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Research Article

The Effect of Grape Pomace Fiber Addition on Quality Parameters of Yogurt

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ABSTRACT

Reducing food and industrial waste is essential to match the novel objectives of sustainable living. In this context, grape pomace, a fiber-rich by-product of wine production, was used as a fiber supplement in yogurt after enriching its fiber content through preprocessing. Within the aim of this study, 0.5% and 1% grape pomace fiber were incorporated into yogurt, and the effect on physicochemical, microbial, and sensory quality was investigated. Throughout the 14-day storage period, no significant changes were observed in pH, acidity, and water holding capacity. The total mesophilic aerobic bacteria count ranged between 2-3 log.cfu/g, and the addition of fiber did not result in any undesirable alterations in these counts. Similarly, the fiber did not affect the counts of specific yogurt bacteria, which was 8-9 log.cfu/g. Moreover, sensory evaluations consistently resulted in scores above "5" for all products, with acidity rated level as moderate as expected for yogurt. There were no adverse effects on sensory quality concerning color, flavor, texture, acidity, and overall acceptability. In conclusion, fiber-enriched yogurt from wine waste is feasible without compromising product quality. This study is expected to contribute to the progress of current sustainable living goals.

1. Introduction

In the food industry, large amounts of food waste, referred to as by-products, are generated as a result of processing. Many of these wastes are either not utilized, leading to significant environmental pollution, or they are used as low-value by-products such as animal feed, fertilizer, etc., using simple technologies. . The effective utilization of waste generated during food processing is important for sustainability with reference to the Sustainable Development Goals (SDGs) set by the United Nations. The evaluations are not only for preventing environmental pollution but also for introducing the by-products to new generation healthy products. Many food industry wastes contain essential nutrients, dietary fibers, and other functional ingredients [1].

Dietary fiber is a crucial food ingredient to maintain digestive health, regulate cholesterol levels, and control blood sugar. Vegetables, fruits, legumes, and grains are sources of dietary fiber. For a healthy life, a total of 25-30 g of fiber is recommended daily. However, with the increasing consumption of fast food in modern diets, the intake of fiber-rich foods has declined, probably to 15 g daily intake, leading to various health issues [2]. Therefore, it is essential to incorporate dietary fibers into our diets through various food sources to promote overall health and well-being.

Yogurt is consumed worldwide and is particularly popular in countries like Turkey, Greece, Bulgaria, Lebanon, and India [3]. It is valued for its various health benefits, including being a rich source of protein, calcium, vitamins, and probiotics. Regular consumption of yogurt is associated with improved digestion and gut

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health due to its probiotic content. Additionally, it is rich in calcium, protein, B vitamins, and other essential nutrients, offering benefits ranging from bone health to muscle development. Its high protein content can increase satiety and aid in weight management. Being fiber-rich, yogurt supports digestive health and regulates bowel movements [4].

In recent years, the significance of dietary fibers in by-product-fruit pomaces has been recognized, so, researchers gained an increasing interest towards valorization of this by-product. , A study on cranberry pomace in yogurt production was reported to enhance the dietary fiber and antioxidant contents of yogurt, affecting rheological characteristics differently depending on addition before or after fermentation and maintaining the viable lactic acid bacteria count [5].

In another research, the use of 1% and 3% wheat bran adversely affected the flavor of yogurt and caused water release while increasing the total mineral content [6]. A study investigated the impact of enriching yogurt with various dietary fibers (inulin, pea, oat, and wheat) on its rheological, physicochemical, and sensory properties, significant effects on viscosity, syneresis, and sensory acceptance, indicating the potential for incorporating fibers into yogurt to enhance its nutritional profile and create functional food products with diverse health benefits [7].

In accordance with the sustainability and healthier food production goals, this study aimed to investigate the potential utilization of grape pomace in yogurt. In this context, the effect of grape pomace on the physicochemical, textural, sensory, and microbiological properties of yogurt was investigated during a 14-day storage period.

2. Materials and Methods

2.1. Preparation of grape pomace fiber

The pomace was obtained from grape must lees from a wine plant in Tekirdag. The pomace was boiled for 25 min in a 1% citric acid solution with a 1:1 (w:v) ratio and then filtered. Consequently, it was concentrated to 24°B using 600 ppm sulfur dioxide. Pectin was precipitated with pure alcohol, dried under vacuum at 40°C, and ground to obtain the grape pomace fiber. The total dietary fiber content of the grape pomace fiber obtained was determined to be 66.5±1.1%.

2.2. Preparation of yogurt samples

First, set-type yogurt production was carried out using raw milk. The chemical composition of yogurt was analyzed using Milkana Express Plus milk analyzer (Mayasan Biotech, Turkey) as 13.6% total solids, 3.6% protein, 4.0% fat, and 4.8% lactose. Milk was pasteurized at 90°C for 10 min. Then, the milk was rapidly cooled to 43°C and inoculated at a ratio of 1:10000 (w:v) with YC-X16 yogurt culture (CHR Hansen, Denmark) containing strains of *Lactobacillus delbrueckii subsp. bulgaricus* (*L. bulgaricus*) and *Streptococcus thermophilus* (*S. thermophilus*). The mixture was incubated at 43°C until a pH of 4.6. The obtained set-yogurt was divided into batches for the addition of other powdered ingredients.

The amount of fiber added to the yogurt was determined through preliminary sensory tests. During trials, it was determined that grape pomace fiber negatively affected the yogurt's sensory properties, so the freeze-dried cherry powder was added to the products at a rate of 2% to mask the off-flavor. In summary, the composition of the resulting fiber-enriched yogurts consisted of 10% sugar, 2% cherry powder, and either 0.5% or 1% grape pomace fiber, depending on the product type. Plain yogurt without powdered additives was referred to as the "control" and coded as "C" in the study. Products containing 0.5% and 1% fiber were labeled "05GF" and "1GF," respectively. All productions were carried out in duplicate.

2.3. Physicochemical analyses

The total solids (TS), titratable acidity in terms of lactic acid (LA), protein, fat, and ash contents were carried out according to AOAC [8] standards. The pH of yogurt was measured at 25°C with a Mettler Toledo Seven Compact S220 pH meter (Switzerland). The water holding capacity (WHC) was determined according to the method described by Silva and O’Mahony [9] with slight modifications: Yogurt samples (5 g) were centrifuged at 5000 rpm for 15 min at 4°C, and the serum phase was weighed. The WHC was calculated as the percentage of total yogurt weight.

2.4. Microbiological analyses

The total mesophilic aerobic bacteria (TMAB) counts were determined by counting the colonies obtained by the spreading on Plate Count Agar and incubation at 25°C for 2 days. The total count of yeasts and molds were enumerated on oxytetracycline glucose yeast extract (OGYE) agar at 25°C for 5-7 days of incubation. For the enumeration of yogurt bacteria, the pour-plate method was applied using de Man, Rogosa, and Sharpe (MRS) agar and M17 agar for inoculations. The incubation parameters were 37°C and 43°C, respectively, for 3 days [10].

2.5. Determination of sensory quality

Sensory tests were carried out with the approval of Sakarya University Ethical Committee on 10 pretrained panel members aged 18-50, both males and females, from Sakarya University. Color, texture, flavor, acidity, and overall acceptability were evaluated using a 9-point Hedonic rating scale, where 9 = like extremely and 1 = dislike extremely [11].

2.6. Statistical analysis

The compositional analyses were conducted in the 1st week of storage. The remaining measurements were performed in triplicate on storage days 1, 7, and 14. The collected data were evaluated using one-way analysis of variance (ANOVA) followed by Tukey's multiple range test in Minitab software (ver.16, USA). Statistical significance was determined at a *P*-value of less than 0.05.

3. Results and Discussion

3.1. The physicochemical properties of yogurt samples

The compositional properties of yogurt samples are given in Table 1.

Table 1. The compositional properties of yogurts

	TS %	Protein %	Fat %	Ash %
C	20.8 ±0.3 C	3.57 ±0.1 A	3.72 ±0.1 B	0.71 ±0.0 C
05GF	23.9 ±0.1 B	3.09 ±0.1 B	3.96 ±0.0 A	0.84 ±0.0 B
1GF	24.8 ±0.0 A	3.05 ±0.1 B	4.02 ±0.0 A	0.87 ±0.0 A

The capital letters in the same column indicate the difference between the samples ($P<0.05$)

The increased fiber content significantly affected the TS content yogurt. In plain yogurt (C), TS was measured as 20.8%, while in 1GF as 24.8%. In contrast, the protein content in yogurt significantly decreased with the addition of fiber, whereas the fat content increased. Similar to the TS, the ash content revealed a significant increase proportional to the increased fiber content. The pH, acidity, and WHC measurements of yogurts are given in Table 2.

Table 2. The physicochemical properties of yogurts

Day	C	05GF	1GF
	pH		
1	4.18 ±0.03 Aa	4.08 ±0.07 Aa	4.05 ±0.13 Aa
7	4.11 ±0.06 Aa	3.99 ±0.15 Aa	3.96 ±0.11 Aa
14	4.04 ±0.08 Aa	3.98 ±0.13 Aa	3.96 ±0.12 Aa
	LA %		
1	0.952 ±0.02 Aa	0.959 ±0.03 Aa	0.945 ±0.04 Aa
7	0.963 ±0.01 Aa	1.030 ±0.01 Aa	0.987 ±0.03 Aa
14	0.985 ±0.02 Aa	1.071 ±0.01 Aa	1.069 ±0.06 Aa
	WHC %		
1	55.4 ±0.2 Cb	64.9 ±0.0 Aa	62.8 ±0.8 Ba
7	60.7 ±0.2 Aa	65.3 ±2.8 Aa	64.9 ±0.5 Aa
14	60.1 ±1.1 Aa	63.6 ±1.7 Aa	62.0 ±1.1 Aa

The differences between samples within the same row is indicated by uppercase letters, and the differences between storage days within the same column is indicated by lowercase letters. ($P<0.05$).

The pH values ranged from 3.96 to 4.18, showing no significant variations between samples and no changes during the 14-d-storage period. Similarly, the acidity levels varied between 0.945% and 1.071% but were not affected by product differences or storage duration. The water holding capacity (WHC) was initially lowest in the control sample on the first day of storage, likely because the hydrogen bonds in the yogurt had not fully formed yet. Subsequently, on days 7 and 14, WHC remained consistent at 60.1% to 65.3%, regardless of storage duration or product type.

A study on yogurt enrichment with 1% pea fiber revealed, consistent with our findings that the titratable acidity was not affected by the addition of fiber [12]. In a study on fiber-enriched yogurt production, similar to our results, the pH and water-binding properties of the products remained unchanged during the 21-day storage period [13]. In another study, it was observed that adding rice bran as a fiber supplement to yogurt before fermentation resulted in better texture stabilization effects. At the same time, when added after fermentation, it was determined that it could lead to a destabilization [14].

3.2. Microbiological properties of yogurt samples

The total bacterial count in yogurts is significant as it directly reflects the product's quality, safety, and shelf life. The TMAB counts of yogurt samples are given in Figure 1. During the storage period, the TMAB counts in all samples remained below the microbial risk factor of 5 log cfu/g recommended by FAO and WHO [15]. In addition, the sample differences and the storage process did not affect these counts (*P*>0.05).

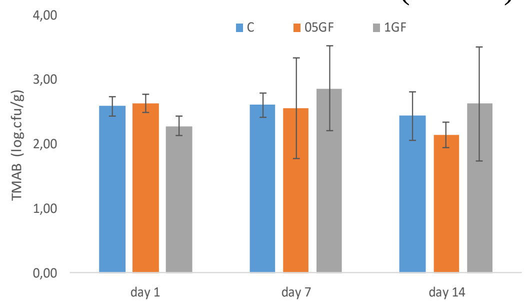

Figure 1. The TMAB counts of yogurt samples during 14-d-storage

In all samples, the total counts of yeasts and molds remained below detectable limits during the storage period.

The counts of *S. thermophilus* and *L. bulgaricus* were as illustrated in Figure 2. The counts of *S. thermophilus* ranged from 8.50 - 8.91 log cfu/g, while the counts of *L. bulgaricus* varied between 7.10 and 7.84 log cfu/g. These results are consistent with the "yogurt" values specified in the regulation [16]. In addition, no differences were observed in strain counts across products and storage durations (*P*>0.05).

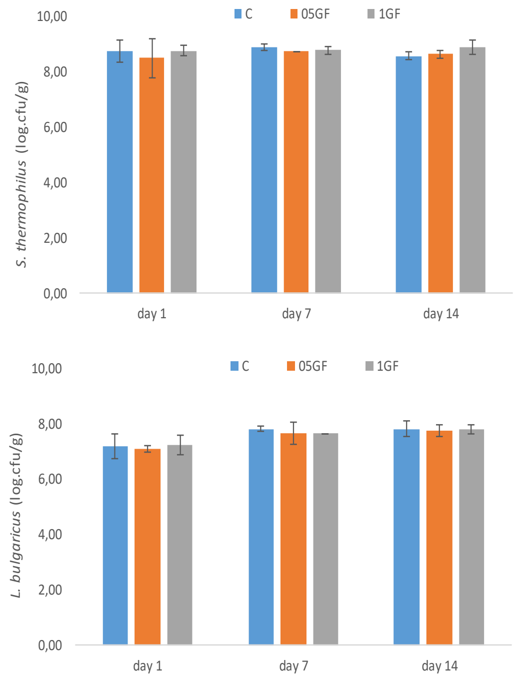

Figure 2. The specific yogurt bacteria counts of yogurt samples during 14-d-storage

Since pomace fiber can also act as a prebiotic supplement, the viability of specific lactic starter cultures could be enhanced through yogurt enrichment with fiber. For instance, in a study involving yogurt supplemented with maltodextrin and konjac fibers, lactic bacteria were reported to be supported by fiber addition [17].

3.3. Sensory properties of yogurt samples

Sensory evaluation ensures the quality and consistency of flavors, ultimately enhancing consumer satisfaction and product acceptance. The sensory properties of the products were evaluated in terms of color, texture, flavor, acidity, and overall acceptability, and the results are presented in Figure 3. To observe the differences between the obtained results, a principle component analysis (PCA) was applied, as illustrated in Figure 4.

The principle component-1 (PC1) explained 88.2 % of the results, while PC2 accounted for 6.6 %. Considering the positive and negative regions of PC1 and PC2, all results formed four distinct regions. Regarding color scores, samples C, 05GF, and 1GF were diverse and diverted into different regions, as the fiber content gave color differences. When examined in terms of texture, the control product (C) was positioned in the positive region of PC1, while the two products with added fiber showed similar results and were positioned in the negative region. In terms of acidity, all products were positioned in the negative region of PC1, while they differentiated in PC2: 05GF and 1GF products showed similar acidity results, whereas the control product (C) diverged from the fiber-added products.

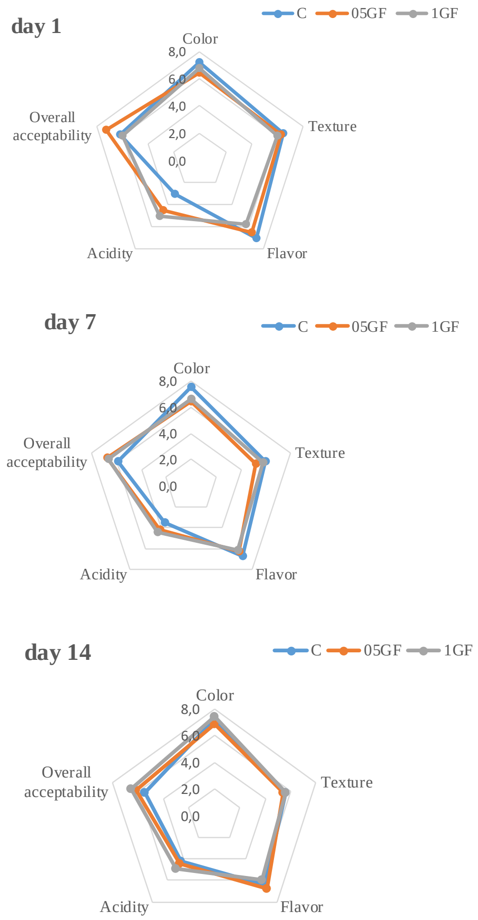

Figure 3. The sensory properties of yogurt samples on storage days 1, 7, and 14

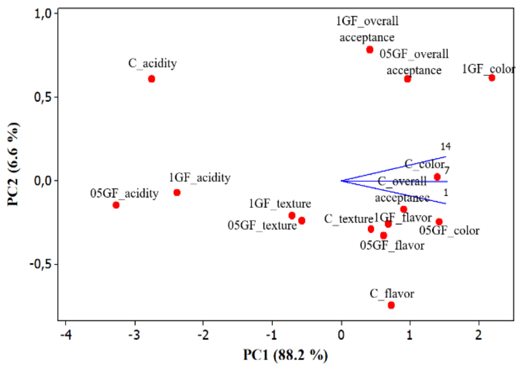

Figure 4. The principle component analysis on sensory properties of yogurt samples

When evaluated with Figure 3, it can be concluded that the addition of fiber increases acidity perception. Regarding flavor, according to PC1, all products were positioned in the same region, however according to PC2, the fiber-added products seperated from the control product. When statistically evaluated, it was determined that the difference in flavor was statistically insignificant (P>0.05). Regarding overall acceptability, fiber-added products received higher scores than the control according to Figures 3 and 4.

The addition of fiber can have varying effects on the sensory quality of yogurts, both enhancing and decreasing it. For instance, in a study, apple fiber was found unacceptable in yogurt, whereas bamboo and wheat fiber revealed acceptable sensory results [18]. In another study, it was noted that with a dietary fiber content of 4.5%, the overall acceptability decreased, while it was suggested that date fiber at a 3% level could be utilized to enhance the nutritional value of yogurt [19].

4. Conclusion

This study examined the potential use of grape pomace, a by-product of wine production, as a food component by enriching its fiber content through preprocessing. The investigation revealed that the addition of grape pomace fiber at levels of 0.5% and 1% to yogurt formulation did not negatively affect the physical and chemical properties of yogurt.

In conclusion, it was determined that the addition of grape pomace fiber to yogurt is available without any adverse effect on the product quality. It is believed that this study will have a contribution to sustainability by promoting healthy lifestyles, reducing production wastes, preserving the environment, and supporting the circular economy.

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Authors' Contribution

The authors contributed equally to the study. All authors have read and agreed to the published version of the manuscript.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval

The sensory test was carried out with the approval of the Sakarya University Ethics Committee.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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