with ACVE (0%, 0.1%, 0.25%, and 0.5%) on the 1st and 21st days of storage.

Treatment/storage time (days)	LAB count (log CFU/g)	
	1	21
Control	7.07 ± 0.03^{aB}	7.49 ± 0.01^{cA}
0.1% ACVE	6.89 ± 0.11^{abB}	7.52 ± 0.005^{bA}
0.25% ACVE	6.77 ± 0.07^{bB}	7.55 ± 0.01^{aA}
0.5% ACVE	6.74 ± 0.04^{bB}	7.57 ± 0.01^{aA}

Note: Results are presented as a mean value ± SD. The different superscript lowercase (a–d) and uppercase (A–D) letters are significant ($p < 0.05$) in each identical column and row, respectively.

dissipated is referred to as the loss modulus (G″) [53]. The G′ was higher than the G″. Furthermore, a slight dependence of the moduli on frequency was observed, as depicted in Figure 3(a). These results indicate the predominance of elasticity and weak gel behavior [26]. An increase in ACVE concentration resulted in an increase in the storage and loss moduli of yogurts. This effect is likely due to the formation of strong three-dimensional networks caused by interactions between milk proteins with polyphenols [38] as well as polysaccharides [34] present in the ACVE. Plant extracts have different effects on the viscoelastic properties of yogurt, depending on the composition and concentration. In agreement with our results, an enhancement of the elastic modulus in yogurt with olive leaf extract was stated by Tarchi et al. [6]. In another study, using 0.1% rose flower extract in yogurt improved the elastic modulus and solid behavior, whereas higher concentrations (0.3% and 0.5%) negatively affected the viscoelastic properties due to the presence of insoluble substances [9]. The Tan (δ) represents the predominance of elastic or viscous properties [54]. As this value was less than 1 (Figure 3(b)), it shows the solid-like characteristics of yogurts. The changes in complex viscosity ($^{*}\eta$) as a function of frequency in Figure 3(c) revealed that complex viscosity decreased as the frequency increased, indicating the pseudoplastic behavior and a weak gel structure. The incorporation of ACVE in yogurt enhanced the complex viscosity. The reason could be explained by an inverse relationship between the gel strength and the syneresis of yogurt [55]. Therefore, the reduction in syneresis of yogurts with the addition of ACVE resulted in higher gel network strength.

3.7. Microstructure. The microstructure of the yogurts is displayed in Figure 4. The fortified treatments exhibited a more compact structure than the control, which was more evident at higher ACVE concentrations. These findings correlated with the higher WHC and reduced syneresis observed in ACVE-fortified yogurts (Table 1). The phenolic compounds in the ACVE may interact with casein, enhancing the stability of the three-dimensional network gel in yogurt and promoting the formation of additional cross-links. In this regard, the yogurt fortified with 0.1% and 0.3% *chrysanthemum* extract showed a denser three-dimensional network with smaller spaces [2]. Additionally, similar findings were reported in yogurts containing edible rose flower [9] and mulberry [4] extracts. The interactions between the polysaccharides in ACVE and milk proteins may also contribute to the formation of a denser structure and the higher stability of yogurt gel. Similarly, Ahmed et al. [34] found that the microstructure of yogurt containing an aqueous extract of lupine seeds (*Lupinus albus* L.) exhibited lower porosity due to hydrophobic interactions between polysaccharides and milk proteins. In another study, yogurt supplemented with *Ganoderma* extract (specifically 0.5%) showed a more uniform and compact network structure, probably due to interactions between the polysaccharides of *Ganoderma* extract and proteins [56].

3.8. Sensory Evaluation. One of the challenges of using bioactive compounds in functional yogurts is changing the sensory properties [5]. Table 4 depicts the results of the sensory evaluation of yogurt treatments. There was a decreasing trend in sensory scores with increasing ACVE concentration, particularly in taste and overall acceptance ($p < 0.05$). However, the overall acceptance of yogurt treatments containing 0.1% and 0.25% ACVE showed no significant difference compared to the control at the end of the storage ($p > 0.05$). Plant extracts are likely to cause bitterness and astringency in foods due to the abundance of phenolic compounds [57]. In this regard, yogurt fortified with 0.5% *chrysanthemum* extract showed lower sensory scores because of the bitter taste of the extract [2]. Additionally, a decrease in overall acceptability of yogurt with increasing moringa leaf extract concentrations has been reported by [10]. The addition of 0.25% and 0.5% ACVE to yogurt resulted in lower color scores, particularly at the end of storage. This may be attributed to the lower brightness compared to the control. Based on the ΔE values obtained from the color analysis, since the ΔE in yogurt with 0.1% ACVE ranged between 1 and 3, the color difference was not easily detectable. However, if ΔE exceeds 3, the color difference becomes more obvious [58]. Therefore, the treatments with higher concentrations of ACVE had lower color scores. The yogurt with 0.5% ACVE exhibited a significant declining trend in some sensory attributes during storage ($p < 0.05$). In this regard, a decrease in sensory scores has been reported during the storage of yogurt treatments with 1% banana peel extract [59] and 5% concentrated sweet pepper extract [60]. The sensory attributes of all yogurt treatments were within the acceptable range of 4–9, which is recommended for yogurt [11]. Therefore, using ACVE in yogurt is considered satisfactory, particularly at lower concentrations.

It should be noted that the present study had some limitations. The level of ACVE used in yogurt was limited, and the analyses were restricted to in vitro evaluations. In

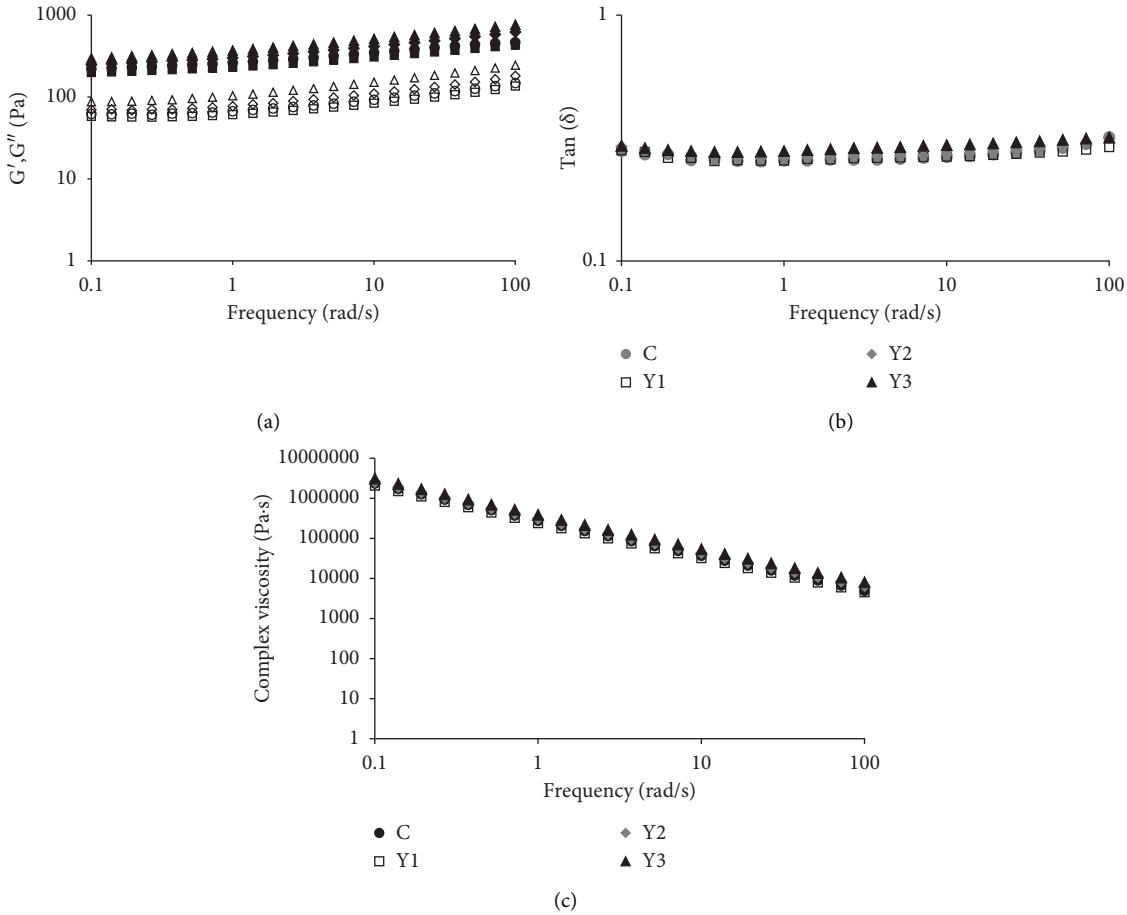


Figure 3: Changes in storage modulus (G′), loss modulus (G″) (a), tan δ (b), and complex viscosity (c) of yogurt treatments containing 0%, 0.1%, 0.25%, and 0.5% ACVE. Filled symbols indicate G′, and empty symbols indicate G″.

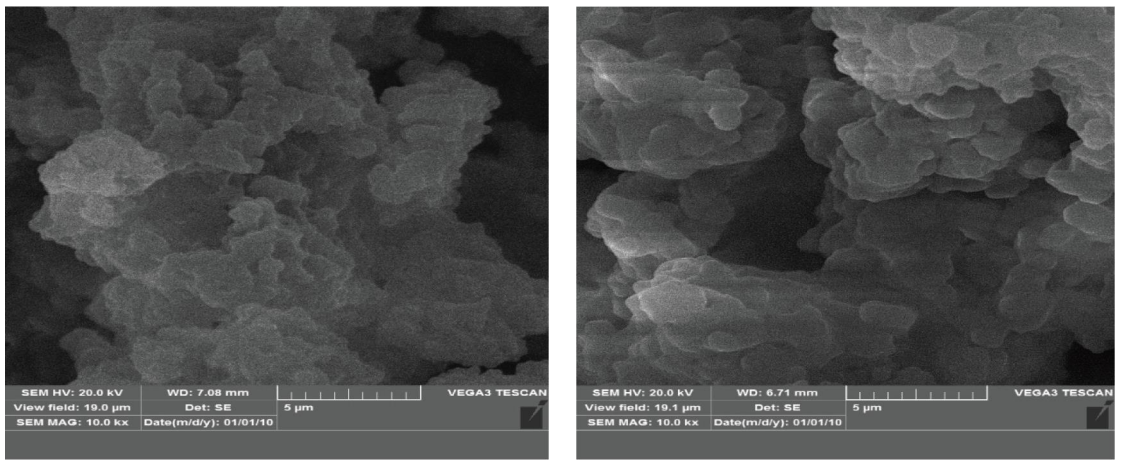
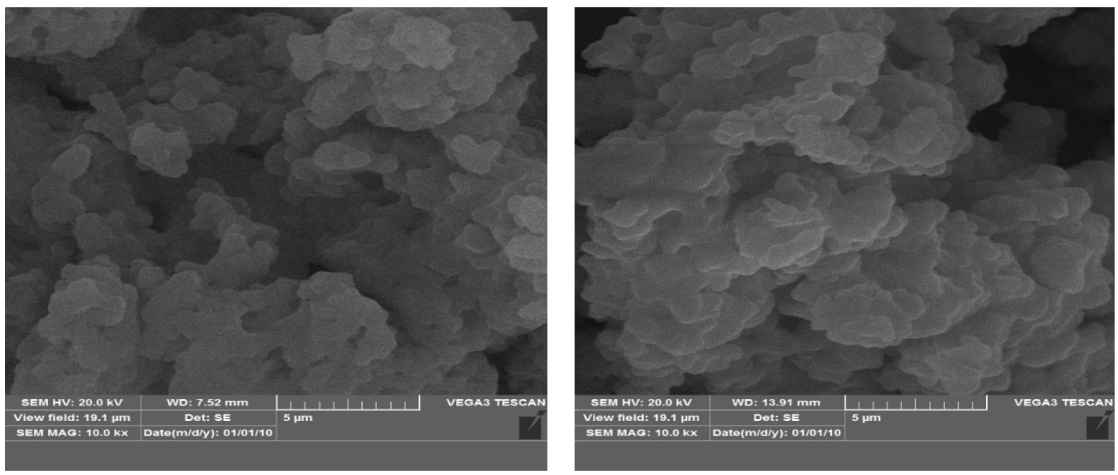


Figure 4: Continued.



(c) (d)

Figure 4: Microstructure of yogurt treatments fortified with 0 (a), 0.1% (b), 0.25% (c), and 0.5% (d) ACVE.

Table 4: Sensory attributes of yogurt treatments containing ACVE (0%, 0.1%, 0.25%, and 0.5%) on the 1st and 21st days of storage.

Parameter	Storage time (days)	Treatment			
		Control	0.1% ACVE	0.25% ACVE	0.5% ACVE
Odor	1	6.76 ± 1.23^{aA}	6.61 ± 1.66^{aA}	6.53 ± 1.05^{aA}	6.23 ± 1.23^{aA}
	21	7.00 ± 1.15^{aA}	7.00 ± 1.22^{aA}	6.07 ± 1.18^{abA}	5.23 ± 1.16^{bB}
Taste	1	7.30 ± 0.75^{abA}	7.38 ± 0.87^{aA}	6.30 ± 1.43^{bcA}	5.38 ± 0.87^{cA}
	21	6.76 ± 1.16^{aA}	7.07 ± 0.95^{aA}	6.53 ± 1.12^{abA}	5.61 ± 1.12^{bA}
Color	1	7.46 ± 1.05^{aA}	7.23 ± 1.09^{aA}	6.84 ± 1.34^{aA}	6.30 ± 1.25^{aA}
	21	7.46 ± 0.87^{abA}	7.69 ± 0.75^{aA}	6.53 ± 1.26^{bcA}	5.84 ± 1.21^{cA}
Texture	1	6.76 ± 1.42^{aA}	7.38 ± 0.96^{aA}	7.46 ± 0.66^{aA}	6.92 ± 1.32^{aA}
	21	7.15 ± 1.21^{aA}	6.61 ± 1.26^{aA}	7.07 ± 1.03^{aA}	6.53 ± 1.39^{aA}
Overall acceptability	1	7.53 ± 0.96^{aA}	7.46 ± 0.96^{aA}	7.30 ± 0.94^{aA}	6.15 ± 1.06^{bA}
	21	7.15 ± 1.14^{aA}	7.30 ± 0.94^{aA}	7.23 ± 0.72^{aA}	6.00 ± 1.35^{bA}

Note: Results are presented as a mean value ± SD. The different superscript lowercase (a–d) and uppercase (A–D) letters are significant ($p < 0.05$) in each identical row and column, respectively.

vivo studies could comprehensively demonstrate the functional effects of consuming yogurt containing ACVE.

4. Conclusion

The effect of ACVE incorporation on the quality characteristics of set-type yogurt was assessed during 21 days of storage. The results revealed that ACVE successfully improved the health benefits of yogurt by enhancing the antioxidant capacity, TPC, and α-amylase inhibition. Furthermore, the addition of ACVE in yogurt led to a reduction in syneresis, an increase in WHC and elasticity, as well as a more compact structure. The fortified yogurts exhibited a higher LAB count than the control at the end of the storage. Additionally, the TPC, antioxidant activity, and LAB counts were increased with prolonged storage. The overall sensory acceptance of yogurt treatments remained within the acceptable range. Therefore, ACVE could be used as an innovative functional additive to enhance the quality characteristics of yogurt. Since this study represents the first application of ACVE in food formulations, further research is needed to evaluate its effects on the quality characteristics of other food products, particularly in reducing spoilage compared to chemical preservatives.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

Funding

No funding was received for this research.

References

[1] C. Guemidi, D. Ait Saada, O. Ait Chabane, et al., "Enhancement of Yogurt Functionality by Adding *Mentha piprita* Phenolic Extract and Evaluation of Its Quality During Cold

Storage," *Food Science and Nutrition* 12, no. 4 (2024): 3007–3020, https://doi.org/10.1002/fsn3.3981.

[2] J. A. Zheng, X. Li, H. Wang, D. Yang, J. Yin, and X. Zhang, "Effects of Chrysanthemum Extract on Physicochemical, Sensory, and *In Vitro* Digestion of Set-Type Yogurt," *Journal of Food Science and Technology* 61, no. 12 (2024): 2343–2353, https://doi.org/10.1007/s13197-024-06000-5.

[3] I. A. Almusallam, I. A. M. Ahmed, E. E. Babiker, et al., "Effect of Date Palm (*Phoenix dactylifera* L.) Spikelets Extract on the Physicochemical and Microbial Properties of Set-Type Yogurt During Cold Storage," *LWT* 148 (2021): 111762, https://doi.org/10.1016/j.lwt.2021.111762.

[4] Z. Cai, S. Zhou, T. Zhang, et al., "Synergistic Enhancement of Bio-Yogurt Properties by *Lactiplantibacillus plantarum* NUC08 and Mulberry Fruit Extract," *Food Chemistry* 468 (2025): 142447, https://doi.org/10.1016/j.foodchem.2024.142447.

[5] S. Pannerchelvan, L. Rios-Solis, H. Wasoh, et al., "Functional Yogurt: A Comprehensive Review of Its Nutritional Composition and Health Benefits," *Food & Function* 15, no. 22 (2024): 10927–10955, https://doi.org/10.1039/d4fo03671a.

[6] I. Tarchi, M. Koubaa, F. Ozogul, M. Bouaziz, and A. Aït-Kaddour, "Influence of Olive Leaf Extract on the Physicochemical Properties of Yogurts Made From Cow, Sheep, and Goat Milk," *Food Bioscience* 63 (2025): 105728, https://doi.org/10.1016/j.fbio.2024.105728.

[7] A. Nazari, S. Zarringhalami, and B. Asghari, "Influence of Germinated Black Cumin (*Nigella sativa* L.) Seeds Extract on the Physicochemical, Antioxidant, Antidiabetic, and Sensory Properties of Yogurt," *Food Bioscience* 53 (2023): 102437, https://doi.org/10.1016/j.fbio.2023.102437.

[8] M. Abdel-Hamid, E. Romeih, Z. Huang, T. Enomoto, L. Huang, and L. Li, "Bioactive Properties of Probiotic Set-Yogurt Supplemented With *Siraitia grosvenorii* Fruit Extract," *Food Chemistry* 303 (2020): 125400, https://doi.org/10.1016/j.foodchem.2019.125400.

[9] L. Qiu, M. Zhang, A. S. Mujumdar, and L. Chang, "Effect of Edible Rose (*Rosa rugosa* cv. Plena) Flower Extract Addition on the Physicochemical, Rheological, Functional and Sensory Properties of Set-Type Yogurt," *Food Bioscience* 43 (2021): 101249, https://doi.org/10.1016/j.fbio.2021.101249.

[10] T. Zhang, C. H. Jeong, W. N. Cheng, et al., "Moringa Extract Enhances the Fermentative, Textural, and Bioactive Properties of Yogurt," *LWT* 101 (2019): 276–284, https://doi.org/10.1016/j.lwt.2018.11.010.

[11] I. A. M. Ahmed, H. A. Alqah, A. Saleh, et al., "Physicochemical Quality Attributes and Antioxidant Properties of Set-Type Yogurt Fortified With Argel (*Solenostemma argel* Hayne) Leaf Extract," *LWT* 137 (2021): 110389, https://doi.org/10.1016/j.lwt.2020.110389.

[12] D. Ahmed and A. Mahmood, "Green Extraction of Antioxidant Compounds From *Adiantum capillus-veneris* L. and Optimization According to Response Surface Methodology," *Asian Journal of Green Chemistry* 8 (2024): 173–187, https://doi.org/10.48309/ajgc.2024.421849.1455.

[13] S. H. Hoseinifar, M. A. Jahazi, R. Mohseni, et al., "Effects of Dietary Fern (*Adiantum capillus-veneris*) Leaves Powder on Serum and Mucus Antioxidant Defence, Immunological Responses, Antimicrobial Activity and Growth Performance of Common Carp (*Cyprinus carpio*) Juveniles," *Fish & Shellfish Immunology* 106 (2020): 959–966, https://doi.org/10.1016/j.fsi.2020.09.001.

[14] M. Yazdani and F. Jookar Kashi, "Bioactivity of Methanolic Leaves and Stem Extracts of *Adiantum capillus-veneris* L. From Southeast of Marivan," *Journal of Plant Productions* 43, no. 4 (2021): 487–496, https://doi.org/10.22055/ppd.2020.29309.1757.

[15] B. Yousaf, Amina, G. Liu, et al., "Bisphenol A Exposure and Healing Effects of *Adiantum capillus-veneris* L. Plant Extract (APE) in Bisphenol A-Induced Reproductive Toxicity in Albino Rats," *Environmental Science and Pollution Research* 23, no. 12 (2016): 11645–11657, https://doi.org/10.1007/s11356-016-6330-0.

[16] A. Zeb, "Phytochemicals of *Adiantum capillus-veneris*," in *Bioactive Compounds in Bryophytes and Pteridophytes, Reference Series in Phytochemistry*, ed. H. N. Murthy (Cham: Springer, 2023), https://doi.org/10.1007/978-3-030-97415-2_21-1.

[17] S. M. B. Hashemi, N. Zahabi, Z. Rezaee, Z. Maherani, P. Boghori, and Z. Keshavarz, "Evaluation of a Starch-Based Edible Film as Carrier of *Adiantum capillus-veneris* Extract to Improve the Shelf Life of Fresh-Cut Pears," *Journal of Food Safety* 3, no. 3 (2016): 291–298, https://doi.org/10.1111/jfs.12241.

[18] W. M. Mutar, A. Y. Al-Hayawi, and M. M. Asaad, "Reduction of Cholesterol and Estimation of Genotoxic Effects of an Aqueous Infusion of *Adiantum capillus-veneris* Leaves in Male White Rats' Testicular Tissue," *Systematic Reviews in Pharmacy* 12, no. 2 (2021): 266–272.

[19] Z. Rabiei and M. Setorki, "Effect of Ethanol *Adiantum capillus-veneris* Extract in Experimental Models of Anxiety and Depression," *Brazilian Journal of Pharmaceutical Sciences* 55 (2019): e18099, https://doi.org/10.1590/s2175-97902019000118099.

[20] A. Zeb and F. Ullah, "Reversed Phase HPLC-DAD Profiling of Carotenoids, Chlorophylls and Phenolic Compounds in *Adiantum capillus-veneris* Leaves," *Frontiers in Chemistry* 5 (2017): 29, https://doi.org/10.3389/fchem.2017.00029.

[21] I. Hadi and H. M. Hussein, "Antimicrobial Activity and Spectral Chemical Analysis of Methanolic Leaves Extract of *Adiantum capillus-veneris* Using GC-MS and FT-IR Spectroscopy," *International Journal of Pharmacognosy and Phytochemical Research* 8, no. 3 (2016): 369–385.

[22] S. Negahdari, H. Galehdari, M. Kesmati, A. Rezaie, and G. Shariati, "Wound Healing Activity of Extracts and Formulations of Aloe Vera, Henna, *Adiantum capillus-veneris*, and Myrrh on Mouse Dermal Fibroblast Cells," *International Journal of Preventive Medicine* 8, no. 1 (2017): 18, https://doi.org/10.4103/ijpvm.IJPVM_338_16.

[23] K. Waszkowiak and A. Gliszczyńska-Świgło, "Binary Ethanol-Water Solvents Affect Phenolic Profile and Antioxidant Capacity of Flaxseed Extracts," *European Food Research and Technology* 242, no. 5 (2016): 777–786, https://doi.org/10.1007/s00217-015-2585-9.

[24] M. Keshavarzi, G. Najafi, H. Ahmadi Gavlighi, P. Seyfi, and H. Ghomi, "Enhancement of Polyphenolic Content Extraction Rate With Maximal Antioxidant Activity From Green Tea Leaves by Cold Plasma," *Journal of Food Science* 85, no. 10 (2020): 3415–3422, https://doi.org/10.1111/1750-3841.15448.

[25] P. Muniandy, A. B. Shori, and A. S. Baba, "Influence of Green, White and Black Tea Addition on the Antioxidant Activity of Probiotic Yogurt During Refrigerated Storage," *Food Packaging and Shelf Life* 8 (2016): 1–8, https://doi.org/10.1016/j.fpsl.2016.02.002.

[26] R. Hamidi Moghaddam, S. Mansouripour, and M. Soltani, "Functional Set-Type Yogurt Prepared Using Turnip Extract (*Brassica rapa* L.): Physicochemical, Antioxidant, Microbiological, Rheological, Microstructural, and Sensory Characteristics," *Journal of Food Measurement and Characterization*

18, no. 2 (2024): 1204–1217, https://doi.org/10.1007/s11694-023-02243-6.

[27] Association of Analytical Chemists, *Official Methods of Analysis*, 18th ed. (AOAC International, 2005).

[28] D. Say, M. Soltani, and N. Guzeler, "Physical, Chemical, and Microstructural Properties of Nonfat Yogurts Fortified With the Addition of Tara Gum Alone or in Combination With Buttermilk Powder," *Journal of Food Processing and Preservation* 43, no. 11 (2019): https://doi.org/10.1111/jfpp.14217.

[29] S. Dai, H. Corke, and N. P. Shah, "Utilization of Konjac Glucomannan as a Fat Replacer in Low-Fat and Skimmed Yogurt," *Journal of Dairy Science* 99, no. 9 (2016): 7063–7074, https://doi.org/10.3168/jds.2016-11131.

[30] M. A. Flores-Mancha, M. G. Ruíz-Gutiérrez, R. Sánchez-Vega, E. Santellano-Estrada, and A. Chávez-Martínez, "Effect of Encapsulated Beet Extracts (*Beta vulgaris*) Added to Yogurt on the Physicochemical Characteristics and Antioxidant Activity," *Molecules* 26, no. 16 (2021): 4768, https://doi.org/10.3390/molecules26164768.

[31] G. Zygmantaitė, M. Keršienė, I. Jasutienė, A. Šipailienė, P. R. Venskutonis, and D. Leskauskaitė, "Extract Isolated From Cranberry Pomace as Functional Ingredient in Yoghurt Production: Technological Properties and Digestibility Studies," *LWT* 148 (2021): 111751, https://doi.org/10.1016/j.lwt.2021.111751.

[32] Z. Liu, B. Bhandari, and M. Zhang, "Incorporation of Probiotics (*Bifidobacterium animalis* Subsp. Lactis) Into 3D Printed Mashed Potatoes: Effects of Variables on the Viability," *Food Research International* 128 (2020): 108795, https://doi.org/10.1016/j.foodres.2019.108795.

[33] Y. Zhao, R. Fu, and J. Li, "Effects of the β-Glucan, Curdlan, on the Fermentation Performance, Microstructure, Rheological and Textural Properties of Set Yogurt," *LWT* 128 (2020): 109449, https://doi.org/10.1016/j.lwt.2020.109449.

[34] S. A. Ahmed, W. A. Helmy, and O. A. Ibrahim, "Evaluation of Lupine Seeds (*Lupinus albus* L.) Neutral Extract as a Texture Improver in Low-Fat Yogurt Production," *International Journal of Biological Macromolecules* 263 (2024): 130303, https://doi.org/10.1016/j.ijbiomac.2024.130303.

[35] A. M. Vanegas-Azuero and L. F. Gutiérrez, "Physicochemical and Sensory Properties of Yogurts Containing Sacha Inchi (*Plukenetia volubilis* L.) Seeds and β-Glucans From *Ganoderma lucidum*," *Journal of Dairy Science* 101, no. 2 (2018): 1020–1033, https://doi.org/10.3168/jds.2017-13235.

[36] M. Salehi, M. Ghorbani, A. Sadeghi Mahoonk, and M. Khomeiri, "Physicochemical, Antioxidant and Sensory Properties of Yogurt Fortified With Common Purslane (*Portulaca oleracea*) Extract," *Journal of Food Measurement and Characterization* 15, no. 5 (2021): 4288–4296, https://doi.org/10.1007/s11694-021-00949-z.

[37] J. X. Lai and S. S. Tang, "Utilizing Pomegranate Extracts for Enhancing Yogurt Quality and Preservation," *Food and Humanity* 3 (2024): 100434, https://doi.org/10.1016/j.foohum.2024.100434.

[38] A. K. Rashwan, A. I. Osman, and W. Chen, "Natural Nutraceuticals for Enhancing Yogurt Properties: A Review," *Environmental Chemistry Letters* 21, no. 3 (2023): 1907–1931, https://doi.org/10.1007/s10311-023-01588-0.

[39] M. Keshavarzi, A. Sharifan, and S. A. Yasini Ardakani, "Effect of the Ethanolic Extract and Essential Oil of *Ferulago angulata* (Schlecht.) Boiss. on Protein, Physicochemical, Sensory, and Microbial Characteristics of Probiotic Yogurt During Storage Time," *Food Science and Nutrition* 9, no. 1 (2021): 197–208, https://doi.org/10.1002/fsn3.1984.

[40] M. Ansari and S. Hasani, "Synthesis and Characterization of a Novel Niosome System Containing *Adiantum capillus-veneris* for Breast Cancer Therapy," *Iranian Journal of Pediatric Hematology & Oncology* 10, no. 4 (2020): 230–240, https://doi.org/10.18502/ijpho.v10i4.4406.

[41] A. A. B. Ali and M. A. Taha, "Controlling *Argas arboreus* and *A. persicus* (Acari: Argasidae) by *Adiantum capillus-veneris* L. Extracts With Phytochemical Analysis," *Veterinary Parasitology* 324 (2023): 110067, https://doi.org/10.1016/j.vetpar.2023.110067.

[42] Z. Jrad, O. Oussaief, T. Bouhemda, T. Khorchani, and H. EL-Hatmi, "Potential Effects of Ultrafiltration Process and Date Powder on Textural, Sensory, Bacterial Viability, Antioxidant Properties and Phenolic Profile of Dromedary Greek Yogurt," *International Journal of Food Science and Technology* 54, no. 3 (2019): 854–861, https://doi.org/10.1111/ijfs.14005.

[43] M. Bulut, Y. Tunçtürk, and D. Alwazeer, "Effect of Fortification of Set-Type Yoghurt With Different Plant Extracts on Its Physicochemical, Rheological, Textural and Sensory Properties During Storage," *International Journal of Dairy Technology* 74, no. 4 (2021): 723–736, https://doi.org/10.1111/1471-0307.12803.

[44] E. Akan, O. Yerlikaya, O. Y. Bayram, and O. Kinik, "The Effect of Aqueous Extracts of Some Plants on *In Vitro* Antioxidant and Antidiabetic Activity of Probiotic Yogurt," *Journal of Food Science and Technology* 59, no. 9 (2022): 3359–3366, https://doi.org/10.1007/s13197-021-05319-7.

[45] A. B. Shori and A. S. Baba, "The Effect of Refrigerated Storage on Anti-Diabetic and Antioxidant Potency of Probiotic Yogurt Treated With Some Medicinal Plants," *Fermentation* 9, no. 5 (2023): 427, https://doi.org/10.3390/fermentation9050427.

[46] S. Dehdari and H. Hajimehdipoor, "Medicinal Properties of *Adiantum capillus-veneris* Linn. in Traditional Medicine and Modern Phytotherapy: A Review Article," *Iranian Journal of Public Health* 47, no. 2 (2018): 188–197.

[47] V. Kasabri, E. K. Al-Hallaq, Y. K. Bustanji, K. K. Abdul-Razzak, I. F. Abaza, and F. U. Afifi, "Antiobesity and Antihyperglycaemic Effects of *Adiantum capillus-veneris* Extracts: *In Vitro* and *In Vivo* Evaluations," *Pharmaceutical Biology* 55, no. 1 (2017): 164–172, https://doi.org/10.1080/13880209.2016.1233567.

[48] T. Herrera, M. Iriondo-DeHond, A. Ramos Sanz, A. I. Bautista, and E. Miguel, "Effect of Wild Strawberry Tree and Hawthorn Extracts Fortification on Functional, Physicochemical, Microbiological, and Sensory Properties of Yogurt," *Foods* 12, no. 18 (2023): 3332, https://doi.org/10.3390/foods12183332.

[49] A. B. Shori, "Inclusion of Phenolic Compounds From Different Medicinal Plants to Increase α-Amylase Inhibition Activity and Antioxidants in Yogurt," *Journal of Taibah University for Science* 14, no. 1 (2020): 1000–1008, https://doi.org/10.1080/16583655.2020.1798072.

[50] C. Singh, N. Chauhan, S. K. Upadhyay, and R. Singh, "Phytochemistry and Ethnopharmacological Study of *Adiantum capillus-veneris* L. (Maidenhair Fern)," *Plant Archives* 20, no. 2 (2020): 3391–3398.

[51] A. M. Hamed, S. H. Taha, A. A. Darwish, and E. Aly, "Antioxidant Activity and Some Quality Characteristics of Buffalo Yoghurt Fortified With Peanut Skin Extract Powder," *Journal of Food Science and Technology* 58, no. 6 (2021): 2431–2440, https://doi.org/10.1007/s13197-020-04835-2.

[52] S. K. K. Paul, M. N. Islam, M. F. Dewan, M. A. Alim, and R. Ahmmed, "Functional Yogurt: An Approach to Enhance Yogurt Quality With Peanut Polyphenols," *Food Bioscience* 60 (2024): 104398, https://doi.org/10.1016/j.fbio.2024.104398.

[53] J. Wu, Y. Lin, Z. Zeng, et al., "Steam-Exploded *Laminaria japonica* Polysaccharide Improved Set Yogurt Quality: Based on Flavor, Storage Stability and Dynamic *In Vitro* Digestive Properties," *Innovative Food Science & Emerging Technologies* 100 (2025): 103933, https://doi.org/10.1016/j.ifset.2025.103933.

[54] A. Izadi, S. Mansouripour, Y. Ramezan, and S. Talebzadeh, "Can Rice Bran, Sesame, and Olive Oils Be Used as Substitutes for Soybean Oil to Improve French Salad Dressing Quality?" *Grasas y Aceites* 73, no. 4 (2022): e479, https://doi.org/10.3989/gya.0435211.

[55] M. Arab, M. Yousefi, E. Khanniri, M. Azari, V. Ghasemzadeh-Mohammadi, and N. Mollakhalili-Meybodi, "A Comprehensive Review on Yogurt Syneresis: Effect of Processing Conditions and Added Additives," *Journal of Food Science and Technology* 60, no. 6 (2023): 1656–1665, https://doi.org/10.1007/s13197-022-05403-6.

[56] C. Bao, M. Yan, M. Diao, A. U. Anastasiia, X. Zhang, and T. Zhang, "Effect of *Ganoderma lucidum* Water Extract on Flavor Volatiles and Quality Characteristics of Set-Type Yogurt," *Food Chemistry* 464 (2025): 141687, https://doi.org/10.1016/j.foodchem.2024.141687.

[57] A. Plaskova and J. Mlcek, "New Insights of the Application of Water or Ethanol-Water Plant Extract Rich in Active Compounds in Food," *Frontiers in Nutrition* 10 (2023): 1118761, https://doi.org/10.3389/fnut.2023.1118761.

[58] S. Ghadarloo, S. Mansouripour, and S. Saremnezhad, "Effect of the Mixture of Oleaster (*E. angustifolia* L.) and Black Cumin (*Nigella sativa*) Flours as Functional Compounds on the Quality Characteristics of Toast Bread," *Food Science and Nutrition* 11, no. 8 (2023): 4678–4687, https://doi.org/10.1002/fsn3.3430.

[59] M. R. Kabir, M. M. Hasan, M. R. Islam, A. R. Haque, and S. K. Hasan, "Formulation of Yogurt With Banana Peel Extracts to Enhance Storability and Bioactive Properties," *Journal of Food Processing and Preservation* 45, no. 3 (2021): e15191, https://doi.org/10.1111/jfpp.15191.

[60] H. Jooyandeh and B. Alizadeh Behbahani, "Development of a Probiotic Low-Fat Set Yogurt Containing Concentrated Sweet Pepper Extract," *Food Science and Nutrition* 12, no. 7 (2024): 4656–4666, https://doi.org/10.1002/fsn3.4114.