

# Evaluation of quality and biochemical characteristics of plant-based fermented yogurt-like products fortified with varying levels of peach pomace

## Farklı oranlarda şeftali posası ile zenginleştirilmiş bitki bazlı fermente yoğurt benzeri ürünlerin kalite ve biyokimyasal özelliklerinin değerlendirilmesi

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### ABSTRACT

This study investigated the effects of peach pomace incorporation on the quality and biochemical characteristics of plant-based fermented yogurt-like products formulated with almond milk. Samples containing 0%, 1%, 3%, and 5% peach pomace were produced using a conventional yogurt starter culture and evaluated in terms of physicochemical properties, total phenolic content (Folin-Ciocalteu method), antioxidant activity (DPPH assay), and microbiological parameters. Significant improvements ( $p < 0.05$ ) were observed in viscosity, water holding capacity, total phenolic content, antioxidant activity, and lactic acid bacteria counts with increasing pomace concentration, while syneresis decreased. Correlation and multivariate analyses revealed positive associations among structural and functional parameters. Among the tested formulations, the 3% pomace level provided the most balanced technological and functional performance. The findings demonstrate that peach pomace can enhance both structural stability and functional properties of plant-based fermented products, highlighting its potential as a sustainable ingredient for value-added food applications.

**Key Words:** Plant-based yogurt, dietary fiber enrichment, peach by-products, antioxidant capacity, functional food development, sustainable food systems

### ÖZ

Bu çalışmada, badem sütü bazlı bitki bazlı fermente yoğurt benzeri ürünlerde şeftali posası ilavesinin kalite ve biyokimyasal özellikler üzerindeki etkileri araştırılmıştır. %0, %1, %3 ve %5 oranlarında şeftali posası içeren örnekler geleneksel yoğurt starter kültürü kullanılarak üretilmiş ve fizikokimyasal özellikler, toplam fenolik madde miktarı (Folin-Ciocalteu yöntemi), antioksidan aktivite (DPPH yöntemi) ile mikrobiyolojik parametreler açısından değerlendirilmiştir. Artan posa konsantrasyonu ile birlikte viskozite, su tutma kapasitesi, toplam fenolik madde miktarı, antioksidan aktivite ve laktik asit bakteri sayılarında istatistiksel olarak anlamlı artışlar ( $p < 0,05$ ) gözlenirken, sineresis oranında azalma belirlenmiştir. Korelasyon ve çok değişkenli analizler, yapısal ve fonksiyonel parametreler arasında pozitif ilişkiler olduğunu ortaya koymuştur. Test edilen formülasyonlar arasında %3 şeftali posası içeren grup, teknolojik ve fonksiyonel özellikler açısından en dengeli performansı göstermiştir. Elde edilen bulgular, şeftali posasının bitki bazlı fermente ürünlerde hem yapısal stabiliteyi hem de fonksiyonel özellikleri artırabileceğini göstermekte olup, katma değerli ve sürdürülebilir gıda uygulamaları için potansiyel bir bileşen olduğunu ortaya koymaktadır.

**Anahtar Kelimeler:** Bitki bazlı yoğurt, diyet lifi zenginleştirme, şeftali yan ürünleri, antioksidan kapasite, fonksiyonel gıda geliştirme, sürdürülebilir gıda sistemleri

## Introduction

In recent years, there has been a remarkable increase in the demand for functional products in the food sector, driven by rising consumer awareness and growing emphasis on healthy nutrition. The shift toward plant-based diets is particularly supported by concerns over environmental sustainability, ethical considerations, and health-related factors such as lactose intolerance. Consequently, the development of alternative products to those derived from animal sources has been increasingly encouraged (McClements, 2020; Boukid, 2021). Within this context, plant-based dairy products especially fermented plant-based yogurt-like products have gained prominence as novel alternatives to traditional dairy, offering enhanced functional properties such as improved antioxidant capacity, dietary fiber enrichment, and potential prebiotic effects (Granato et al., 2020; Chen et al., 2025; Rashwan et al., 2025; Thivya et al., 2026).

Vegan yogurts are typically produced by fermenting plant-based milks such as almond, soy, coconut, or oat with lactic acid bacteria. However, compared to their animal-based counterparts, these products are known to have limitations in terms of structure, texture, fermentation dynamics, and microbiological stability due to their relatively low protein and mineral content (Sethi et al., 2016). To address these challenges, various natural texturizers, dietary fiber sources, and phenolic-rich additives have been incorporated into plant-based formulations, improving both texture and functional characteristics (McClements et al., 2019; Grasso et al., 2020). Fruit pomace, a common by-product of the fruit processing industry, has recently attracted attention as a functional ingredient owing to its high levels of fiber, phenolics, and antioxidant compounds (Slavin, 2013; Stefanović et al., 2015). Among them, peach pomace, with its dietary fiber

content reaching up to 20% and its abundance of natural phenolic compounds, has emerged as a promising candidate for food enrichment (Ouattmani et al., 2022). Compared to other fruit pomaces, peach pomace is characterized by a balanced composition of soluble dietary fibers and phenolic compounds, which may simultaneously improve texture and antioxidant capacity. This dual functionality makes it particularly suitable for plant-based fermented matrices that typically suffer from weak gel structure and limited bioactive content (Ziarno et al., 2025; Johansson et al., 2026). However, research on the incorporation of peach pomace into plant-based fermented yogurt-like products and its impact on product quality remains limited.

Most existing studies have focused on fruit additives in dairy-based yogurts, with little systematic evaluation of the functional effects of fruit-derived by-products in fermented plant-based milk systems.

Although several studies have investigated the incorporation of fruit pomaces into dairy-based yogurts, limited research has systematically examined the application of peach pomace in plant-based fermented yogurt-like systems. Most available studies focus on apple, grape, or pomegranate pomace in dairy matrices, whereas data on almond-based fermented products remain scarce. Therefore, a comprehensive evaluation of the structural, biochemical, and microbiological impacts of peach pomace in plant-based formulations is still needed.

In this study, vegan yogurt samples were produced using almond milk and supplemented with different levels of peach pomace (0%, 1%, 3%, and 5%). The resulting products were evaluated in terms of their physical, chemical and microbiological quality attributes. The main objective of the study was to determine the effects of peach pomace addition on the structural integrity, stability, and functional compound content of plant-based yogurts. Furthermore, the study aimed to develop an innovative functional product while also exploring

the potential of integrating agricultural by-products often considered waste into sustainable food systems.

## Materials and Methods

### Material

In this study, a commercially available unsweetened and additive-free almond milk (Alpro®, Unsweetened Almond Milk, Alpro C.V.A., Belgium) was used as the plant-based base for yogurt production. Peach pomace was obtained as a by-product from a local fruit juice processing facility following fresh fruit extraction and was stored at  $-20\text{ }^{\circ}\text{C}$  in a deep freezer (Vestfrost VT 306M) until analysis. Before incorporation into the formulations, the peach pomace was thawed at  $4\text{ }^{\circ}\text{C}$  and homogenized to obtain a uniform particle distribution. No additional drying or particle size standardization was applied, and the pomace was used in its natural moisture state as obtained from the processing facility.

A commercial yogurt starter culture (YO-MIX® 200, Chr. Hansen, Denmark) containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* strains was used as the inoculum. To improve yogurt consistency and structural stability, a plant-based stabilizer mixture consisting of 0.2% locust bean gum (Sigma-Aldrich, C3157), 0.05% carrageenan (Sigma-Aldrich, C1013), and 0.01% agar-agar (Merck, 101614) was incorporated. The selected stabilizer concentrations were determined based on preliminary formulation trials and previous studies on plant-based fermented yogurt-like products to ensure adequate gel formation and structural stability without adversely affecting fermentation performance.

### Experimental design

Four different levels of peach pomace were tested in the formulations: 0% (control), 1%, 3%, and 5% (w/w). Each treatment was performed in triplicate ( $n=3$ ), and the experiment was arranged according to a Completely Randomized Design (CRD). For each group, three individual 100 mL

yogurt samples were prepared and analyzed.

### Yogurt production and fermentation process

The almond milk was heated to  $80\text{ }^{\circ}\text{C}$  using a water bath (Mettler W200), and the stabilizer blend was added while stirring. Homogenization was performed using a magnetic stirrer (IKA® C-MAG HS 7) for 10 minutes. The mixture was then pasteurized at  $90\text{ }^{\circ}\text{C}$  for 10 minutes. After cooling to  $45\text{ }^{\circ}\text{C}$ , the starter culture was inoculated at a concentration of 0.1 g per 100 mL. The inoculated mixtures were transferred into sterile 120 mL plastic containers and incubated at  $45\text{ }^{\circ}\text{C}$  for 8 hours (Binder BD115 incubator). The inoculated mixtures were transferred into sterile 120 mL plastic containers and incubated at  $45\text{ }^{\circ}\text{C}$  for 8 hours (Binder BD115 incubator). The fermentation conditions were selected according to the optimal growth requirements of the commercial yogurt starter culture used in this study and were uniformly applied to all formulations to ensure experimental consistency. Following fermentation, the samples were refrigerated at  $4\text{ }^{\circ}\text{C}$  for 12 hours to allow maturation. All analyses were conducted thereafter.

### Physical and biochemical analyses

To evaluate the structural and functional characteristics of the yogurt samples, a series of physical and chemical analyses were conducted. These included pH measurement, viscosity, water holding capacity (WHC), syneresis, total phenolic content (TPC), and antioxidant activity, each of which plays a critical role in determining product quality and stability.

**pH measurement:** pH values were determined using a digital pH meter (Hanna Instruments HI2211). For each sample, 10 g was homogenized with 90 mL of distilled water before measurement.

**Viscosity:** Viscosity was measured using a Brookfield DV2T viscometer equipped with spindle No. 10 at 100 rpm and  $25\text{ }^{\circ}\text{C}$ .

**Water holding capacity (WHC):** Ten grams of yogurt sample was centrifuged at 5000 rpm for 10

minutes (Nüve NF200 centrifuge). The supernatant was discarded, and the remaining mass was weighed to calculate WHC (%).

**Syneresis:** The amount of separated whey was measured under the same centrifugation conditions to determine the syneresis percentage. Although both WHC and syneresis were determined under identical centrifugation conditions, WHC reflects the retained water within the gel matrix, whereas syneresis represents the expelled whey fraction. Therefore, these parameters provide complementary but inverse information regarding water retention behavior.

**Total phenolic content (TPC):** TPC was measured by the Folin-Ciocalteu method using a UV-Vis spectrophotometer (Shimadzu UV-1800). Results were expressed as mg gallic acid equivalents (GAE) per 100 g of sample (Singleton and Rossi, 1965).

**Antioxidant activity:** Antioxidant activity was evaluated by the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, and absorbance was measured at 517 nm. Results were reported as % inhibition (Brand-Williams et al., 1995). A calibration curve was constructed using standard solutions, and linearity was confirmed ( $R^2 > 0.99$ ). All measurements were performed in triplicate.

#### *Microbiological analyses*

Total viable counts (TVC) were determined using Plate Count Agar (Merck 1.05463), and lactic acid bacteria (LAB) counts were determined using MRS Agar (Merck 1.10660). Ten grams of yogurt was homogenized in 90 mL of sterile 0.85% NaCl solution. From the appropriate dilutions, 1 mL aliquots were plated using the pour plate method. PCA plates were incubated at 37 °C for 48 hours, and MRS plates were incubated anaerobically at 37 °C for 72 hours. Results were

expressed as log CFU/g. All microbiological analyses were conducted in triplicate to ensure analytical reliability.

#### *Statistical analyses*

All quantitative data were obtained in triplicate and expressed as mean  $\pm$  standard deviation (SD). Statistical evaluations were conducted using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) was applied to determine significant differences among the groups, followed by Duncan's multiple range test to identify specific differences ( $p < 0.05$ ). Additionally, multivariate statistical analyses were performed to provide a more comprehensive visualization of the multidimensional effects of peach pomace incorporation. For this purpose, Python version 3.11 was used, along with the pandas (v2.2.2), numpy (v1.26.4), matplotlib (v3.8.4), and seaborn (v0.13.2) libraries. Pairwise scatter matrix plots were generated using the seaborn library to explore the correlation structure among physicochemical and functional parameters. Moreover, heatmaps were constructed via seaborn to holistically assess microbiological attributes. These visual representations effectively illustrated the multifaceted impacts of different levels of peach pomace addition on the overall quality of plant-based yogurts.

## **Results and Discussion**

### *Effect of peach pomace on physical properties*

The addition of peach pomace at different concentrations (1%, 3%, and 5%) had a statistically significant effect on the physical properties of the plant-based yogurt samples ( $P < 0.05$ ). The mean values and statistical groupings for pH, viscosity, water holding capacity (WHC), and syneresis are presented in Table 1.

**Table 1.** Effects of peach pomace addition on the physical properties of plant-based yogurt samples\*

Peach Pomace (%)	pH Value	Viscosity (cP)	Water Holding Capacity (%)	Syneresis (%)
0 (Control)	4.52 ± 0.02 <sup>a</sup>	450 ± 15 <sup>c</sup>	51.2 ± 1.3 <sup>c</sup>	24.7 ± 1.0 <sup>a</sup>
1	4.50 ± 0.03 <sup>ab</sup>	560 ± 20 <sup>b</sup>	56.5 ± 1.1 <sup>b</sup>	20.4 ± 0.9 <sup>ab</sup>
3	4.46 ± 0.01 <sup>b</sup>	690 ± 18 <sup>ab</sup>	61.9 ± 1.5 <sup>ab</sup>	16.1 ± 1.1 <sup>b</sup>
5	4.42 ± 0.02 <sup>c</sup>	740 ± 25 <sup>a</sup>	66.7 ± 1.2 <sup>a</sup>	12.9 ± 0.8 <sup>c</sup>

\* Data are presented as mean ± standard deviation (n = 3). Different letters in the same column represent significant differences (P<0.05)

A gradual decrease in pH values was observed with increasing peach pomace concentration. While the pH was 4.52 in the control group, it declined to 4.42 in the sample containing 5% pomace. This trend may be attributed to the phenolic compounds and organic acids present in the pomace, which can influence the fermentation process by increasing the overall acidity. A similar pattern of pH reduction with higher pomace levels was reported in plant-based yogurts enriched with mango pomace (Ali et al., 2024). Viscosity increased significantly as the concentration of peach pomace rose. The lowest viscosity value was recorded in the control group (450 cP), while the highest was observed in the 5% pomace group (740 cP). This increase is likely due to the high soluble fiber content of the pomace, which contributes to the formation of a gel-like structure with strong water retention capacity. Comparable trends were documented in probiotic yogurts enriched with apple pomace (Ahmad et al., 2020) and in plant-based yogurts formulated with fig fiber (Abd El Moneem et al., 2021). Peach pomace also showed a positive effect on water holding capacity (WHC). The WHC increased from 51.2% in the control group to 66.7% in the 5% pomace group. This enhancement, in parallel with viscosity, suggests that the yogurt matrix became denser and more capable of retaining water. These findings support the role of pomace in improving water-binding capacity and matrix stability (Stefanović et al., 2015; Ganjoo et al., 2024). Conversely, syneresis significantly decreased with higher pomace levels. The percentage of whey separation dropped from 24.7% in the control to 12.9% in the 5% pomace group. This indicates that the structural binding effect of peach pomace limited free water release

from the yogurt matrix. These results are consistent with previous studies reporting the syneresis-reducing effects of fruit by-products such as pomegranate and pear pomace (Popescu et al., 2022; Blejan et al., 2024). Overall, the incorporation of peach pomace significantly improved the physical characteristics of vegan yogurts. The 5% pomace group demonstrated the most favorable results, yielding the highest viscosity and WHC values and the lowest syneresis level, thereby indicating superior structural stability.

#### *Effect of peach pomace on biochemical properties*

The incorporation of peach pomace resulted in statistically significant differences (p < 0.05) in the total phenolic content (TPC) and antioxidant activity (AA) of the vegan yogurt samples. As shown in Table 2, both parameters increased progressively with higher pomace concentrations. Total phenolic content (TPC) increased proportionally with the addition of peach pomace. While the TPC value in the 5% pomace group reached 67.8 mg GAE/100 g, it was measured at 38.5 mg GAE/100 g in the control group. This increase can be attributed to the high concentration of phenolic compounds naturally present in peach pomace. In particular, peach pomace is known to be rich in antioxidant compounds such as neochlorogenic acid, caffeic acid, and flavonoids (Mandache et al., 2025). Similar trends have been widely reported in the literature for other fruit processing by-products, including grape, apple, mango, and pomegranate pomace, which significantly elevated the TPC values when incorporated into yogurt formulations (Marchiani et al., 2016; Popescu et al., 2022). Antioxidant activity, assessed using the

DPPH radical scavenging assay, was also significantly influenced by pomace concentration. The 5% pomace group exhibited the highest inhibition value at 40.9%, compared to 22.6% in the control group (Table 2). The observed increases in antioxidant capacity were statistically significant, with a notable transition occurring between 1% and 3% pomace levels. These results suggest that peach pomace enhances not only the structural properties but also the functional bioactive profile of plant-based yogurts. The

incorporation of peach pomace into vegan yogurt formulations effectively improves the product’s nutritional and functional quality, particularly through enrichment in phenolic compounds and antioxidant potential. These findings underscore the importance of revalorizing fruit by-products such as peach pomace not only as waste management solutions but also as valuable ingredients for the development of health-promoting functional foods.

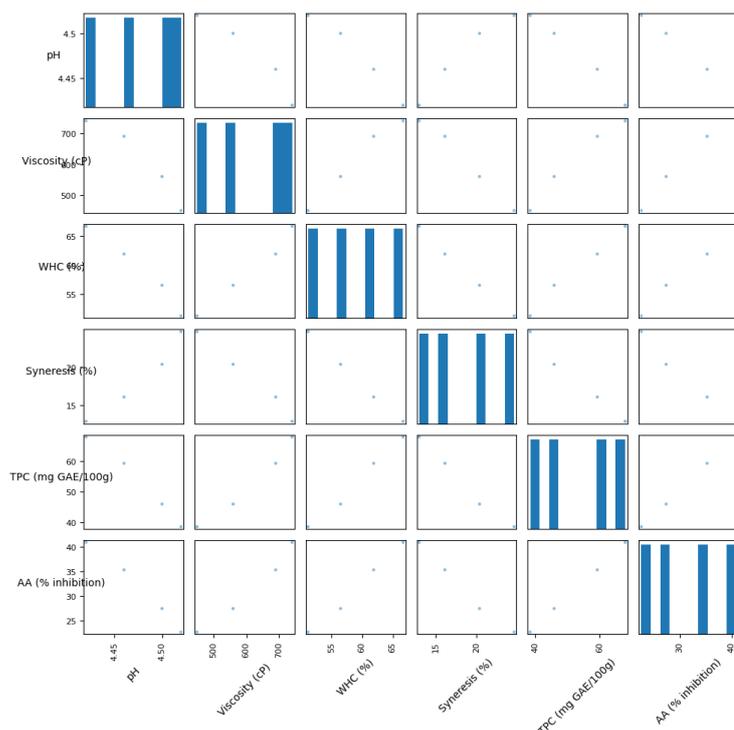
**Table 2.** Effect of different peach pomace concentrations on the biochemical properties of vegan yogurts\*

Peach Pomace (%)	Total Phenolic Content (mg GAE/100 g)	Antioxidant Activity (% Inhibition)
0 (Control)	38.5 ± 1.2 <sup>c</sup>	22.6 ± 0.8 <sup>c</sup>
1	45.9 ± 1.5 <sup>b</sup>	27.4 ± 0.9 <sup>bc</sup>
3	59.2 ± 1.8 <sup>ab</sup>	35.3 ± 1.1 <sup>b</sup>
5	67.8 ± 2.0 <sup>a</sup>	40.9 ± 1.3 <sup>a</sup>

\*Results are presented as mean ± standard deviation (n = 3). Different letters within the same column denote significant differences at P<0.05 (Duncan’s test)

In order to examine the interrelationships among physicochemical and functional properties of peach pulp-fortified yogurt samples, a scatter matrix (pairwise scatterplot) was generated using six core parameters: pH, viscosity, water holding capacity (WHC), syneresis, total phenolic content

(TPC), and antioxidant activity (AA). This multivariate visualization offers a comprehensive overview of potential linear trends, covariances, and inverse associations among the measured variables, thereby facilitating an integrative understanding of how peach pulp inclusion affects the product matrix holistically (Figure 1).



**Figure 1.** Scatter matrix illustrating pairwise relationships among selected quality parameters of peach pulp-enriched yogurt samples. The variables include pH value, viscosity, water holding capacity (WHC), syneresis, total phenolic content (TPC), and antioxidant activity (AA). Histograms on the diagonal represent the distribution of each variable, while the lower triangle plots show bivariate scatter plots across all combinations. The matrix reveals strong positive correlations between viscosity, WHC, and TPC, as well as between TPC and AA, while syneresis is inversely correlated with most other parameters. These results highlight the multifactorial impact of peach pulp addition on yogurt quality attributes

The scatter matrix reveals distinct and interpretable patterns of correlation. Notably,

viscosity demonstrated a strong positive association with both WHC and TPC, indicating that increased structural density due to fiber and bioactive constituents in the pulp contributes to enhanced water retention and phenolic enrichment. This relationship aligns with the hypothesis that pectic polysaccharides and soluble dietary fibers contribute to a denser protein-polysaccharide network in yogurt, which in turn improves textural firmness and minimizes moisture migration. These findings are supported by earlier studies where the inclusion of fiber-rich fruit by-products similarly enhanced WHC and viscosity (Lau et al., 2021; Salehi, 2021). Furthermore, a highly significant positive correlation was observed between TPC and AA, substantiating the biochemical premise that the majority of antioxidant potential in fruit-derived matrices is conferred by phenolic constituents, particularly chlorogenic acid derivatives and flavonoids. This relationship confirms the functional enrichment capability of peach pulp, consistent with previous reports on the antioxidant-enhancing effects of fruit pomace fortification in dairy matrices (Paduret et al., 2024; Bastos et al., 2025). Conversely syneresis exhibited a strong negative correlation with viscosity, WHC, TPC, and AA, underscoring the inverse dynamics between product structural integrity and whey separation. This implies that as the gel matrix becomes denser and enriched with water-binding and bioactive compounds, the propensity for phase separation is markedly reduced. This phenomenon has been attributed to the network-reinforcing and hydration-enhancing effects of plant-based polysaccharides, which stabilize the protein lattice and reduce serum release during storage (Stefanović et al., 2015; Ziarno et al., 2024). Interestingly, pH values displayed relatively weaker correlations with most other variables, suggesting that the acidification profile of the yogurt was not significantly modulated by the inclusion level of

peach pulp, likely due to the buffering capacity of the plant matrix and the similar fermentation kinetics across treatments. This independence reinforces the notion that the observed changes in texture and functionality are predominantly attributed to structural and compositional modifications rather than alterations in acidity. The pairwise scatter matrix illustrates the relationships among the measured quality parameters following peach pomace supplementation. The increase in phenolic content was associated with improvements in viscosity, water holding capacity, and antioxidant activity, suggesting that peach pomace contributed to both structural and functional properties of the product. These results indicate that incorporating fiber- and polyphenol-rich fruit by-products into plant-based fermented systems may improve technological performance while also enhancing nutritional value.

#### *Effect of peach pomace on microbiological properties*

Significant differences were observed in total viable counts (TVC) and lactic acid bacteria (LAB) populations among the vegan yogurt samples ( $P < 0.05$ ). The impact of peach pomace addition on microbial growth is presented in Table 3. The results indicate that increasing levels of peach pomace positively influenced the proliferation of beneficial microorganisms. This effect is likely attributed to the presence of fermentable dietary fibers and bioactive compounds in the pomace, which may have provided a more favorable growth environment for LAB strains. Moreover, the improved textural matrix due to pomace enrichment may have contributed to microbial entrapment and stability during storage. These findings are in agreement with previous studies reporting enhanced LAB viability in fruit-fortified or fiber-enriched plant-based fermented products.

**Table 3.** Effect of peach pomace addition on the microbiological properties of vegan yogurts\*

Peach Pomace (%)	TVC (log CFU/g)**	LAB (log CFU/g)***
0 (Control)	7.42 ± 0.15 <sup>c</sup>	7.05 ± 0.12 <sup>b</sup>
1	7.53 ± 0.18 <sup>b</sup>	7.18 ± 0.10 <sup>ab</sup>
3	7.65 ± 0.11 <sup>ab</sup>	7.39 ± 0.09 <sup>a</sup>
5	7.70 ± 0.13 <sup>a</sup>	7.40 ± 0.11 <sup>a</sup>

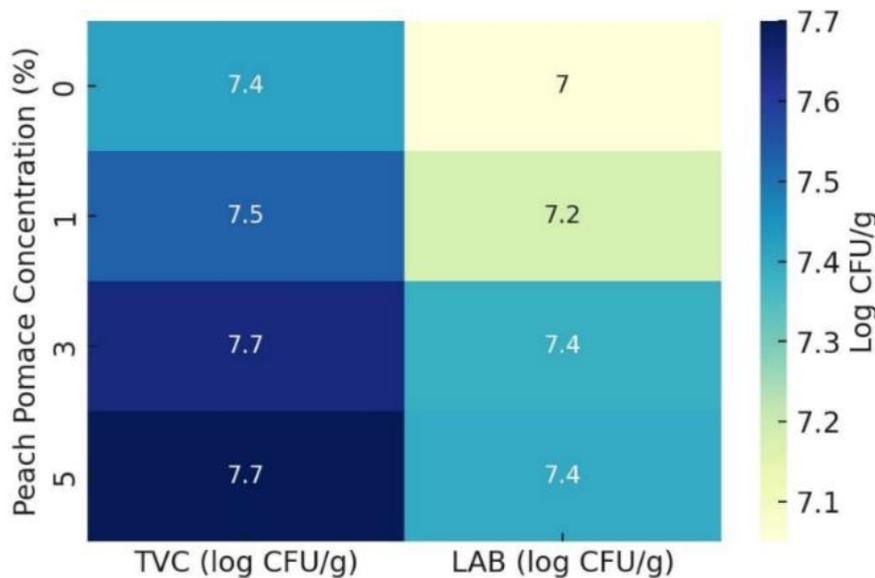
\*Values are shown as mean ± SD (n = 3). Means with different letters in the same column differ significantly at P < 0.05 (Duncan's test).

\*\*TVC: Total Viable Count; \*\*\*LAB: Lactic Acid Bacteria

The addition of peach pomace resulted in significant increases in both total aerobic bacterial counts (TVC) and lactic acid bacteria (LAB) populations. The control group exhibited TVC and LAB levels of 7.42 and 7.05 log CFU/g, respectively, whereas the 5% pomace group showed elevated counts of 7.70 and 7.40 log CFU/g, respectively. This enhancement is attributed to the soluble dietary fibers and simple carbohydrates in peach pomace, which serve as substrates for fermentative bacteria. Additionally, the prebiotic potential of peach pomace to support microbial growth has been reported in the literature (Ahmad et al., 2020; Abdelmotilib et

al., 2022).

The highest bacterial densities were observed in the 3% and 5% pomace groups, which did not differ significantly from each other ( $P > 0.05$ ). Notably, the LAB population exceeding 7.0 log CFU/g indicates a promising probiotic potential of the product. These values are well above the minimum threshold of 6.0 log CFU/g recommended by FAO/WHO for functional foods. Therefore, peach pomace supplementation not only improves the structural and functional properties of the yogurt but also enhances its microbiological quality by promoting probiotic bacterial growth (Figure 2).



**Figure 2.** Illustrates a heatmap depicting the effect of different concentrations of peach pomace (0%, 1%, 3%, 5%) on the microbiological properties of almond milk-based vegan yogurts. The heatmap displays the logarithmic values of Total Viable Count (TVC) and Lactic Acid Bacteria (LAB) expressed as log CFU/g. Color intensity corresponds to the magnitude of the values, with darker shades indicating higher bacterial counts. The results show a clear increase in both TVC and LAB counts with rising pomace concentrations

The heatmap results clearly demonstrate that the addition of peach pomace positively influences the microbiological quality of vegan yogurts. While the control group exhibited TVC and LAB values of 7.42 and 7.05 log CFU/g respectively, these values increased to 7.70 and 7.40 log CFU/g in the 5% pomace group. This enhancement can be attributed to the soluble dietary fibers, pectins, and phenolic compounds present in peach pomace, which support the

proliferation of fermentative bacterial populations (Ahmad et al., 2020; Ge et al., 2025).

Similar findings in the literature report the prebiotic effects of fruit pomaces in promoting the viability of probiotic and lactic acid bacteria (Rachwał et al., 2024; Sirini et al., 2021). Specifically, complex carbohydrates such as pectins and oligosaccharides act as suitable substrates for bacterial growth (Carlson, 2018). Moreover, pomace-derived phenolic compounds

may modulate microbial metabolism, thereby enhancing the functional value of the yogurt (Du et al., 2021). Furthermore, the structural matrix of the yogurt is strengthened and its water retention capacity improved by pomace addition, creating a physical environment conducive to microbial stability and viability (Sowa-Borowiec et al., 2025). This suggests that the observed increase in bacterial counts is influenced not only by the nutritional substrate but also by the provision of a favorable microenvironment. These findings highlight the potential of peach pomace as an effective ingredient to enhance both the microbiological viability and functional quality of vegan yogurts, supporting the sustainable utilization of fruit processing by-products in food innovation. It should be noted that the formulation included a stabilizer blend consisting of locust bean gum, carrageenan, and agar. Therefore, the observed improvements in viscosity, water holding capacity, and syneresis reduction may not be attributed solely to peach pomace addition, but potentially to synergistic interactions between pomace-derived fibers and hydrocolloid stabilizers. Further studies designed without added stabilizers or with controlled single-hydrocolloid systems would help to better isolate the specific contribution of peach pomace.

## Conclusion

This study revealed that the incorporation of peach pomace into plant-based yogurt significantly improved various quality parameters, including viscosity, water holding capacity, antioxidant activity, and microbial viability, while effectively reducing syneresis and pH in a controlled manner. The group enriched with 3% peach pomace showed the most favorable results in terms of functional attributes, indicating that this concentration represents an optimal level for technological improvement. The improvements observed can be attributed to the high soluble fiber content and the structural binding capacity of peach pomace, which contributed to the formation of a more stable gel matrix in the

yogurt system. In addition, the enhancement in lactic acid bacteria counts in the pomace-enriched groups suggests a potential prebiotic effect, thereby increasing the functional value of the product. These results are in agreement with previous findings reported for other fruit pomace additions, such as apple, cranberry, and pomegranate. However, the potential synergistic interaction between peach pomace and the stabilizer system should be considered when interpreting the structural results. It should also be noted that all analyses were performed at a single post-fermentation time point. Therefore, storage stability and shelf-life behavior of the products were not evaluated in this study. In addition, sensory evaluation was not performed in the present study. Therefore, the consumer acceptability of higher pomace concentrations, particularly the 5% level, should be verified through comprehensive sensory analysis in future research. Furthermore, microbiological evaluation was limited to total viable count and lactic acid bacteria populations. Yeast and mold counts were not assessed and should be included in future studies to provide a more comprehensive evaluation of microbiological safety and stability. Further studies are needed to evaluate the effects of different pomace types, long-term storage stability, and consumer preferences under real market conditions. Standardization of pomace preparation techniques will also be important to ensure consistent product quality in future applications.

## Conflict of interest

The author declares no conflict of interest.

## Author Contributions

Çağlar Kaya was responsible for the conceptualization, experimental design, methodology, data analysis, resources, supervision, execution of the study, and writing-original draft preparation, review, and final editing of the manuscript.

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