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Preparation of "Ginger-Enriched Wine" and Study of Its Physicochemical and Organoleptic Stability

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Abstract

Wine is the world's leading alcoholic beverage, with Greece having a centuries-old history of winemaking processes. A common practice among winemakers is the addition of herbs and plants to wine, which is believed to increase its antioxidant capacity. A well-known example is retsina, produced from resin. This paper is based on the study of Roditis Alepou (Roditis Fox) and Muscat of Patras, two euphemistic grape varieties of Achaia, at different stages of maturity, with the addition of ginger to prepare ginger-enriched wine. Ginger is considered one of the most ancient plants, with its main cultivation countries being India and Malaysia. The present study included physicochemical analyses, involving total and effective acidity of the samples, antioxidant capacity, total phenolics, and pigments in the spectra of 420, 520, and 620 nm. This work aimed to study the wine prepared by these indigenous grape varieties of Achaia with added ginger at different concentrations (0.2%, 0.5%, and 1.2%, *w*/*v*) post-fermentation, and to determine if it conforms with the typical physicochemical characteristics of dry white wine. An increase in total and effective acidity of the samples was observed. Some fluctuations in total phenolics and antioxidant capacity were noted. Finally, pigments showed increased values in all three spectra. The organoleptic evaluation yielded encouraging results, leading us to conclude that the product warrants further study, with prospects for producing wine aromatized with ginger or ginger extract.

Keywords: wine; roditis alepou; muscat of patras; ginger powder; ginger extract; antioxidant capacity; total phenolics

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1. Introduction

Wine is an alcoholic beverage with a long history and many uses [1] and is primarily produced by crushing grapes and carrying out alcoholic fermentation in the juice. In the must, (i.e., the unfermented grape juice), fermentation is carried out by micro-organisms known as yeasts. In modern winemaking, these yeasts are either indigenous, i.e., yeasts naturally present in the grape, or commercial yeasts added by the winery and selected according to the properties they add to wine. The conversion of grape sugars into ethanol and carbon dioxide is either complete or partial, with the partial conversion being expressed as residual sugars in the wine. The final residual sugar content in the wine separates them into dry, semi-dry, semi-sweet, and sweet wines. The two main components of wine are water and ethanol, which account for 97% (*w*/*w*) of its content; the other compounds responsible for the taste, aroma, and color of wine are present in concentrations of less

than 10 g/L. Many volatile compounds are found in concentrations of nanograms per liter (ng/L). The chemical compounds in wine (continue to evolve for years even after bottling, so their composition may be altered) can also be found in coffee, beer, bread, spices, vegetables, cheese, and other foods [2]. There are several types of wine, which are classified according to their color and their content of sugars and carbon dioxide. The best-known types of wine are rosé, white, and red wine, while there are also modern types of white wines, such as white wines produced with skin contact, or orange wines, natural wines, oxidative white wines (oxidative white or sherry wines and natural sparkling wines or Petillant-Naturel) [3].

Classic methods of white winemaking techniques typically do not involve prolonged contact between the solid parts of the grapes and the grape must during fermentation, together with post-fermentation stages. To extract specific volatile or phenolic compounds, winemakers often use pre-fermentation maceration, a method commonly utilized for aromatic wine varieties. This technique allows for the enhanced extraction of desired compounds before the actual fermentation process. The ancient winemaking technique utilizing clay vessels known as ''qvevri'', has sparked a trend for long-macerated white wines both in Europe and beyond, known as "orange" wine [4].

Moderate consumption of red wine, defined as one to two glasses per day, has been associated with a reduction in cardiovascular mortality and a decreased risk of developing cardiovascular diseases. This protective effect is primarily attributed to the presence of polyphenolic compounds, which exhibit antioxidant and anti-inflammatory properties [5]. Furthermore, studies have shown that individuals who consume small amounts of wine, regardless of type, often follow healthier dietary patterns and generally maintain a more balanced lifestyle compared to those who consume other types of alcoholic beverages [6].

Ginger, also known as zingiber or ginger root, belongs to the family Zingiberaceae, which contains 300 species with 24 genera. It is used as a spice, beverage, and dietary supplement. There are various varieties, such as elephant ginger, emprit ginger, and red ginger, which have similar characteristics but different colors, scents, and fiber content. The consumption of ginger has increased in recent years, as it is used for detoxifying the body and treating gastroesophageal and cardiac diseases. According to research studies, ginger helps lower cholesterol and blood pressure, improves blood circulation, and suppresses thromboxane [7]. Ginger is also used as a treatment for urinary tract infections, and one of the most important properties of its extract is its analgesic effect. It is added to food either as a spice or as a dietary supplement [8]. Moreover, ginger powder is widely used both in its pure form and as a key ingredient in other powder blends. Its applications include ginger wine, ginger beer, and various baked goods. Additionally, it is utilized in the pharmaceutical industry, primarily for the production of herbal medicinal products [9].

Thus, the present study aimed to prepare wine enriched with ginger powder and ginger extract, in different proportions, and study the changes in selected physicochemical parameters and organoleptic stability. For this purpose, domestic grape varieties of the Achaia region, Roditis Alepou, and Muscat of Patras were used. To the best of our knowledge, this is the first study on Roditis Alepou and Muscat of Patras wines aromatized with ginger, and this constitutes the novelty of the present work.

2. Materials and Methods

2.1. Samples

A total of 16 wines and must samples were prepared for the study, including control samples. The experimental design involved the combination of ginger powder and ginger extracts with grape must and finished wine from two white grape varieties cultivated in Greece: Roditis Alepou (Roditis Fox in English) and Muscat of Patras (locally known

as "Moschoudi"). The control samples were from Mavrogianni Estate Winery. The must was taken fresh a week after fermentation. The Mavrogianni Estate winery produces approximately 1.5 tons of wine. Roditis Alepou is cultivated in the majority of the country's vineyard areas, with Achaia being the largest viticultural zone. It occupies approximately 95,000 hectares of the total planting area. This particular variety occurs in the Peloponnese, Central Greece, Thessaly, Epirus, Thrace, and the Ionian Islands. On the other hand, Muscat is produced in various versions: Muscat of Alexandria, Muscat of Tyrnavos, Muscat of Patras, Muscat of Samos, and Muscat of Spina. The vegetative period of this variety is long, and it germinates and ripens early compared to other varieties. Quality wines are produced, and it is a PDO sweet wine in many regions of Greece, such as Achaia.

Regarding the alcohol volume and residual sugars of the wine samples, these were as follows: (i) 12.5% vol. and 1.9 g/L for Roditis Alepou, respectively, and (ii) 12.5% vol. and 0.97 g/L for Muscat of Patras, respectively. Each grape variety was used to prepare samples in the following categories: (i) grape must enriched with ginger powder, (ii) wine enriched with ginger powder, and (iii) wine enriched with ginger extract. All samples were prepared in sterilized bottles of 1 L and stored under identical conditions (temperature of 24 $\pm$ 1 °C and apart from light) throughout the experimental period. All analyses in samples were repeated in triplicate (n = 3). The total polyphenolic content (TPC) was measured twice, with a difference of one week between the measurements (TC1, TC2).

2.2. Preparation of Wine Samples

2.2.1. Preparation of Ginger Extracts in Ethanol

An ethanolic extract of ginger powder with viticultural ethanol was prepared by adding 50 mL of ethanol to a glass beaker, followed by the addition of 5 g of ginger powder (Sun spices, Agiou Ioanni Renti, Athens, Greece). The mixture was stirred until complete homogenization was achieved. The beaker was then covered with aluminum foil to prevent light exposure and stored in a dark place at ambient temperature for a short period to allow extraction.

2.2.2. Filtration of the Ethanol Extract

The crude extract was filtered using a standard gravity filtration setup, consisting of a conical flask, a glass funnel, and qualitative filter paper. The filtrate was collected in Falcon tubes (Sarstedt, Nümbrecht, Germany) and stored at room temperature.

2.2.3. Ginger Powder Extraction in Grape Must

To examine the effect of ginger powder in must, three concentrations (0.2%, 0.5%, and 1.2%, *w*/*v*) were weighed into separate bottles of 1 L. Each concentration was prepared in duplicate using must from two different grape varieties. The must was poured directly from the fermentation tank into the bottles, and one bottle per grape variety served as the control sample. The samples were vigorously shaken by hand to ensure uniform dispersion of the powder and stored under identical conditions.

2.2.4. Filtration of Ginger Must

The ginger must samples were filtered to remove residual solid particles. The contents were transferred into conical flasks equipped with glass funnels and filter paper. The filtered must was collected in clean bottles of 1 L. Air was expelled, compressing the bottle walls before sealing (Ferrero, N Matricola Anno di costruzione, Italy). This procedure was applied consistently across all must samples.

2.2.5. Ginger Powder Extraction in Wine

The extraction procedure was repeated using dry white wine derived from the same grape varieties. Ginger powder (0.2%, 0.5%, and 1.2%, w/v) was weighed into sterile beakers and transferred into 1 L bottles. Wine was added directly from the storage tank, with one bottle per grape variety, and without ginger (0%), serving as the control sample. All samples were vortexed to ensure homogeneity and stored at room temperature.

2.2.6. Filtration of Ginger-Enriched Wine

Each wine sample was filtered using the same gravity filtration method described above to remove undissolved ginger particles. The filtrates were transferred to clean bottles of 1 L and sealed after removing residual air.

2.2.7. Wine Distillation

To obtain ethanol from the wine samples, 200 mL of wine was measured using a 250 mL graduated cylinder and transferred into a boiling flask. Distillation was performed using a simple distillation setup, with a beaker serving as the receiving vessel. The distillation continued until 500 mL of distillate was collected. The procedure was repeated as necessary to reach the target volume.

2.2.8. Ginger Powder Extraction in Viticultural Ethanol

Ethanol derived from wine distillation was used for further extraction. Ginger powder was weighed into separate beakers as above. Each sample received 50 mL of viticultural ethanol. The beakers were covered with aluminum foil and stirred on a magnetic stirrer (LMS-1003, Daihan Labtech Co. LTD, Batam City, Indonesia) until complete dissolution.

2.2.9. Filtration and Application of Ginger Extracts

Each extract was filtered using a syringe and a disposable membrane filter. Aliquots of 10 mL were filtered per cycle into clean beakers until the full volume of extract had been clarified. The resulting filtrates were immediately added to their corresponding wine samples and mixed before storage.

2.3. Preparation of DPPH· Standard Solution

To prepare the standard DPPH. (2,2-diphenyl-1-picrylhydrazyl) solution, 0.0051 g of DPPH. (TCI, Tokyo, Japan) was dissolved in 100 mL of absolute ethanol under continuous stirring, to obtain a final concentration of 1.29×10^{-4} M. The solution was placed in a volumetric flask and wrapped with aluminum foil to avoid any photooxidation. It was left in the refrigerator for 2 h to stabilize before being used for the rest of the experiments.

Determination of In Vitro Antioxidant Activity

The antioxidant activity of the prepared samples was determined using the method of Intzirtzi et al. [10]. More specifically, in a cuvette, 1 mL of acetate buffer ($CH_3COONa \times 3H_2O$, 0.1 M) (Unichem Laboratories Ltd., Mumbai, India) was added, followed by 100 µL of each prepared sample and 1.9 mL of DPPH. solution. The absorbance was measured at λ = 517 nm every 30 min, using a Shimadzu Ultraviolet-Visible (UV/VIS) spectrophotometer (UV-1280, Kyoto, Japan), until the reaction reached a plateau. The antioxidant activity was calculated using the following equation:

$$AA\% = (A_0 - A_t)/(A_0) \times 100 \quad (1)$$

where A_0 is the initial absorbance of the DPPH. solution, and A_t is the absorbance of the remaining DPPH after reaction with the antioxidants. Each sample was analyzed in triplicate (n = 3).

2.4. Determination of Total Acidity and Effective Acidity (pH)

The determination of total acidity was achieved with titration with sodium hydroxide (NaOH, 0.1 N) (Lach-Ner, Zagreb, Croatia) according to the official AOAC 962.12 method, with slight modifications [11]. Briefly, in a conical flask, 10 mL of each sample was transferred and slightly heated to remove CO_2. Then, 8 mL of distilled water was added, followed by 4–5 drops of phenolphthalein ($C_{20}H_{14}O_4$) indicator (Merck, Darmstadt, Germany), and the final solution was titrated to an endpoint pink (pH = 8.2). The total acidity was expressed as g/L of tartaric acid, considering that at the endpoint, 1 mL of NaOH 0.1 N corresponds to 7.5 mg of tartaric acid. Each sample was analyzed in triplicate (n = 3).

The pH of all the prepared samples was measured by adding 40 mL of each sample to a beaker, after direct immersion of a portable pH-meter (pHep+, HANNA Instruments, HI9808, Athens, Greece). Results were expressed as pH values at 20 °C, originating from three replicates (n = 3).

2.5. Determination of Color Parameters

The determination of color parameters was measured with the spectrophotometric method described in the study of Lazaridis et al. [12]. In a plastic cuvette, 3 mL of each sample was transferred, and the absorbance was measured at λ = 420 nm (Yellow), λ = 520 nm (Blue), and λ = 620 nm (Red). Results were expressed as absorbance values out of three replicates (n = 3).

2.6. Determination of Total Phenolic Content

The total phenolic content of the prepared samples was determined following the Folin–Ciocalteu method according to Kitsios et al. [13]. In a 5 mL volumetric flask, 2.50 mL of deionized water was added, followed by the addition of 200 μL of each sample and 250 μL of Folin–Ciocalteu reagent (Sigma-Aldrich, Darmstadt, Germany). The mixture was left in the dark for 3 min, and 0.5 mL of saturated sodium carbonate (Na_2CO_3) (RDH GmbH & Co, Seelze, Germany) 30% (*w*/*v*) was also added. Finally, deionized water was transferred until it reached a final volume of 5 mL. The solution was left in the dark for 2 h at room temperature. The absorbance was measured at λ = 760 nm, using the spectrophotometer mentioned previously. The results were expressed as mg of gallic acid equivalents per liter (mg GAE/L) based on the following calibration curve:

$$y = 0.0047x + 0.1732;\ R^2 = 0.9925 \quad (2)$$

Each sample was analyzed in triplicate (n = 3).

2.7. Sensory Analysis

For the sensory analysis, a series of grape must and wine samples enriched with ginger were prepared: ginger powder and ethanolic extract, using different concentrations (2 g/L, 5 g/L, and 12 g/L). Control samples without added ginger were also included in the analysis. A sensory evaluation was subsequently carried out to assess the impact of ginger addition on key sensory parameters. A total of 17 voluntary participants (untrained panelists) evaluated the samples using a structured five-point scale according to a descriptive sensory analysis test [14]. The panel consisted of individuals across a range of age groups (18–55 years old), who were asked to evaluate aroma, taste, color, acidity, and perceived ginger intensity. Participants also responded to questions regarding overall

product acceptability, willingness to consume it again, and whether knowledge of potential health benefits would influence their consumption behavior. All evaluations were conducted under consistent conditions, and panelists provided their informed consent before participation. In all stages of the sensory analyses, the complete anonymity of participants was assured. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Patras (protocol code 17538/10-11-2025, 10 November 2025).

2.8. Statistical Analysis

The data were analyzed using one-way analysis of variance (ANOVA) to identify statistically significant ($p < 0.05$) differences among the control and the prepared wine/must samples and the measured parameters. Tukey's honestly significant difference (HSD) test was also used to indicate the level of significance between pairs of treatments (i.e., different added ginger concentrations in must or wine). This analysis was performed for all three formulated samples: (a) must enriched with ginger powder, (b) wine enriched with ginger powder, and (c) wine enriched with ginger extract. Statistical processing was conducted using the IBM SPSS Statistics software (version 28, IBM Corp., Armonk, NY, USA, 2021).

3. Results

3.1. Physicochemical Parameters

Table 1 represents the results of Muscat of Patras must enriched with ginger powder at various concentrations [0% (control), 0.2%, 0.5%, and 1.2%, w/v]. The pH values showed statistically significant ($p < 0.05$) differences among treatments. In contrast, the total acidity did not exhibit any statistically significant ($p > 0.05$) differences. In the case of antioxidants, the antioxidant activity demonstrated statistically significant ($p < 0.05$) differences among the samples studied. The pigment measurements at the wavelengths 420 nm and 620 nm also revealed statistically significant ($p < 0.05$) differences, while at 520 nm, no statistically significant ($p > 0.05$) differences were observed. The total phenolic content, measured, did not show any statistically significant ($p > 0.05$) differences. Furthermore, the must with a concentration of 1.2% (w/v) of added ginger, exhibited a 0.1 unit increase in pH compared to the must without ginger addition (control sample). According to Table 1, antioxidant activity increased by 9.61 units in the concentration of 1.2% (w/v) of added ginger compared to the control (0%, w/v). Color analysis revealed differences at 420 nm and 620 nm for the concentration of 0.2% (w/v) of added ginger.

Table 1. Physicochemical parameters of different grapes must enriched with ginger powder.

Must	Ginger Powder Concentration	pH	Acidity (g/L)	AA (%)	A420	A520	A620	TPC1 (mg GAE/L)	TPC2 (mg GAE/L)
Muscat of Patras	0%	3.58 ± 0.01^{a}	5.3 ± 0.0^{a}	65 ± 0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.2^{a}	0.2 ± 0.0^{a}	16 ± 16^{a}	61 ± 63^{a}
Muscat of Patras	0.2%	3.61 ± 0.01^{b}	5.0 ± 0.1^{a}	76 ± 0^{b}	0.6 ± 0.0^{b}	0.4 ± 0.0^{a}	0.4 ± 0.0^{b}	23 ± 25^{a}	70 ± 24^{a}
Muscat of Patras	0.5%	3.63 ± 0.01^{c}	5.0 ± 0.5^{a}	75 ± 0^{c}	0.3 ± 0.0^{c}	0.3 ± 0.2^{a}	0.2 ± 0.1^{a}	25 ± 8^{a}	162 ± 38^{a}
Muscat of Patras	1.2%	3.68 ± 0.01^{d}	4.9 ± 0.1^{a}	75 ± 0^{d}	0.4 ± 0.0^{a}	0.2 ± 0.0^{a}	0.2 ± 0.0^{a}	54 ± 33^{a}	96 ± 61^{a}
Roditis Alepou	0%	3.80 ± 0.01^{a}	4.2 ± 0.1^{a}	80 ± 0^{a}	0.4 ± 0.0^{a}	0.3 ± 0.0^{a}	0.2 ± 0.0^{a}	0 ± 0^{a}	0 ± 0^{a}
Roditis Alepou	0.2%	3.82 ± 0.01^{b}	4.3 ± 0.1^{a}	80 ± 0^{b}	0.5 ± 0.0^{b}	0.4 ± 0.0^{b}	0.4 ± 0.0^{b}	0 ± 0^{a}	0 ± 0^{a}
Roditis Alepou	0.5%	3.84 ± 0.01^{c}	4.2 ± 0.0^{a}	82 ± 0^{c}	0.2 ± 0.0^{c}	0.1 ± 0.0^{c}	0.1 ± 0.0^{c}	0 ± 0^{a}	3 ± 6^{a}
Roditis Alepou	1.2%	3.89 ± 0.01^{d}	4.2 ± 0.1^{a}	56 ± 0^{d}	0.3 ± 0.0^{d}	0.1 ± 0.0^{c}	0.1 ± 0.0^{c}	26 ± 15^{b}	10 ± 9^{a}

Different letters in each row indicate statistically significant ($p < 0.05$) differences according to Tukey's honestly significant difference (HSD) test. AA: antioxidant activity. TPC1: total phenolic content after one week. TPC2: total phenolic content after two weeks.

Table 1 presents the results of Roditis Alepou must enriched with ginger powder at the various concentrations reported previously. Statistically significant ($p < 0.05$) differences were observed in the pH values of the samples. In contrast, total acidity did not show statistically significant ($p > 0.05$) differences. The antioxidant activity exhibited statistically

significant ($p < 0.05$) differences, as did the color absorbance at 420 nm, 520 nm, and 620 nm. Regarding total phenolic content, statistically significant ($p < 0.05$) differences were observed in the first replicate (TC1), whereas no significant ($p > 0.05$) differences were found in the second replicate (TC2) across the different concentrations. More specifically, Table 1 shows a 0.08 unit increase in pH at the 1.2% (w/v) of added ginger concentration compared to the control samples. The antioxidant activity decreased in the concentration of 1.2% (w/v) added ginger compared to the other concentrations. Table 1 indicates variations in color intensity across all four concentrations. Additionally, results show the presence of phenolics or any other reducing substances only in the concentration of 1.2% (w/v) of added ginger powder.

Table 2 presents the results of Muscat of Patras wine enriched with ginger powder at different concentrations. The pH and total acidity values showed no statistically significant ($p > 0.05$) differences across the treatments. Similarly, the antioxidant activity did not exhibit statistically significant ($p > 0.05$) differences among the different ginger concentrations. Regarding the color intensity, no significant ($p > 0.05$) differences were observed at 420 nm, whereas at 520 nm and 620 nm statistically significant ($p < 0.05$) differences were recorded. As for the total phenolic content, no statistically significant ($p > 0.05$) differences were recorded.

Table 2. Physicochemical parameters of different wines enriched with ginger powder.

Wine	Ginger Powder Concentration	pH	Acidity (g/L)	AA (%)	A420	A520	A620	TPC1 (mg GAE/L)	TPC2 (mg GAE/L)
Muscat of Patras	0%	3.76 ± 0.05^{a}	6.3 ± 0.1^{a}	52 ± 0^{a}	0.3 ± 0.4^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	215 ± 36^{a}	265 ± 40^{a}
Muscat of Patras	0.2%	3.83 ± 0.04^{a}	6.5 ± 0.0^{a}	49 ± 4^{a}	0.1 ± 0.0^{a}	0.0 ± 0.0^{b}	0.0 ± 0.0^{a}	262 ± 43^{a}	257 ± 50^{a}
Muscat of Patras	0.5%	3.83 ± 0.01^{a}	6.5 ± 0.0^{a}	51 ± 1^{a}	0.1 ± 0.0^{a}	0.0 ± 0.0^{c}	0.0 ± 0.0^{b}	221 ± 41^{a}	247 ± 65^{a}
Muscat of Patras	1.2%	3.86 ± 0.05^{a}	6.3 ± 0.3^{a}	48 ± 1^{a}	0.2 ± 0.0^{a}	0.0 ± 0.0^{d}	0.0 ± 0.0^{a}	282 ± 19^{a}	223 ± 21^{a}
Roditis Alepou	0%	3.99 ± 0.00^{a}	6.0 ± 0.0^{a}	52 ± 5^{a}	0.1 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	158 ± 10^{a}	141 ± 10^{a}
Roditis Alepou	0.2%	4.01 ± 0.00^{b}	6.5 ± 0.0^{b}	51 ± 3^{a}	0.1 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	108 ± 10^{b}	95 ± 24^{b}
Roditis Alepou	0.5%	4.03 ± 0.00^{c}	6.4 ± 0.1^{b}	52 ± 5^{a}	0.2 ± 0.0^{b}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	113 ± 17^{b}	118 ± 11^{b}
Roditis Alepou	1.2%	4.09 ± 0.00^{d}	6.5 ± 0.1^{b}	45 ± 2^{a}	0.2 ± 0.0^{c}	0.1 ± 0.0^{b}	0.0 ± 0.0^{a}	83 ± 8^{c}	90 ± 7^{b}

Different letters in each row indicate statistically significant ($p < 0.05$) differences according to Tukey's honestly significant difference (HSD) test. AA: antioxidant activity. TPC1: total phenolic content after one week. TPC2: total phenolic content after two weeks.

Table 2 also presents the results of Roditis Alepou wine enriched with ginger powder at the different concentrations mentioned previously. According to the data, statistically significant ($p < 0.05$) differences were observed in the pH values. The total acidity also showed statistically significant ($p < 0.05$) differences among the samples, as did the color absorbance values at 420 nm and 520 nm. However, no statistically significant differences ($p > 0.05$) were recorded at 620 nm. Furthermore, the total phenolic content showed statistically significant ($p < 0.05$) differences in both experimental replicates (TC1 and TC2). More specifically, Table 2 indicates a 0.1 unit increase in the pH at the concentration of 1.2% (w/v) of added ginger powder compared to the control samples. The total acidity increased by 0.5 units at the concentration of 1.2% (w/v) of added ginger powder, relatively close to the control samples. Finally, the absorbance at 420 nm and 520 nm was increased at the concentration of 1.2% (w/v) of added ginger powder, while interestingly, the total phenolic content was higher in the control samples.

Table 3 presents the data for Muscat of Patras wine enriched with ginger extract at different concentrations (0%, 0.2%, 0.5%, and 1.2%, w/v). Based on the results, pH exhibited statistically significant ($p < 0.05$) differences among the different concentrations of ginger extract. Similarly, total acidity and antioxidant activity also showed statistically significant ($p < 0.05$) differences. In contrast, no statistically significant ($p > 0.05$) differences were observed in color intensity at 420 nm, whereas significant ($p < 0.05$) differences were recorded at 520 nm and 620 nm. Regarding total phenolic content, both experimental

repetitions (TC1 and TC2) demonstrated statistically significant ($p < 0.05$) differences. More specifically, Table 3 shows that pH increased by 1.5 units at the concentration of 1.2% (w/v) of added ginger extract compared to the control (0%, w/v). Total acidity was increased by 0.45 units at the concentration of 1.2% (w/v) of added ginger extract relative to the control sample (0%, w/v). Antioxidant activity differed noticeably at the 0.5% (w/v) concentration of added ginger extract. Moreover, Table 3 shows that the absorbance values at 520 nm and 620 nm increased at the concentration of 1.2% (w/v) of added ginger extract compared to the other samples. Lastly, Table 3 indicates that the control wine samples (0%, w/v) exhibited the highest concentration of total phenolic compounds.

Table 3. Physicochemical parameters of different wines enriched with ginger extract.

Wine	Ginger Extract Concentration	pH	Acidity (g/L)	AA (%)	A420	A520	A620	TPC1 (mg GAE/L)	TPC2 (mg GAE/L)
Muscat of Patras	0%	3.76 ± 0.05^{a}	6.3 ± 0.1^{a}	52 ± 0^{a}	0.3 ± 0.4^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	215 ± 36^{a}	265 ± 40^{a}
Muscat of Patras	0.2%	3.95 ± 0.06^{b}	6.4 ± 0.1^{a}	48 ± 1^{b}	0.1 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	127 ± 15^{b}	126 ± 22^{b}
Muscat of Patras	0.5%	4.01 ± 0.01^{b}	6.4 ± 0.2^{a}	47 ± 3^{b}	0.2 ± 0.0^{a}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	162 ± 17^{b}	172 ± 5^{b}
Muscat of Patras	1.2%	4.00 ± 0.01^{b}	6.8 ± 0.1^{b}	50 ± 1^{b}	0.3 ± 0.0^{a}	0.1 ± 0.1^{b}	0.1 ± 0.0^{b}	143 ± 19^{b}	176 ± 1^{b}
Roditis Alepou	0%	3.99 ± 0.00^{a}	6.0 ± 0.0^{a}	52 ± 5^{a}	0.1 ± 0.0^{a}	0.2 ± 0.1^{a}	0.0 ± 0.0^{a}	161 ± 14^{a}	152 ± 27^{a}
Roditis Alepou	0.2%	3.93 ± 0.02^{b}	5.8 ± 0.2^{a}	47 ± 3^{a}	0.2 ± 0.0^{b}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	109 ± 3^{b}	137 ± 8^{a}
Roditis Alepou	0.5%	3.97 ± 0.02^{b}	6.1 ± 0.2^{a}	48 ± 3^{a}	0.2 ± 0.0^{b}	0.3 ± 0.2^{b}	0.03 ± 0.03^{a}	111 ± 10^{b}	141 ± 34^{a}
Roditis Alepou	1.2%	3.96 ± 0.00^{b}	6.0 ± 0.1^{a}	49 ± 1^{a}	0.2 ± 0.0^{b}	0.1 ± 0.0^{b}	0.03 ± 0.03^{a}	135 ± 35^{ab}	149 ± 38^{a}

Different letters in each row indicate statistically significant ($p < 0.05$) differences according to Tukey's honestly significant difference (HSD) test. AA: antioxidant activity. TPC1: total phenolic content after one week. TPC2: total phenolic content after two weeks.

Furthermore, Table 3 represents the results of Roditis Alepou wine enriched with different concentrations of ginger extracts. According to the results, pH exhibited statistically significant ($p < 0.05$) differences among the different ginger extract concentrations. In contrast, the total acidity and the antioxidant activity values did not show any statistically significant ($p > 0.05$) differences. As for the color intensity, statistically significant ($p < 0.05$) differences were observed at 420 nm and 520 nm, whereas no significant ($p > 0.05$) differences were found at 620 nm. Regarding the total phenolic content, statistically significant ($p < 0.05$) differences were found in the first measurement, while no significant ($p > 0.05$) differences were observed in the second measurement, conducted one week later. More specifically, Table 3 indicates a clear pH difference between the control (0%, w/v) and the 1.2% (w/v) concentration of the added ginger extract. Color absorbance at 420 nm and 520 nm increased at the concentration of 0.5% (w/v) of added ginger extract, compared to the other concentrations. Lastly, Table 3 shows a decrease in the total phenolic content in the control samples.

3.2. Sensory Parameters

Figure 1 illustrates the results of the sensory evaluation of Roditis Alepou wine samples enriched with ginger powder at four concentrations [0% (control), 0.2%, 0.5%, and 1.2%, w/v], assessed across five categories: color, aroma, taste, acidity, and ginger intensity. The addition of ginger powder imparted light brown pigments to the wine, affecting its color. Ten panelists rated the Roditis Alepou control samples with a score of 5/5, indicating it as superior in color. The Roditis Alepou samples enriched with 1.2% (w/v) of ginger powder also received a high rating, with eight panelists giving it a score of 5/5. In terms of aroma, the control samples were rated 5/5 by six panelists. The samples enriched with a concentration of 1.2% (w/v) of ginger powder received a score of 5/5 from five panelists, while the samples fortified with a concentration of 0.5% (w/v) of ginger powder received a score of 4/5 from seven panelists. Regarding taste, the control samples again received the highest score, with six panelists rating these samples with a score of 5/5. The samples enriched with a concentration of 0.2% (w/v) of ginger powder followed the order, receiving

a score of 5/5 from one panelist and 4/5 from sixteen panelists. Acidity, based on the perceived balance, was rated with a score of 5/5 by five panelists for the samples enriched with a concentration of 0.2% (*w*/*v*) of ginger powder, indicating an optimal acidity at that concentration. Ginger intensity was perceived as the strongest in the samples enriched with a concentration of 1.2% (*w*/*v*) ginger powder, with ten panelists giving it the maximum score of 5/5.

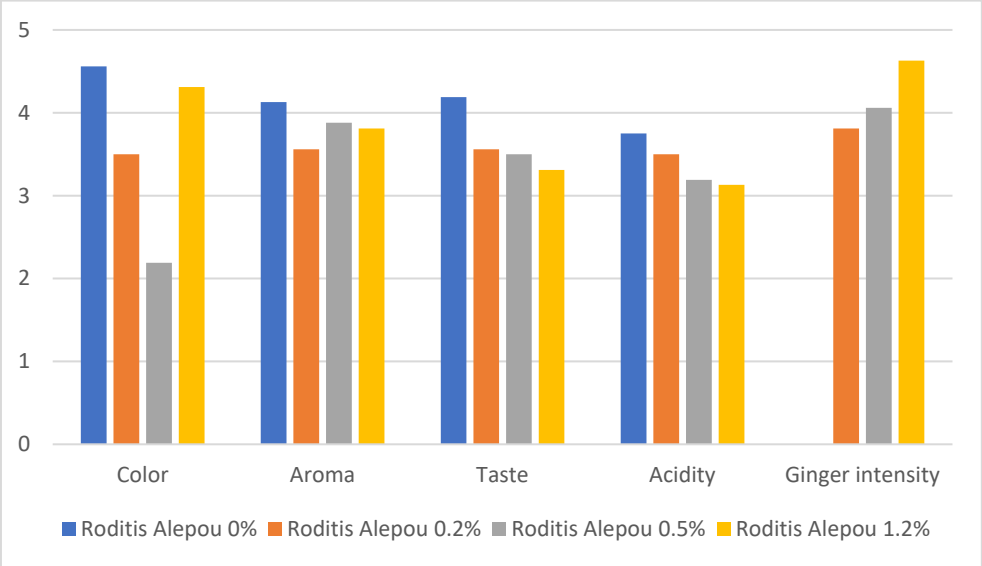


Figure 1. Sensory evaluation of Roditis Alepou wine enriched with ginger powder of different concentrations (%, *w*/*v*).

Figure 2 shows sensory responses to the same Roditis Alepou samples regarding two additional categories: overall pleasantness and willingness to consume it again. The control samples were considered the most pleasant, receiving a score of 5/5 from seven panelists and 4/5 from 10 panelists. In terms of re-consumption, the control samples received a score of 5/5 from seven panelists and 4/5 from ten panelists.

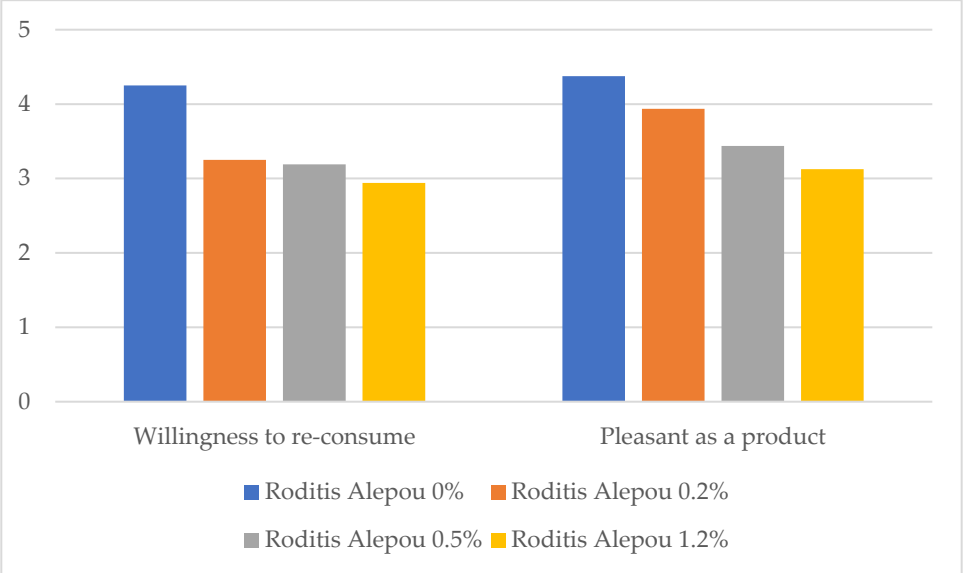


Figure 2. Perceived pleasantness and repurchase intent of Roditis Alepou wine enriched with ginger powder of different concentrations (%, *w*/*v*).

Figure 3 presents the sensory evaluation results for Muscat of Patras wine enriched with ginger powder at the same concentrations (*w*/*v*) mentioned before, assessed across the same five categories. The color was again affected by the extraction of light brown pigments. The control sample received a score of 5/5 from ten panelists, ranking it in the highest position. The samples enriched with concentrations of 0.2% and 1.2% (*w*/*v*) of ginger powder followed the order, each rated with a score of 5/5 by seven panelists. Aroma was most positively evaluated in the control samples (rated with a score of 5/5 by ten panelists), with both the samples enriched with a concentration of 0.2% and 1.2% (*w*/*v*) of ginger powder having a score of 4/5 by seven panelists. Regarding taste, nine panelists gave the control (0%, *w*/*v*) samples a score of 5/5, followed by the samples fortified with a concentration of 0.2% (*w*/*v*) of ginger, which received a score of 5/5 from eight panelists. Acidity was perceived as optimal in the control samples, with five panelists scoring it 5/5. Regarding ginger intensity, the samples enriched with a concentration of 1.2% (*w*/*v*) of ginger powder were rated 5/5 by 12 panelists, indicating the highest perceived intensity of ginger.

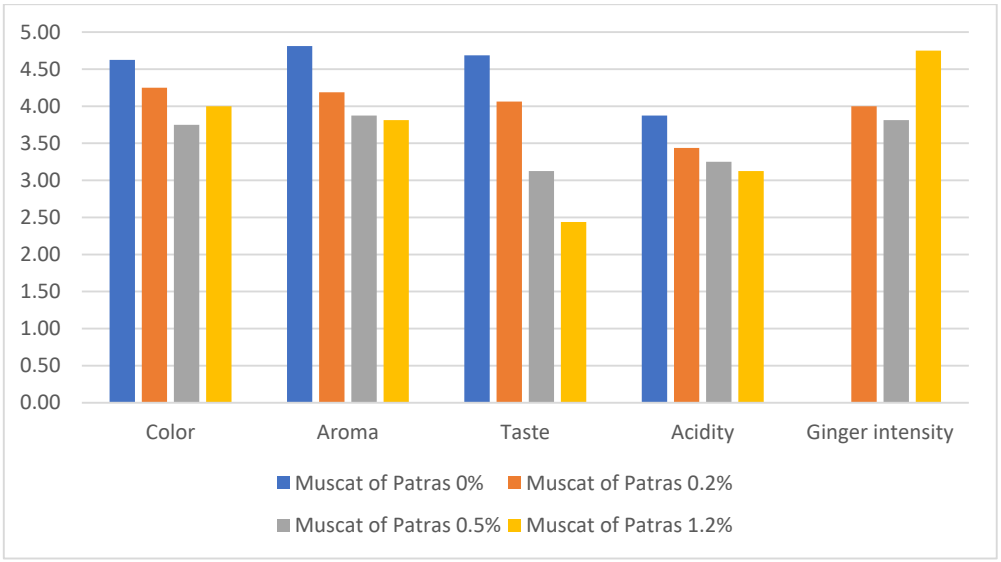


Figure 3. Sensory evaluation of Muscat wine enriched with ginger powder of different concentrations (%, *w*/*v*).

Figure 4 represents the results on pleasantness and willingness to re-consume the Muscat of Patras wine samples. The control samples were rated 5/5 by ten panelists, and 4/5 by seven panelists. Regarding re-consumption, the control samples received a score of 5/5 from 11 panelists and 4/5 from six panelists. The samples enriched with a concentration of 0.2% (*w*/*v*) of ginger powder received a score of 4/5 from 8 panelists and 5/5 from 9 panelists.

Figure 5 shows responses to the final questionnaire question: "If you knew that wine enriched with ginger offers health benefits, would you consume it?". The results revealed that 11 panelists rated their likelihood of consumption as 5/5, and 6 panelists as 4/5.

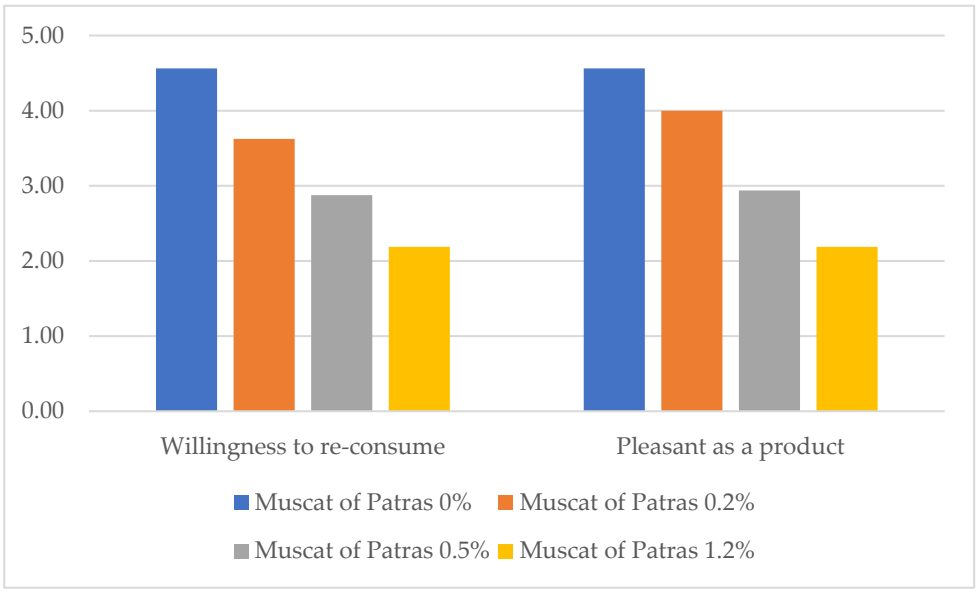


Figure 4. Perceived pleasantness and repurchase intent of Muscat wine enriched with ginger powder of different concentrations (%, w/v).

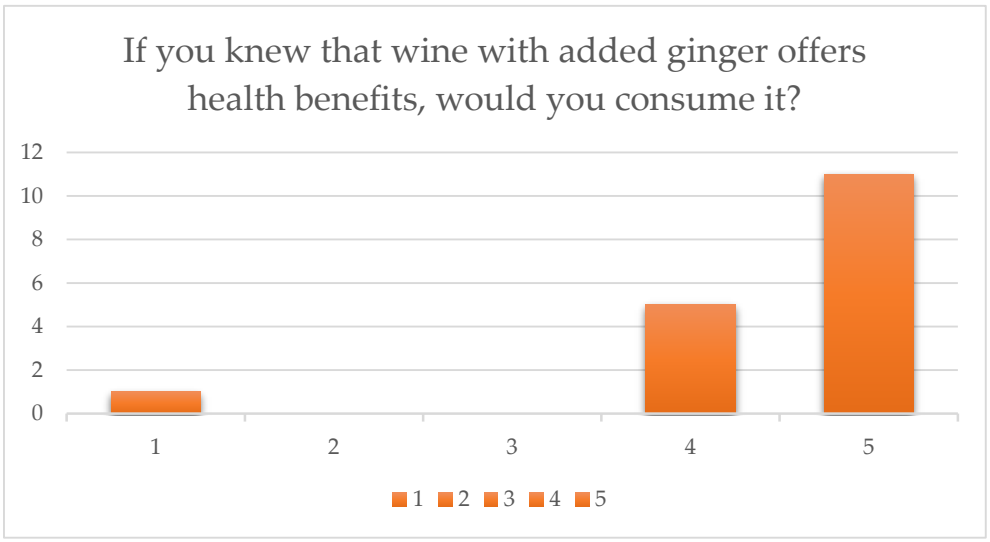


Figure 5. Impact of health benefit awareness on willingness to consume wine enriched with ginger.

Additional findings based on the questionnaire's comments:

(i) 60% of panelists felt that ginger was better suited to Muscat of Patras, while 40% preferred it in Roditis Alepou.
(ii) 70% of panelists do not consume ginger in their daily diets, while 30% do.
(iii) 80% reported that the concentration of 0.2% (w/v) of the added ginger powder in Muscat of Patras was the most pleasant combination, compared to 20% who preferred it in Roditis Alepou.
(iv) A spicy taste was noted as intense in the samples that were enriched with ginger powder at concentrations of 0.5% and 1.2% (w/v), though no significant olfactory intensity was observed in these concentrations.
(v) Panelists noted a disconnection between aroma and flavor, as the ginger aroma did not accurately predict the spicy taste.
(vi) Finally, 70% stated they would certainly consume the product if health benefits were confirmed as a health claim label (5/5), 25% answered very likely (4/5), and only 5% answered they would not consume it (1/5).

4. Discussion

In line with previous studies in the literature on enriched wine, there are reports on the importance of the addition of herbs or spices. Herbs are extracted differently in the sample depending on when they were added, whether this occurred before or after the end of alcoholic fermentation, or whether the wine was fully matured. The addition of herbs such as sage and basil to Roditis has shown that there was an increase in total phenolics and antioxidant activity [15]. Regarding the enrichment of wines with herbal extracts, the herbal species *Cannabis sativa*, *Melissa officinalis*, and *Salvia officinalis* have been shown to enrich wine varieties such as Roditis, Muscat, and Fokiano with polyphenols and other antioxidant compounds. Notably, when the herbs are added to the wine after fermentation, the level of enrichment is significantly higher. Specifically, according to previous studies, *Melissa officinalis* induced a considerable increase in phenolic content and antioxidant activity, which also contributed to the enhancement of the wine's organoleptic properties [16]. In another research, where the production of alcoholic beverage by fermentation of ginger with honey and sugar was studied, it was observed that the use of ginger can result in alcoholic beverages with similar alcoholic degree as wine (11.6%vol., 10.6%vol., and 11.8% vol.), with residual sugars (25 g/L–45 g/L) which are in the category of semi-dry and semi-sweet wines, but with high acidities (16.6 g/L and 12.5 g/L, respectively) [17]. A previous study on the production of wine incorporating ginger and honey reported relatively low acidity levels, ranging between 0.37 and 1.3 g/L. The pH values remained stable within the range of 3.5 to 4.0, which aligns with the results of the present study. Wines enriched with fruits or vegetables are generally characterized as acidic, typically presenting pH values below 6. Furthermore, sensory evaluation performed by both students and academic staff indicated that the ginger and honey wine samples were clear, without signs of turbidity or undesirable suspended particles. These findings are also in agreement with those observed in the current research. Moreover, in this study, the aroma score of the samples was higher in the enriched samples with ginger powders and was not compatible with their taste profile score. From our perspective, this is true in general, as the aroma of a food does not match exclusively with its taste, due to parameters that cannot always be detected with the aroma analysis (i.e., stiffness, bitterness, saltiness, etc.). Additionally, the taste criteria and overall acceptability can change depending on the consumer's experience. In this context, we must stress that there is scarce data in the recent literature on the addition of ginger extracts or ginger powder into must or wine for the preparation of wine aromatized with ginger. The studies discussed above show that, in general, herbs and especially ginger can increase antioxidants and total phenolics in wine samples, thus producing alcoholic products with functionality. However, in our case, total phenolic content showed some fluctuations after the addition of ginger powder and ginger extract. The addition of ginger powder in the must increased the total phenolic content after the fermentation in all treatments (Roditis Alepou and Muscat of Patras). Furthermore, the addition of ginger powder in some concentrations to Muscat of Patras wine increased the TPC. On the other hand, the addition of ginger powder to Roditis Alepou wine decreased the TPC in all concentrations compared to the control sample. Similarly, the addition of ginger extract did not increase the TPC in all wine samples. We noticed that the addition of an antioxidant food in powder form allows a better release of phenolic compounds in the mixture. This is owed to the irreversible interaction of phenolic compounds with food macromolecules, especially proteins or ethanol, resulting in covalent reactions between them, along with non-covalent interactions through electrostatic, hydrophobic, van der Waals forces, and hydrogen bonding [17,18]. Additionally, temperature, pH, and ionic strength are factors that can affect the interaction of phenolic compounds with food matrix components [17]. Polyphenols are well-known for their ability to form complexes with

proteins, leading to changes in the functional, structural, and nutritional properties of both compounds [19]. Protein-ethanol interactions can also negatively affect the phenolic extraction, causing proteins to bind, trapping phenolic compounds. This mechanism can significantly affect the extraction yield of phenolic compounds, depending on these protein-binding effects [18,20]. However, the exact mechanism of how polyphenols are influenced by proteins is still unknown, and the aforementioned parameters (pH, temperature, protein type, etc.) are investigated for their effect on the structural and functional properties [19]. Several studies have reported that the addition of spices to wine can enhance both its physicochemical properties and sensory characteristics, highlighting the potential of spices to improve overall wine quality. In line with these findings, the addition of cinnamon to red wine led to increased concentrations of esters and alcohols. During sensory evaluation, panelists perceived the wine as fruitier, with floral and sweet aroma attributes [21]. Similarly, Dordevic et al. [22] reported that the inclusion of spices in wine is commonly applied in mulled wines. Mulled wines enriched with clove exhibited higher total acidity compared to the control samples, along with increased phenolic content. This addition demonstrated improvements in both chemical composition and potential health-related properties. Another study examined wine production using dates as the main ingredient, enriched with clove, ginger, cardamom, and cinnamon [23]. In agreement with previous observations, the results demonstrated enhancements in both sensory attributes and bioactive properties. Sensory analysis of wines, such as those made of papaya, banana [24], and watermelon [25], revealed that spice addition can improve wine characteristics without compromising overall sensory acceptance [26]. Based on earlier studies involving wine enriched with ginger and raisins, it may enhance its therapeutic efficacy. Variants of raisin-ginger wine exhibit reduced alcohol content relative to commercially available wines, thereby rendering them safe for consumption and non-detrimental to health. Moreover, such wines offer multiple health-promoting benefits. Although their alcohol levels are lower than commercial wines, these still retain appreciable alcoholic strength, are acidic in nature, and range from sweet to dry in taste [27]. Mahapatra et al. [27] also reported that a high-quality enriched wine can be produced using ginger and raisin blends. Due to the preservation of essential phytochemical compounds found in both ginger and raisins, the resulting herbal wine may exhibit antibacterial activity against various pathogenic microorganisms [27]. As evidenced by prior organoleptic studies, four enriched wines containing herbal extracts (tulsi, lemongrass, mint, and ginger) demonstrated acceptable and enhanced sensory attributes. The wines received favorable ratings in terms of appearance, aroma, and taste. Fortification of wine with herbal additives may not only improve its sensory characteristics but also confer additional health benefits, thereby potentially reducing reliance on synthetic pharmaceutical agents [28]. Moreover, we should not forget that herbal wines may exhibit antimicrobial activity against food pathogens. Indeed, in a recent study [29], it was reported that ginger and aloe vera-based herbal wines showed antimicrobial activity against *Escherichia coli* and *Bacillus cereus*, whereas the enriched wines retained their proper physicochemical characteristics. Moreover, the addition of ginger extract as a biochemical preservative in "plantain" wine increased its short shelf-life and inhibited its microbial growth [30]. In general terms, the ginger powder or ginger extract should be added to the wine after the completion of the fermentation process. The effect of gingerols it contains affects yeast growth and metabolism, leading to major problems, such as slow or incomplete fermentation [31]. Considering the above, we explicitly state that the present study comprised an enrichment of must and wine with ginger or ginger extract, and not a co-fermentation process, to avoid conceptual confusion with "ginger fermentation beverages".

5. Conclusions, Limitations, and Future Perspectives

In conclusion, the results of the present study showed that the addition of ginger to wine and must resulted in statistically significant ($p < 0.05$) differences in physicochemical parameters (acidity, pH, pigments, antioxidant activity, and total phenolic content). The Roditis Alepou and Muscat of Patras wines, without the addition of ginger, showed an increased antioxidant activity and total phenolic content. The results of the samples enriched with ginger extracts, compared to the samples containing ginger powder, showed that phenolic substances and antioxidants were extracted. However, in all samples, the addition of ginger released volatile substances, according to panelists, and positively affected the color, while increasing the antioxidant activity and total phenolic content of the enriched wine. The results are encouraging for the preparation of wine-based products aromatized with ginger, with potential health benefits for consumers, featuring enhanced aroma and flavor. Future perspectives for this research include developing the product on a commercial level. In this context, additional analyses are required. For example, (i) further sensory work with a trained panel and multi-season replications are necessary to validate the observed trends, and (ii) the determination of specific aroma or phenolic compounds with potential bioactive properties, using instrumental methods of chemical analysis during consecutive harvesting years to better monitor the long-term stability data of ginger-enriched wine. Integrating spices and herbs into wine production using different extraction methods and larger-scale validation represents a promising area of study. These practices are expected to increase the levels of antioxidant and phenolic compounds in wine, enhance its aroma, giving it a more distinctive characteristic, and contribute to the promotion of consumers' health. Given that herbs and spices are associated with various health benefits, their fortification in wine opens a wide field of research, including market testing. Finally, herbs and spices have an impact on the fermentation process, providing unique combinations both in taste and aroma, which can be achieved by combining wine from different grape varieties, leading to insights for promising production strategies.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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