

Article

Influence of Yeast and Enzyme Formulation on Prosecco Wine Aroma During Storage on Lees

Jessica Anahi Samaniego Solis ¹, Giovanni Luzzini ^{1,*}, Naíssa Prévêde Bernardo ¹, Anita Boscaini ²,
Andrea Dal Cin ², Vittorio Zandonà ², Maurizio Ugliano ¹, Olga Melis ¹ and Davide Slaghenaufi ^{1,*}

¹ Department of Biotechnology, University of Verona, Via della Pieve 70, 37029 San Pietro Cariano, Italy; jessicaanahi.samaniegosolis@univr.it (J.A.S.S.); naissa.previdebernardo@univr.it (N.P.B.); maurizio.ugliano@univr.it (M.U.); olga.melis@univr.it (O.M.)

² Masi Agricola, Via Monteleone 26, 37015 Sant' Ambrogio di Valpolicella, Italy; anita.boscaini@masi.it (A.B.); andrea.dalcin@masi.it (A.D.C.); vittorio.zandona@masi.it (V.Z.)

* Correspondence: giovanni.luzzini@univr.it (G.L.); davide.slaghenaufi@univr.it (D.S.)

Abstract

This study investigated the impact of two yeast strains (SP665 and CGC62) and glucanase enzyme treatments (A-D) on the secondary fermentation kinetics and aroma profile of sparkling Prosecco wines. The strains exhibited markedly different fermentation behaviors: SP665 induced rapid refermentation, reaching 8.5 bar in 46 days, while CGC62 showed a slower fermentation rate, reaching 6.5 bar in 64 days. Despite these kinetic differences, basic enological parameters after refermentation and following three months of lees aging were similar for both strains. A total of 66 volatile compounds across various chemical families were identified and quantified. Principal component analysis (PCA) revealed that aging time (T1 vs. T2) was the main driver of variability (50.74% of total variance), with SP665 and CGC62 wines showing distinct profiles. At T1, SP665 wines had higher levels of acetate esters and norisoprenoids, while CGC62 wines were richer in volatile sulfur compounds (VSCs) and monoterpenoids. At T2, SP665 wines showed increased levels of carbon disulfide, higher alcohols, and ethyl butanoate, whereas CGC62 wines retained higher concentrations of varietal compounds and certain esters. The effect of glucanase enzymes varied depending on yeast strain and aging stage. Enzyme treatments, especially C (β -glucanase) and D, influenced the concentration of several aroma compounds, particularly in CGC62 wines, enhancing varietal aromas and esters. However, the impact on SP665 wines was more limited and emerged primarily after aging. Although differences in aroma composition were statistically significant, most changes were below olfactory perception thresholds. Overall, glucanase enzymes and yeast selection influenced aroma development, though their effects may have limited sensory relevance.

Keywords: Prosecco; sparkling wine; aroma compound; glucanase; GC-MS; secondary fermentation



Received: 6 November 2025

Revised: 10 December 2025

Accepted: 23 December 2025

Published: 6 January 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

Prosecco sparkling wine has an increasing success all over the world. In 2023, among sparkling wines, Prosecco ranked first in volume of exports and second in export value after Champagne [1,2]. This success is partly due to a generally positive trend in sparkling wines, which are no longer consumed only on special occasions but are increasingly enjoyed on a daily basis. Moreover, Prosecco has benefited from being picked up as a casual drink and also as an ingredient in cocktails [3]. Prosecco is perceived by consumers as an everyday luxury without

being as expensive as Champagne. In addition to its lower price, Prosecco also benefits from a distinctive and characteristic taste pleasantness, making it accessible to a broader range of consumers, including non-experts [3]. Nevertheless, it has been reported that a too low price will affect consumers' loyalty [4]. Another factor affecting loyalty is the appellation system. An extensive zonation study of the Prosecco appellation area has been conducted, aiming to assess terroirs and cru vineyards [5], which has resulted in the definition of high-quality "Denominazione di Origine Controllata e Garantita" (Controlled and Guaranteed Designation of Origin, DOCG) sub-areas. Those areas have been reported to significantly influence the Prosecco volatile profile [6]. Moreover, the hills of Conegliano and Valdobbiadene, where the homonymous DOCG is produced, have been designated as a "United Nations Educational, Scientific and Cultural Organization" (UNESCO) World Heritage site, further linking wine and place with a sense of quality. According to the "Denominazione di Origine Controllata" (Controlled Designation of Origin, DOC) regulation, Prosecco sparkling wine is made using the Glera grape variety, with small amounts of other authorized grape varieties also admitted (<15%). The secondary fermentation is carried out following the Charmat method in a stainless-steel pressurized tank (autoclave). The profound impact of secondary fermentation on the chemical composition, particularly the aromatic profile, of base wines is a widely documented phenomenon [7,8]. The obtained wines are aromatic and crisp, with floral and fruity notes that are meant to be consumed young [3]. Starting from these winemaking characteristics, a possible product differentiation could be achieved by aging the wine on the yeast lees in the autoclave after secondary fermentation, thereby promoting the yeast cell lysis process characteristic of Champagne wine production. Yeast cell lysis is a slow process with multiple steps, which, in the champenoise method, begins to occur after 3–6 months of the second fermentation's start, with kinetics that are very slow [9]. During aging on lees, the wine is enriched in macromolecules, such as polysaccharides and mannoproteins, as well as small molecules resulting from the lysis of yeast cells [10]. Mannoproteins and polysaccharides are well known for their ability to improve wine stability, foamability, and mouthfeel [11]. Several aroma precursors, mainly amino acids [12,13], are also released, favoring the appearance of complex aroma nuances resulting in enhanced aroma complexity, which was reported to be linked to an increase in wine perceived value [14–16]. Due to the relatively short production timeframe of Prosecco, acceleration of the lysis process is necessary, particularly given the lower market value of Prosecco compared to Champagne. The possible strategies to accelerate the lysis are the increase in temperature, the addition of exogenous yeast autolysates, and the use of enzymes that are able to degrade yeast cell walls, for example, glucanase enzymes [17,18]. Studies have primarily evaluated the impact of enzyme use on accelerating yeast lysis and the quality of sparkling wine foam [19]. Still, there is a lack of knowledge regarding the effect of this enological practice on wine aroma. Notwithstanding its popularity and success, the aroma and volatile composition of Prosecco wine have not been extensively studied, and few data have been reported on the profile of Glera grapes [20]. Moreover, an influence of these enological practices on CO₂ aroma-boosting action [21] could be expected, as macromolecules can affect foamability and bubble size.

The primary objective of this study was to evaluate the effect of sur lie enzymes on the aroma profile of Prosecco wines during lees aging. Commercial enzymes proposed for cell lysis and lees aging were used, combined with two different yeasts used for secondary fermentation to assess a possible strain effect. These findings could contribute to a better understanding of the role of yeast and enzymes in shaping the aromatic complexity of Prosecco over time.

2. Materials and Methods

2.1. Winemaking Treatments

For this study, the following experimental refermentation plan was adopted: a single mass of base wine from Glera grapes (180 L) was inoculated with two different yeasts,

CGC62 and SP665 (Perdomini-IOC, San Martino Buon Albergo, Italy). For each yeast, five modalities were prepared: 4 enzyme preparations and a control. The enzyme preparations were recommended by the producer for sur lies maturation; they were coded as A (EC 232-885-6), B (EC 232-894-5), C (EC 232-885-6; EC 263-462-4), D (EC 232-885-6; EC 263-462-4; EC 232-957-7). To obtain an overpressure of 8 bar during the second fermentation, sucrose was dissolved in the base wine mass (33 g/L). Furthermore, a preparation based on ammonium phosphate and thiamine (10 g/hL) (Laffort, Tortona, Italy) and a second preparation based on inactivated yeasts and ammonium salts (10 g/hL) (Laffort, Tortona, Italy) were added, for a total addition of approximately 32 mg/hL of N. The wine was then transferred to 1.5 L Magnum bottles for refermentation. The inoculum and enzymes were added directly to the bottles, and each trial was conducted in triplicate. After secondary fermentation (T1), wines were subjected to aging for three months (T2) at 15 °C.

2.2. Basic Parameter Analysis

The pH was measured using a Basic 20+ pH meter (Crison, Barcelona, Spain). Total acidity was evaluated by titration following the official OIV method; sugar and volatile acidity were analyzed using a Y15 multiparametric analyzer (Biosystems, Barcelona, Spain). Ethanol was determined with an FT-IR Lyza 5000 spectrophotometer (Anton Paar, Graz, Austria). The overpressure was measured using aphrometers.

2.3. Major Volatile Compounds Analysis

Fermentative compounds (esters, organic acids, and higher alcohols) were analyzed as described by Slaghenaufi et al. (2019) [22]. Twenty µL of internal standard solution (2-octanol at 42 mg/L in ethanol, both from Sigma Aldrich, Milan, Italy) was added to 50 mL of the sample and diluted with 50 mL of distilled water. The solution was then loaded on an SPE cartridge, BOND ELUT-ENV (1 g of sorbent, Agilent Technologies, Santa Clara, CA, USA). The SPE cartridge was previously activated by passing 20 mL of methanol followed by 20 mL of distilled water. After sample loading, the cartridge was washed with 15 mL of water. Volatile compounds were eluted with 10 mL of dichloromethane, and prior to GC injection, they were concentrated to 200 µL using a gentle stream of nitrogen. Two microliters of sample solution were injected in splitless mode (250 °C) into an HP 7890A gas chromatograph coupled to a 5977B mass spectrometer (Agilent Technologies, Santa Clara, CA, USA). A DB-WAX UI capillary column (30 m × 0.25 mm, 0.25 µm film thickness, Agilent Technologies, Santa Clara, CA, USA) was used to perform chromatographic separation. Helium was used as carrier gas at a constant flow of 1.2 mL/min. The oven temperature was initially set at 40 °C for 3 min, then increased at a rate of 4 °C/min to 230 °C, which was maintained for 10 min. The transfer line, ion source, and quadrupole were kept at 200, 250, and 150 °C, respectively. The mass spectra were acquired in electron ionization (EI) at 70 eV in single-ion monitoring (SIM) mode [6]. Quantification was performed using an internal standard calibration.

2.4. Terpene and Norisoprenoid Analysis

Terpene analysis was performed using solid-phase microextraction (SPME) [6]. Three grams of NaCl (Sigma Aldrich, Milan, Italy) are added to 20 mL vials. Four milliliters of the sample were taken and placed in a vial with the addition of 4 mL of distilled water and 50 µL of internal standard, 2-octanol (0.42 mg/100 mL) (Sigma Aldrich, Milan, Italy). The sample was then analyzed by SPME-GC-MS. The fiber used was a CAR-PDMS-DVB (Supelco, Bellefonte, PA, USA). Sampling was performed by exposing the fiber in the headspace of the sample for 50 min at an extraction temperature of 40 °C by Gerstel MPS3 autosampler (Müllheim/Ruhr, Germany). The injection took place in spitless mode at 270 °C for 3 min; the chromatographic separation was performed on a DB-WAX capillary

column (30 m $\times$ 0.25 mm diameter $\times$ 0.25 μ m film thickness, Agilent Technologies, Santa Clara, CA, USA), with a helium flow of 1.2 mL/min; the oven temperature was set at 40 °C for 3 min with a progressive increase of 4 °C per minute until reaching 250 °C for 20 min. The mass spectrometer was used in SIM mode. Quantification was performed using an internal standard calibration method.

2.5. Statistical Analysis

Kruskal–Wallis test ($\alpha = 0.05$, Dunn multiple pairwise comparison), one-way ANOVA ($\alpha = 0.1$, Tukey post hoc test), and Principal Component Analysis (PCA, Spearman correlation matrix) were performed using XLSTAT 2022.4 (Addinsoft SARL, Paris, France).

3. Results

3.1. Fermentation Conditions and Yeast Strain Effect

The two yeasts used in this study exhibited distinct fermentation kinetics during secondary fermentation, as shown in Figure 1. Different behavior of inoculums during the second fermentation has already been reported [23]. The samples inoculated with the SP665 strain showed a pressure increase immediately after the inoculation, maintaining a high fermentation rate in the first 20 days of the second fermentation (approximately 0.3 bar/day) and then slowing down towards the end of refermentation in 46 days, and developing in total 8.5 bar of overpressure (Figure 1). Instead, the CGC62 strain showed a slower refermentation rate, much slower than the SP665 strain. After 10 days, an overpressure of only 0.2 bar was produced, then maintaining a constant rate of about 0.1 bar/day, reaching 6.5 bar at the end of refermentation after 64 days. From a chemical point of view, differences were mainly observed between the base wine and the samples after refermentation (Table 1), indicating the consumption of sugars added to the tirage liqueur, resulting in a consequent increase in alcohol content. The same was observed for pH. Instead, no significant differences were observed in the basic enological parameters between the two yeast strains at the end of the second fermentation, even after three months of aging on the lees.

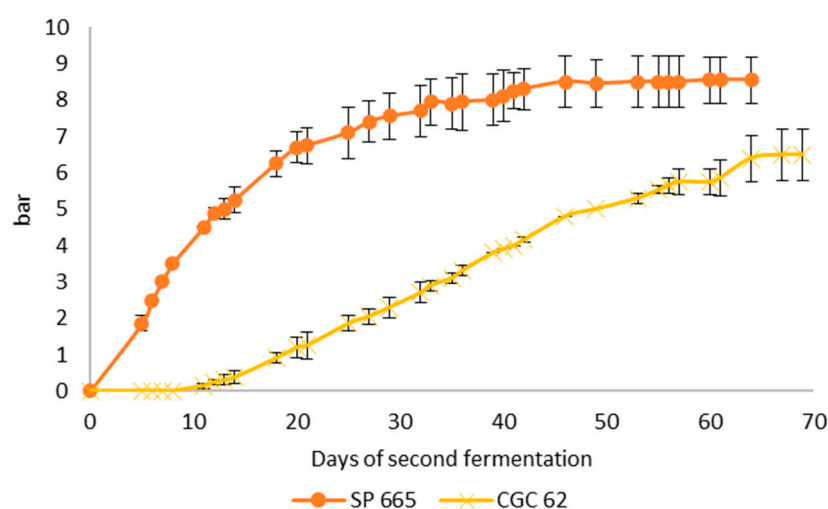


Figure 1. Kinetics of the second fermentation of the two yeast strains SP665 and CGC62. Error bars represent standard deviation ($n = 3$).

A total of sixty-six free volatile aroma compounds were identified and quantified in the wines. These compounds belong to the following chemical families: volatile sulfur compounds (5), higher alcohols (6), C6 alcohols (4), acetate esters (3), ethyl esters of straight-chain fatty acids (4), ethyl esters of branched acids (4), fatty acids (3), monoterpenoids (20), norisoprenoids (8), sesquiterpenes (3), and benzenoids (6).

Table 1. Enological parameters at different times (base wine—T0, end of second fermentation—T1, and 3 months of aging—T2).

Yeast Time	Base Wine T0	CGC62 T1	SP665 T1	CGC62 T2	SP665 T2
Alcohol (%vol)	9.02 ± 0.02 a	11.45 ± 0.02 b	11.46 ± 0.03 b	11.49 ± 0.01 b	11.29 ± 0.26 b
Sugar (g/L)	45.0 ± 0.3 a	0.38 ± 0.11 b	0.73 ± 0.18 b	0.30 ± 0.08 b	1.98 ± 2.83 b
Total acidity (g/L)	6.4 ± 0.11 a	5.56 ± 0.35 a	6.14 ± 0.02 a	6.2 ± 0.01 a	5.75 ± 1.05 a
pH	3.13 ± 0.01 a	3.29 ± 0.04 b	3.23 ± 0.01 b	3.21 ± 0.03 b	3.27 ± 0.09 b
Volatile acidity (g/L)	0.1 ± 0.02 a	0.18 ± 0 a	0.18 ± 0.01 a	0.2 ± 0.02 a	0.27 ± 0.06 a

Different letters in the same row denote statistically significant difference as obtained by ANOVA ($\alpha = 0.1$) with Tukey post hoc test.

To better visualize the overall dataset, principal component analysis (PCA) was performed on the wines' volatile composition (Figure 2). PC1, which explains 50.74% of the total variance, clearly separates wines at the end of the second fermentation (T1) from those aged for three months (T2). At T1, wines were primarily associated with higher levels of acetates, higher alcohols, fatty acids, and benzenoids. In contrast, T2 wines were more strongly associated with ethyl esters, C₆ alcohols, volatile sulfur compounds (VSC), sesquiterpenes, monoterpenoids, and norisoprenoids. This trend aligns with expectations, as aging affects aroma compounds, particularly VSC, ethyl esters of branched fatty acids, and varietal compounds such as terpenoids and norisoprenoids [24–30]. PC2 primarily reflects variability associated with yeast strain, though its effect (15.77%) was less pronounced than the differences between T1 and T2. Wines fermented with the two yeasts displayed significantly different aroma profiles (Table 2). At T1, CGC62 wines exhibited significantly higher levels of volatile sulfur compounds and varietal compounds, particularly sesquiterpenoids and most monoterpenoids, except for geraniol, linalool, α -terpineol, and geranyl acetate. In contrast, SP665 wines contained significantly higher concentrations of the norisoprenoids β -damascenone and 4-oxoisophorone, as well as C₆ alcohols, acetate esters, and ethyl esters such as ethyl butanoate and ethyl 3-hydroxybutyrate. This aligns with the producer's specifications, which indicate that yeast SP665 tends to generate high levels of acetates.

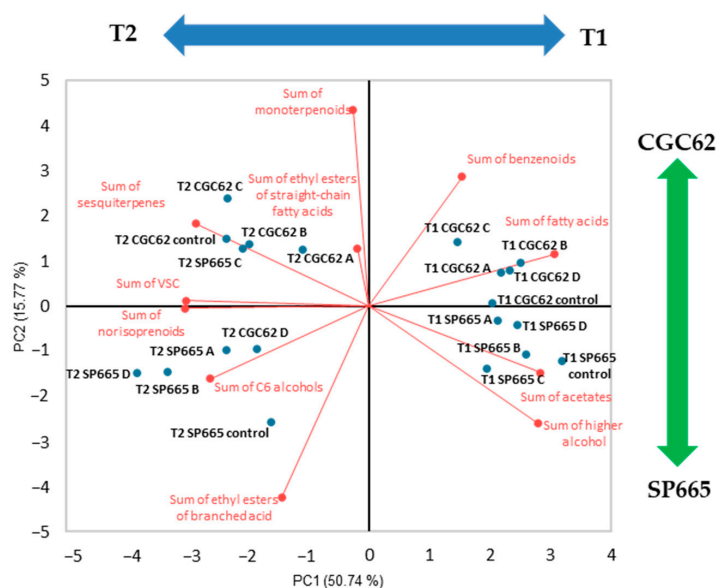
**Figure 2.** PCA analysis of volatile aroma compounds of wines inoculated with two different yeasts (SP 665 and CGC62, green arrow) and at two different times (T1—end of second fermentation and T2—three months of aging, blue arrow). The scores are shown as blue dots with black labels, whereas the loadings are shown in red.

Table 2. The concentration in g/L of volatile aroma compounds of wines inoculated with two different yeasts (SP 665 and CGC62) and at two different times (T1—end of second fermentation and T2—three months of aging).

	SP665	T1 CGC62	<i>p</i> -Value	SP665	T2 CGC62	<i>p</i> -Value
Methanethiol	<LOQ	<LOQ		2.73 ± 0.92	5.23 ± 0.66	0.019
Carbon disulfide	3.05 ± 0.15	8.09 ± 0.49	<0.0001	5.59 ± 0.19	1.00 ± 0.05	<0.0001
DMS	1.34 ± 0.09	1.69 ± 0.04	0.003	3.42 ± 0.17	4.45 ± 0.24	0.004
DES	0.10 ± 0.01	0.35 ± 0.04	0.0004	0.73 ± 0.09	0.37 ± 0.04	0.003
DMDS	<LOQ	<LOQ		<LOQ	<LOQ	
Sum of VSC	4.49 ± 0.21	10.2 ± 0.51	<0.0001	12.5 ± 0.72	11.1 ± 0.95	0.109
1-Butanol	39.4 ± 2.16	33.1 ± 0.70	0.009	64.6 ± 4.52	53.6 ± 2.79	0.023
1-Pentanol	145 ± 59.9	174 ± 34.7	0.517	531 ± 55.4	540 ± 61.6	0.857
Isoamyl alcohol	184,684 ± 6213	178,453 ± 190	0.157	72,667 ± 3105	61,337 ± 5997	0.044
Methionol	166 ± 9.38	129 ± 5.44	0.004	177 ± 18.9	158 ± 14.2	0.227
Phenylethyl Alcohol	17,206 ± 1636	17,532 ± 212	0.749	7208 ± 632	7054 ± 390	0.737
Benzyl Alcohol	38.9 ± 1.75	38.2 ± 2.68	0.724	54.5 ± 2.53	219 ± 9.92	<0.0001
Sum of higher alcohol	202,279 ± 7755	196,358 ± 365	0.257	80,703 ± 3730	69,362 ± 6456	0.058
1-Hexanol	384 ± 4.54	360 ± 1.83	0.001	499 ± 17.8	515 ± 40.5	0.558
cis-3-Hexen-1-ol	7.75 ± 0.24	7.41 ± 0.11	0.096	8.21 ± 0.98	8.57 ± 0.65	0.628
trans-3-Hexen-1-ol	121 ± 2.17	112 ± 1.21	0.004	124 ± 13.0	146 ± 12.0	0.096
cis-2-hexen-1-ol	4.72 ± 0.24	4.47 ± 0.60	0.531	13.4 ± 1.30	12.4 ± 0.82	0.355
Sum of C6 alcohols	517 ± 6.53	483 ± 3.62	0.001	644 ± 32.7	682 ± 53.7	0.356
Isoamyl acetate	2255 ± 137	1963 ± 104	0.042	1598 ± 115	1596 ± 113	0.984
n-Hexyl acetate	52.4 ± 10.3	47.6 ± 8.31	0.566	40.2 ± 3.79	43.9 ± 5.94	0.422
2-Phenethyl acetate	258 ± 31.8	219 ± 23.2	0.162	168 ± 12.8	168 ± 15.4	0.956
Sum of acetates	2564 ± 179	2229 ± 135	0.061	1807 ± 128	1808 ± 132	0.993
Ethyl butanoate	225 ± 3.22	211 ± 1.78	0.002	243 ± 9.74	118 ± 6.49	<0.0001
Ethyl hexanoate	684 ± 135	677 ± 122	0.951	679 ± 61.6	686 ± 74.0	0.897
Ethyl octanoate	500 ± 159	514 ± 165	0.923	355 ± 48.1	514 ± 42.9	0.013
Ethyl decanoate	65.0 ± 15.9	107 ± 28.0	0.087	34.4 ± 4.00	82.6 ± 4.78	0.0001
Sum of ethyl esters of straight-chain fatty acids	1474 ± 308	1508 ± 317	0.900	1312 ± 123	1401 ± 128	0.433
Ethyl-2-methylbutanoate	2.80 ± 0.18	2.91 ± 0.11	0.407	5.33 ± 0.52	4.47 ± 0.38	0.082
Ethyl 3-methylbutanoate	4.11 ± 0.71	5.67 ± 1.48	0.176	10.5 ± 1.32	11.1 ± 0.94	0.555
Ethyl 3-hydroxybutyrate	65.9 ± 2.79	56.4 ± 2.00	0.009	64.3 ± 4.83	58.2 ± 2.24	0.119
Ethyl di-2-hydroxyhexanoate	0.48 ± 0.01	0.48 ± 0.01	0.643	0.97 ± 0.09	0.93 ± 0.05	0.520
Sum of ethyl esters of branched fatty acids	73.3 ± 2.94	65.5 ± 1.73	0.017	81.1 ± 6.57	74.7 ± 3.54	0.213
3-Methylbutanoic acid	196 ± 4.66	183 ± 5.26	0.035	266 ± 22.2	261 ± 33.9	0.840
Hexanoic acid	5922 ± 434	5621 ± 313	0.385	4547 ± 318	4047 ± 372	0.152
Octanoic acid	10,317 ± 645	10,537 ± 441	0.651	7282 ± 442	7238 ± 567	0.921
Sum of fatty acids	16,435 ± 1077	16,342 ± 757	0.908	12,095 ± 781	11,547 ± 964	0.487
α-Phellandrene	0.02 ± 0.00	0.06 ± 0.01	0.0003	0.01 ± 0.00	0.01 ± 0.01	0.374
α-Terpinene	<LOQ	<LOQ		<LOQ	<LOQ	
γ-Terpinene	<LOQ	0.11 ± 0.00		<LOQ	0.12 ± 0.01	
β-Pinene	0.00 ± 0.00	0.02 ± 0.01	0.047	0.01 ± 0.01	0.01 ± 0.01	0.643
3-Carene	<LOQ	<LOQ		<LOQ	<LOQ	
β-Myrcene	0.07 ± 0.01	0.17 ± 0.01	0.0001	0.10 ± 0.03	0.28 ± 0.02	0.001
Limonene	0.34 ± 0.01	0.38 ± 0.01	0.008	0.34 ± 0.00	0.40 ± 0.01	<0.0001
1,4-Cineole	0.02 ± 0.01	<LOQ		0.10 ± 0.01	<LOQ	
1,8-Cineole	0.01 ± 0.01	<LOQ		<LOQ	<LOQ	
p-Cymene	<LOQ	<LOQ		<LOQ	<LOQ	
Terpinolene	0.07 ± 0.03	<LOQ		0.05 ± 0.01	<LOQ	
Linalool	2.63 ± 0.42	1.92 ± 0.04	0.042	2.36 ± 0.09	3.43 ± 0.33	0.006
Terpinen-4-ol	0.19 ± 0.04	0.16 ± 0.01	0.665	0.30 ± 0.02	0.33 ± 0.02	0.067
α-Terpineol	1.13 ± 0.26	0.72 ± 0.09	0.459	1.55 ± 0.28	1.95 ± 0.26	0.146

Table 2. Cont.

	SP665	T1 CGC62	<i>p</i> -Value	SP665	T2 CGC62	<i>p</i> -Value
β-Citronellol	1.24 ± 0.36	1.04 ± 0.06	0.677	1.48 ± 0.96	0.79 ± 0.10	0.287
Nerol	0.19 ± 0.07	0.24 ± 0.03	0.725	0.46 ± 0.04	1.96 ± 0.28	0.110
Geraniol	2.01 ± 0.10	0.09 ± 0.01	<0.0001	0.92 ± 0.20	3.82 ± 0.42	0.004
Linalyl acetate	0.16 ± 0.06	4.51 ± 0.83	0.021	0.18 ± 0.01	2.57 ± 0.78	0.212
Geranyl acetate	0.07 ± 0.04	0.07 ± 0.02	1.00	0.08 ± 0.01	0.12 ± 0.01	0.001
Geranyl acetone	0.91 ± 0.02	0.05 ± 0.02	0.055	0.10 ± 0.03	0.28 ± 0.07	0.016
Sum of monoterpenoids	9.14 ± 1.27	9.54 ± 3.24	0.787	8.00 ± 1.13	16.1 ± 2.82	0.009
β-Damascenone	1.39 ± 0.34	1.13 ± 0.04	0.251	1.21 ± 0.02	1.92 ± 0.12	0.001
α-Ionol	<LOQ	<LOQ		<LOQ	<LOQ	
4-Oxoisophorone	5.21 ± 1.79	3.22 ± 0.92	0.161	0.44 ± 0.05	0.57 ± 0.08	0.468
Vitispirane 1	0.06 ± 0.02	0.06 ± 0.02	0.927	24.6 ± 3.75	39.1 ± 1.70	0.004
Vitispirane 2	0.08 ± 0.00	0.07 ± 0.01	0.043	24.7 ± 5.05	32.6 ± 5.74	0.148
* TPB	0.00 ± 0.00	0.01 ± 0.00	0.128	1.87 ± 0.11	3.10 ± 0.11	0.0001
* TDN	0.06 ± 0.02	0.07 ± 0.01	0.286	29.9 ± 9.12	36.1 ± 2.44	0.316
3-hydroxy-β-damascone	0.00 ± 0.00	0.15 ± 0.01	<0.0001	0.00 ± 0.00	0.31 ± 0.01	<0.0001
Sum of norisoprenoids	6.82 ± 2.12	4.71 ± 0.92	0.189	82.7 ± 17.2	114 ± 8.13	0.047
Farnesol 1	0.47 ± 0.09 a	0.27 ± 0.01 a	0.305	0.25 ± 0.10 a	0.66 ± 0.04 ab	0.266
Nerolidol 1	0.02 ± 0.01 a	1.86 ± 0.38 ab	0.001	1.78 ± 0.16 a	3.81 ± 0.67 ab	0.007
Bisabolol	<LOQ	<LOQ		<LOQ	<LOQ	
Sum of sesquiterpenes	0.49 ± 0.29 a	2.13 ± 0.42 ab	0.005	2.03 ± 0.07 a	4.50 ± 0.51 a	0.001
Methyl salicylate	2.08 ± 0.27	1.85 ± 0.09	0.237	1.69 ± 0.05	19.7 ± 2.56	0.002
Benzaldehyde	1.70 ± 0.16	1.10 ± 0.11	0.005	1.47 ± 0.04	2.25 ± 0.23	0.005
2,6-Dimethoxyphenol	3.88 ± 0.73	3.99 ± 0.23	0.821	2.96 ± 0.12	2.89 ± 0.24	0.671
Vanillin	34.5 ± 0.91	32.8 ± 0.85	0.077	22.2 ± 0.81	24.7 ± 0.80	0.020
Eugenol	2.02 ± 0.08	1.92 ± 0.08	0.197	0.23 ± 0.01	0.23 ± 0.01	0.983
Ethyl cinnamate	0.19 ± 0.03	0.12 ± 0.01	0.018	0.12 ± 0.02	0.16 ± 0.03	0.094
Sum of benzenoids	44.4 ± 0.64	41.8 ± 0.70	0.009	28.7 ± 1.02	49.9 ± 3.27	0.0004

* TPB: Trimethylphenyl(-buta-1,3-diene), TDN: 1,1,6-Trimethyl-1,2-dihydronaphthalene. Different letters in the same row denote statistically significant differences as obtained by one-way ANOVA ($\alpha = 0.1$) with Tukey post hoc test.

After three months of aging (T2), differences between the yeasts were less pronounced. Wines inoculated with SP665 exhibited higher levels of carbon disulfide and diethyl sulfide (DES) while retaining higher concentrations of higher alcohols, isoamyl alcohol, and ethyl butanoate. These compounds typically decrease during aging, but in SP665 wines, the reduction was less pronounced. Meanwhile, CGC62 wines contained significantly higher levels of varietal compounds, as well as dimethyl sulfide (DMS), benzyl alcohol, and ethyl octanoate and decanoate. Notably, VSC levels increased significantly in aged wines from SP665, whereas this increase was much lower in CGC62 wines, which maintained VSC levels similar to those observed before aging. The well-documented differential capacity of diverse yeast strains to generate distinct wine aroma profiles is fundamentally governed by their specific enzymatic activities, which not only impact fermentative compounds (e.g., higher alcohols and esters) but also directly modulate the profile of varietal compounds, including terpenes, norisoprenoids, and thiols [31–37].

3.2. Glucanase Effect on Aroma Profile of Prosecco Wines

The effect of glucanase enzymes on the wine aroma profile was investigated. These enzymes are typically added to wine to promote yeast cell lysis, thereby increasing the release of compounds that affect mouthfeel and foam formation. However, little research focuses on the influence of this technique on the aroma profile. Since the results indicated a significant impact of yeast strain and time (Figure 2), the data were analyzed separately for each yeast strain and time point (Tables 3 and 4).

Table 3. The concentration in µg/L of volatile aroma compounds of wines inoculated with yeast CGC62 at two different times (T1—end of second fermentation and T2—three months of aging).

	Control	A	T1 B	C	D	Control	A	T2 B	C	D
Methanethiol	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	5.23 ± 0.66 a	5.17 ± 0.31 a	4.98 ± 0.49 a	5.95 ± 1.15 a	4.72 ± 1.03 a
Carbon disulfide	8.09 ± 0.49 b	4.9 ± 1.07 ab	5.56 ± 1.77 ab	4.61 ± 0.93 a	6.32 ± 0.50 ab	1.00 ± 0.05 a	0.94 ± 0.12 a	1.05 ± 0.05 a	0.97 ± 0.16 a	0.83 ± 0.24 a
DMS	1.69 ± 0.04 ab	2.21 ± 0.22 b	1.45 ± 0.22 a	1.84 ± 0.46 ab	1.79 ± 0.16 ab	4.45 ± 0.24 ab	4.46 ± 0.13 ab	4.48 ± 0.17 ab	4.60 ± 0.21 b	3.36 ± 0.72 a
DES	0.35 ± 0.04 b	0.33 ± 0.00 ab	0.18 ± 0.06 a	0.29 ± 0.04 ab	0.28 ± 0.02 ab	0.37 ± 0.04 b	0.25 ± 0.03 ab	0.34 ± 0.01 ab	0.34 ± 0.09 ab	0.17 ± 0.09 a
DMDS	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Sum of VSC	10.2 ± 0.51 b	8.02 ± 2.3 ab	7.19 ± 1.83 ab	6.74 ± 1.43 a	8.39 ± 0.60 ab	11.1 ± 0.95 a	10.8 ± 0.50 a	10.9 ± 0.48 a	11.9 ± 1.39 a	9.08 ± 1.84 a
1-Butanol	33.1 ± 0.70 a	29.9 ± 4.39 a	30.0 ± 5.86 a	24.2 ± 5.69 a	29.6 ± 0.59 a	53.6 ± 2.79 ab	23.8 ± 1.31 a	62.5 ± 2.23 b	62.9 ± 1.91 b	61.4 ± 5.24 ab
1-Pentanol	174 ± 34.7 a	109 ± 41.6 a	160 ± 48.4 a	140 ± 67.5 a	137 ± 70.7 a	540 ± 61.6 b	274 ± 28.7 a	372 ± 40.1 ab	302 ± 21.1 a	389 ± 35.2 ab
Isoamyl alcohol	178,453 ± 190 ab	181,291 ± 4985 b	173,692 ± 4473 ab	154,754 ± 12,989 a	169,087 ± 4919 ab	61,337 ± 5997 ab	46,363 ± 4209 a	65,239 ± 6180 ab	61,739 ± 4078 ab	67,160 ± 3966 b
Methionol	129 ± 5.44 a	134 ± 3.92 a	127 ± 16.2 a	139 ± 6.13 a	140 ± 11.1 a	158 ± 14.2 ab	17.6 ± 1.29 a	156 ± 21.8 ab	147 ± 7.92 ab	162 ± 13.0 b
Phenylethyl Alcohol	17,532 ± 212 b	17,688 ± 1218 b	16,299 ± 864 ab	15,369 ± 1473 a	16,286 ± 391 ab	7054 ± 390 ab	9747 ± 1018 b	7213 ± 655 ab	6803 ± 434 a	7412 ± 627 ab
Benzyl Alcohol	38.2 ± 2.68 ab	58.7 ± 2.02 b	36.9 ± 1.57 a	37.3 ± 0.10 ab	48.9 ± 6.56 ab	219 ± 9.92 ab	85.7 ± 10.3 a	248 ± 16.5 ab	165 ± 15.2 ab	298 ± 27.0 b
Sum of higher alcohol	196,358 ± 365 b	199,311 ± 5120 b	190,343 ± 4799 ab	170,463 ± 12,108 a	185,729 ± 4578 ab	69,362 ± 6456 ab	56,511 ± 5243 a	73,291 ± 6858 ab	69,219 ± 4553 ab	75,482 ± 4481 b
1-Hexanol	360 ± 1.83 a	388 ± 10.4 a	367 ± 8.28 a	364 ± 13.3 a	341 ± 56.7 a	515 ± 40.5 b	396 ± 39.6 a	4745 ± 41.6 ab	472 ± 44.7 ab	496 ± 29.7 ab
cis-3-Hexen-1-ol	7.41 ± 0.11 a	7.77 ± 0.28 a	7.56 ± 0.22 a	7.22 ± 0.25 a	6.63 ± 1.69 a	8.57 ± 0.65 b	6.01 ± 0.39 a	8.14 ± 1.03 ab	7.19 ± 0.56 ab	7.76 ± 0.59 ab
trans-3-Hexen-1-ol	112 ± 1.21 a	122 ± 3.76 a	113 ± 2.97 a	110 ± 3.34 a	103 ± 23.5 a	146 ± 12.0 ab	90.0 ± 8.42 a	141 ± 18.3 ab	131 ± 5.59 ab	151 ± 12.1 b
cis-2-hexen-1-ol	4.47 ± 0.60 a	4.85 ± 0.32 a	4.37 ± 0.22 a	4.54 ± 0.27 a	4.16 ± 0.75 a	12.4 ± 0.82 a	13.0 ± 0.86 a	14.2 ± 1.67 a	13.0 ± 0.13 a	13.7 ± 1.13 a
Sum of C6 alcohols	483 ± 3.62 a	523 ± 14.6 a	492 ± 11.7 a	486 ± 17.1 a	455 ± 82.6 a	682 ± 53.7 b	505 ± 48.5 a	638 ± 60.9 ab	623 ± 50.6 ab	669 ± 43.0 ab
Isoamyl acetate	1963 ± 104 a	1762 ± 147 a	2125 ± 123 a	1941 ± 318 a	1947 ± 26.5 a	1596 ± 113 b	859 ± 114 a	1463 ± 139 ab	1439 ± 74.8 ab	1585 ± 139 ab
n-Hexyl acetate	47.6 ± 8.31 ab	33.7 ± 7.09 a	56.2 ± 2.86 b	47.9 ± 13.7 ab	38.4 ± 2.5 ab	43.9 ± 5.94 b	27.0 ± 2.62 a	38 ± 4.01 ab	42.8 ± 2.62	44.2 ± 3.37 b
2-Phenethyl acetate	219 ± 23.2 a	182 ± 20.2 a	247 ± 5.7 a	222 ± 41.8 a	243 ± 35.4 a	168 ± 15.4 a	165 ± 14.0 a	154 ± 8.59 a	155 ± 15.8 a	166 ± 13.9 a
Sum of acetates	2229 ± 135 a	1978 ± 170 a	2429 ± 131 a	2211 ± 371 a	2228 ± 28.7 a	1808 ± 132 b	1051 ± 130 a	1655 ± 151 ab	1637 ± 92.9 ab	1795 ± 154 ab
Ethyl butanoate	211 ± 1.78 a	215 ± 9.47 a	211 ± 3.76 a	202 ± 24.0 a	213 ± 6.17 a	118 ± 6.49 ab	95.0 ± 6.83 a	220 ± 22.5 ab	220 ± 11.1 ab	228 ± 24.1 b
Ethyl hexanoate	677 ± 122 ab	491 ± 108 a	774 ± 44.5 b	666 ± 180 ab	534 ± 50.2 ab	686 ± 74.0 ab	531 ± 13.4 a	704 ± 56.8 b	682 ± 48.2 ab	666 ± 58.4 ab
Ethyl octanoate	514 ± 165 ab	293 ± 83.5 a	573 ± 32.7 ab	556 ± 157 ab	645 ± 132 b	514 ± 42.9 a	602 ± 48.1 a	581 ± 56.8 a	507 ± 63.7 a	574 ± 71.1 a
Ethyl decanoate	107 ± 28.0 ab	66.2 ± 16.8 a	100 ± 15.5 ab	114 ± 40.1 ab	155 ± 43.8 b	82.6 ± 4.78 a	105 ± 9.84 ab	107 ± 14.6 b	81.1 ± 7.26 a	101 ± 7.87 ab
Sum of ethyl esters of straight-chain fatty acids	1508 ± 317 ab	1065 ± 198 a	1659 ± 31.0 b	1538 ± 457 ab	1547 ± 353 ab	1401 ± 128 ab	1332 ± 77.3 a	1612 ± 151 b	1490 ± 128 ab	1570 ± 156 ab
Ethyl-2-methylbutanoate	2.91 ± 0.11 a	2.91 ± 0.21 a	3.06 ± 0.10 a	2.81 ± 0.32 a	2.73 ± 0.38 a	4.47 ± 0.38 ab	3.32 ± 0.35 a	5.20 ± 0.48 b	4.88 ± 0.47 ab	4.85 ± 0.34 ab
Ethyl 3-methylbutanoate	5.67 ± 1.48 b	5.20 ± 1.17 ab	4.79 ± 0.81 ab	3.76 ± 0.45 a	5.09 ± 1.13 ab	11.1 ± 0.94 ab	6.95 ± 0.81 a	8.99 ± 0.91 ab	11.7 ± 0.47 ab	12.4 ± 0.62 b
Ethyl 3-hydroxybutyrate	56.4 ± 2.00 a	60.2 ± 1.77 a	56.2 ± 5.25 a	60.2 ± 4.15 a	59.0 ± 0.48 a	58.2 ± 2.24 a	55.7 ± 6.22 a	59.9 ± 4.91 a	56.8 ± 3.69 a	57.0 ± 7.93 a
Ethyl di-2-hydroxyhexanoate	0.48 ± 0.01 ab	0.50 ± 0.02 b	0.49 ± 0.01 ab	0.47 ± 0.02 a	0.50 ± 0.02 b	0.93 ± 0.05 a	0.86 ± 0.06 a	1.04 ± 0.09 a	0.89 ± 0.08 a	0.97 ± 0.07 a
Sum of ethyl esters of branched fatty acids	65.5 ± 1.73 a	68.8 ± 2.53 a	64.5 ± 5.32 a	67.2 ± 4.37 a	67.3 ± 0.28 a	74.7 ± 3.54 a	66.9 ± 7.41 a	75.2 ± 6.37 a	74.3 ± 4.64 a	75.3 ± 8.96 a
3-Methylbutanoic acid	183 ± 5.26 a	191 ± 8.20 a	190 ± 7.06 a	185 ± 7.03 a	197 ± 13.2 a	261 ± 33.9 a	250 ± 25.1 a	256 ± 29.3 a	254 ± 14.5 a	257 ± 30.7 a
Hexanoic acid	5621 ± 313 a	6067 ± 135 a	5978 ± 31.0 a	5824 ± 135 a	6550 ± 1309 a	4047 ± 372 a	6149 ± 401 b	4849 ± 440 ab	4479 ± 274 ab	4776 ± 475 ab
Octanoic acid	10,537 ± 441 a	10,888 ± 144 a	11,020 ± 32.7 a	10,556 ± 139 a	11,759 ± 1520 a	7238 ± 567 a	9490 ± 569 b	7996 ± 912 ab	7537 ± 754 ab	8045 ± 1078 ab
Sum of fatty acids	16,342 ± 757 a	17,146 ± 273 a	17,189 ± 52.7 a	16,565 ± 273 a	18,506 ± 2841 a	11,547 ± 964 a	15,888 ± 994 b	13,100 ± 1373 ab	12,270 ± 1034 ab	13,078 ± 1583 ab
α-Phellandrene	0.06 ± 0.01 a	0.04 ± 0.00 a	0.07 ± 0.01 a	0.08 ± 0.01 a	0.06 ± 0.00 a	0.01 ± 0.01 a	0.01 ± 0.00 a	0.02 ± 0.01 a	0.01 ± 0.01 a	0.01 ± 0.00 a
α-Terpinene	<LOQ	<LOQ	<LOQ	0.04 ± 0.02	0.03 ± 0.01	<LOQ	0.03 ± 0.01	<LOQ	<LOQ	<LOQ
γ-Terpinene	0.11 ± 0.00 ab	0.16 ± 0.02 b	0.12 ± 0.01 ab	0.10 ± 0.03 ab	0.08 ± 0.01 a	0.12 ± 0.01 b	0.07 ± 0.00 ab	0.10 ± 0.03 ab	0.09 ± 0.00 ab	0.05 ± 0.00 a
β-Pinene	0.02 ± 0.01 a	0.04 ± 0.00 a	0.02 ± 0.01 a	0.02 ± 0.01 a	0.02 ± 0.01 a	0.01 ± 0.01 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.02 ± 0.01 a
3-Carene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ

Table 3. Cont.

	Control	A	T1 B	C	D	Control	A	T2 B	C	D
β -Myrcene	0.17 $\pm$ 0.01 a	0.27 $\pm$ 0.02 b	0.22 $\pm$ 0.02 ab	0.22 $\pm$ 0.03 ab	0.16 $\pm$ 0.02 ab	0.28 $\pm$ 0.02 b	0.24 $\pm$ 0.06 ab	0.27 $\pm$ 0.06 b	0.29 $\pm$ 0.03 b	0.16 $\pm$ 0.01 a
Limonene	0.38 $\pm$ 0.01 a	0.41 $\pm$ 0.01 a	0.39 $\pm$ 0.01 a	0.39 $\pm$ 0.03 a	0.39 $\pm$ 0.02 a	0.40 $\pm$ 0.01 b	0.35 $\pm$ 0.01 ab	0.39 $\pm$ 0.01 ab	0.40 $\pm$ 0.01 ab	0.34 $\pm$ 0.01 a
1,4-Cineole	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
1,8-Cineole	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
p-Cymene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Terpinolene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Linalool	1.92 $\pm$ 0.04 a	2.30 $\pm$ 0.36 a	2.07 $\pm$ 0.15 a	2.25 $\pm$ 0.27 a	1.93 $\pm$ 0.16 a	3.43 $\pm$ 0.33 ab	2.85 $\pm$ 0.10 ab	3.23 $\pm$ 0.46 ab	3.83 $\pm$ 0.20 b	2.43 $\pm$ 0.11 a
Terpinen-4-ol	0.16 $\pm$ 0.01 a	0.17 $\pm$ 0.02 a	0.18 $\pm$ 0.01 a	0.18 $\pm$ 0.03 a	0.16 $\pm$ 0.01 a	0.33 $\pm$ 0.02 ab	0.26 $\pm$ 0.01 a	0.34 $\pm$ 0.03 ab	0.37 $\pm$ 0.02 b	0.28 $\pm$ 0.00 ab
α -Terpineol	0.72 $\pm$ 0.09 a	0.60 $\pm$ 0.08 a	0.73 $\pm$ 0.01 a	0.67 $\pm$ 0.08 a	0.63 $\pm$ 0.08 a	1.95 $\pm$ 0.26 ab	1.08 $\pm$ 0.03 ab	1.70 $\pm$ 0.24 ab	2.02 $\pm$ 0.17 b	1.03 $\pm$ 0.03 a
β -Citronellol	1.04 $\pm$ 0.06 a	0.90 $\pm$ 0.19 a	0.72 $\pm$ 0.25 a	0.65 $\pm$ 0.19 a	0.67 $\pm$ 0.11 a	0.79 $\pm$ 0.10 ab	0.70 $\pm$ 0.02 ab	0.74 $\pm$ 0.04 ab	2.02 $\pm$ 0.02 b	0.51 $\pm$ 0.03 a
Nerol	0.24 $\pm$ 0.03 a	0.40 $\pm$ 0.02 ab	0.28 $\pm$ 0.05 a	0.57 $\pm$ 0.03 b	0.44 $\pm$ 0.03 ab	1.96 $\pm$ 0.28 ab	0.29 $\pm$ 0.03 a	1.88 $\pm$ 0.63 ab	2.50 $\pm$ 0.84 b	0.95 $\pm$ 0.13 ab
Geraniol	0.09 $\pm$ 0.01 a	0.70 $\pm$ 0.15 ab	0.64 $\pm$ 0.15 ab	0.86 $\pm$ 0.21 ab	2.29 $\pm$ 0.50 b	3.82 $\pm$ 0.42 ab	2.24 $\pm$ 0.06 ab	2.50 $\pm$ 0.43 ab	4.23 $\pm$ 0.85 b	1.23 $\pm$ 0.17 a
Linalyl acetate	4.51 $\pm$ 0.83 ab	5.77 $\pm$ 1.79 ab	4.63 $\pm$ 0.68 ab	6.92 $\pm$ 1.06 b	1.82 $\pm$ 0.68 a	2.57 $\pm$ 0.78 ab	1.98 $\pm$ 0.41 ab	3.48 $\pm$ 0.42 b	1.06 $\pm$ 0.05 ab	0.33 $\pm$ 0.02 a
Geranyl acetate	0.07 $\pm$ 0.02 ab	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.02 ab	0.14 $\pm$ 0.04 b	0.08 $\pm$ 0.02 ab	0.12 $\pm$ 0.01 ab	0.09 $\pm$ 0.01 ab	0.60 $\pm$ 0.04 b	0.13 $\pm$ 0.01 ab	0.08 $\pm$ 0.01 a
Geranyl acetone	0.05 $\pm$ 0.02 a	0.12 $\pm$ 0.03 ab	0.18 $\pm$ 0.03 b	0.10 $\pm$ 0.00 ab	0.08 $\pm$ 0.00 ab	0.28 $\pm$ 0.07 ab	0.22 $\pm$ 0.05 ab	0.78 $\pm$ 0.07 b	0.17 $\pm$ 0.06 a	0.27 $\pm$ 0.04 ab
Sum of monoterpenoids	9.54 $\pm$ 3.24 a	12.0 $\pm$ 0.96 a	10.3 $\pm$ 3.74 a	13.2 $\pm$ 2.79 a	9.00 $\pm$ 3.45 a	16.1 $\pm$ 2.82 ab	10.4 $\pm$ 1.58 ab	16.0 $\pm$ 2.19 ab	17.1 $\pm$ 1.25 b	7.69 $\pm$ 0.55 a
β -Damascenone	1.13 $\pm$ 0.04 a	1.36 $\pm$ 0.09 a	1.34 $\pm$ 0.18 a	1.35 $\pm$ 0.11 a	1.35 $\pm$ 0.11 a	1.92 $\pm$ 0.12 b	1.38 $\pm$ 0.07 ab	1.98 $\pm$ 0.18 b	1.62 $\pm$ 0.60 ab	1.26 $\pm$ 0.14 a
α -Ionol	0.01 $\pm$ 0.01 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.02 $\pm$ 0.01 a	0.04 $\pm$ 0.00 a	0.01 $\pm$ 0.00 ab	0.03 $\pm$ 0.01 b	0.01 $\pm$ 0.01 ab	0.02 $\pm$ 0.00 ab	0.00 $\pm$ 0.00 a
4-Oxoisophorone	3.22 $\pm$ 0.92 a	4.24 $\pm$ 0.03 ab	5.16 $\pm$ 0.20 ab	6.07 $\pm$ 1.13 b	5.67 $\pm$ 0.67 ab	0.57 $\pm$ 0.08 b	0.35 $\pm$ 0.06 ab	0.44 $\pm$ 0.18 ab	0.47 $\pm$ 0.02 ab	0.22 $\pm$ 0.01 a
Vitispirane 1	0.06 $\pm$ 0.02 a	0.06 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.05 $\pm$ 0.01 a	0.04 $\pm$ 0.01 a	39.1 $\pm$ 1.70 ab	27.3 $\pm$ 3.02 a	39.0 $\pm$ 2.75 ab	40.9 $\pm$ 3.35 b	30.3 $\pm$ 0.76 ab
Vitispirane 2	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.02 a	0.06 $\pm$ 0.00 a	0.06 $\pm$ 0.01 a	0.06 $\pm$ 0.01 a	32.6 $\pm$ 5.74 ab	15.0 $\pm$ 1.15 a	30.0 $\pm$ 2.92 ab	33.1 $\pm$ 3.61 b	18.8 $\pm$ 1.15 ab
TPB	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	3.10 $\pm$ 0.11 ab	1.98 $\pm$ 0.12 a	2.84 $\pm$ 0.41 ab	3.25 $\pm$ 0.19 b	2.18 $\pm$ 0.06 ab
TDN	0.07 $\pm$ 0.01 a	0.08 $\pm$ 0.01 a	0.08 $\pm$ 0.00 a	0.07 $\pm$ 0.01 a	0.07 $\pm$ 0.01 a	36.1 $\pm$ 2.44 ab	20.3 $\pm$ 2.68 a	41.5 $\pm$ 7.37 b	41.6 $\pm$ 7.07 b	33.1 $\pm$ 2.96 ab
3-hydroxy- β -damascone	0.15 $\pm$ 0.01 a	0.19 $\pm$ 0.02 a	0.13 $\pm$ 0.02 a	0.12 $\pm$ 0.03 a	0.17 $\pm$ 0.04 a	0.31 $\pm$ 0.01 ab	0.07 $\pm$ 0.01 a	0.38 $\pm$ 0.02 ab	0.28 $\pm$ 0.01 ab	0.74 $\pm$ 0.06 b
Sum of norisoprenoids	4.71 $\pm$ 0.92 a	6.01 $\pm$ 0.06 ab	6.83 $\pm$ 0.00 ab	7.74 $\pm$ 1.19 b	7.41 $\pm$ 0.81 ab	114 $\pm$ 8.13 ab	66.4 $\pm$ 0.81 a	116 $\pm$ 13.3 ab	121 $\pm$ 11.0 b	86.6 $\pm$ 1.44 ab
Farnesol 1	0.27 $\pm$ 0.01 a	0.31 $\pm$ 0.05 ab	0.32 $\pm$ 0.01 ab	0.58 $\pm$ 0.07 b	0.44 $\pm$ 0.07 ab	0.66 $\pm$ 0.04 ab	0.31 $\pm$ 0.05 a	0.60 $\pm$ 0.04 ab	0.31 $\pm$ 0.12 a	1.81 $\pm$ 0.63 b
Nerolidol 1	1.86 $\pm$ 0.38 ab	1.76 $\pm$ 0.16 a	1.91 $\pm$ 0.45 ab	2.75 $\pm$ 0.59 b	2.20 $\pm$ 0.63 ab	3.81 $\pm$ 0.67 ab	3.46 $\pm$ 0.36 ab	3.79 $\pm$ 1.00 ab	4.87 $\pm$ 0.97 b	2.65 $\pm$ 0.07 a
Bisabolol	0.03 $\pm$ 0.00 a	0.01 $\pm$ 0.00 a	0.03 $\pm$ 0.00 a	0.03 $\pm$ 0.01 a	0.02 $\pm$ 0.01 a	0.03 $\pm$ 0.02 a	0.05 $\pm$ 0.01 a	0.04 $\pm$ 0.02 a	0.07 $\pm$ 0.04 a	0.03 $\pm$ 0.01 a
Sum of sesquiterpenes	2.15 $\pm$ 0.42 ab	2.08 $\pm$ 0.13 a	2.25 $\pm$ 0.38 ab	3.36 $\pm$ 0.78 b	2.66 $\pm$ 0.67 ab	4.50 $\pm$ 0.51 a	3.83 $\pm$ 0.32 a	4.42 $\pm$ 0.89 a	5.25 $\pm$ 1.05 a	4.49 $\pm$ 1.68 a
Methyl salicylate	1.85 $\pm$ 0.09 a	2.66 $\pm$ 0.32 a	2.32 $\pm$ 0.13 a	2.25 $\pm$ 0.42 a	2.47 $\pm$ 0.24 a	19.7 $\pm$ 2.56 b	2.42 $\pm$ 0.20 ab	6.27 $\pm$ 2.46 ab	19.8 $\pm$ 5.76 b	1.93 $\pm$ 0.08 a
Benzaldehyde	1.10 $\pm$ 0.11 a	1.22 $\pm$ 0.23 ab	1.49 $\pm$ 0.23 ab	2.25 $\pm$ 0.98 b	1.39 $\pm$ 0.79 ab	2.25 $\pm$ 0.23 ab	2.29 $\pm$ 0.19 b	1.47 $\pm$ 0.09 ab	1.41 $\pm$ 0.08 a	1.82 $\pm$ 0.20 ab
2,6-Dimethoxyphenol	3.99 $\pm$ 0.23 a	4.34 $\pm$ 0.05 a	3.96 $\pm$ 0.39 a	3.70 $\pm$ 0.58 a	3.89 $\pm$ 0.76 a	2.89 $\pm$ 0.24 a	3.04 $\pm$ 0.36 a	3.02 $\pm$ 0.18 a	3.00 $\pm$ 0.32 a	3.08 $\pm$ 0.19 a
Vanillin	32.8 $\pm$ 0.85 a	35.7 $\pm$ 2.25 a	32.2 $\pm$ 0.76 a	30.7 $\pm$ 2.26 a	37.0 $\pm$ 7.32 a	24.7 $\pm$ 0.80 a	28.1 $\pm$ 1.15 a	31.2 $\pm$ 2.01 a	24.3 $\pm$ 2.10 a	31.4 $\pm$ 1.78 a
Eugenol	1.92 $\pm$ 0.08 a	2.98 $\pm$ 0.11 b	2.12 $\pm$ 0.10 ab	1.98 $\pm$ 0.03 a	2.52 $\pm$ 0.28 ab	0.23 $\pm$ 0.01 a	0.21 $\pm$ 0.01 a	0.23 $\pm$ 0.01 a	0.22 $\pm$ 0.03 a	0.23 $\pm$ 0.01 a
Ethyl cinnamate	0.12 $\pm$ 0.01 a	0.33 $\pm$ 0.05 b	0.12 $\pm$ 0.03 a	0.22 $\pm$ 0.06 ab	0.25 $\pm$ 0.06 ab	0.16 $\pm$ 0.03 a	0.33 $\pm$ 0.01 ab	0.20 $\pm$ 0.01 ab	0.31 $\pm$ 0.04 ab	0.38 $\pm$ 0.02 b
Sum of benzenoids	41.8 $\pm$ 0.70 a	47.2 $\pm$ 1.67 a	42.2 $\pm$ 0.57 a	41.1 $\pm$ 2.74 a	47.6 $\pm$ 7.16 a	49.9 $\pm$ 3.27 b	36.4 $\pm$ 1.53 a	42.4 $\pm$ 3.58 ab	49.1 $\pm$ 5.11 ab	38.8 $\pm$ 2.03 ab

Different letters in the same row denote statistically significant differences as obtained by the Kruskal–Wallis test ($\alpha = 0.05$) and Dunn's test.

Table 4. The concentration in µg/L of volatile aroma compounds of wines inoculated with yeast SP665 at two different times (T1—end of second fermentation and T2—three months of aging).

	Control	A	T1 B	C	D	Control	A	T2 B	C	D
Methanethiol	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	2.73 ± 0.92 a	3.40 ± 0.23 a	4.85 ± 0.47 a	2.61 ± 0.58 a	3.96 ± 0.90 a
Carbon disulfide	3.05 ± 0.15 a	2.96 ± 0.08 a	2.98 ± 0.05 a	3.15 ± 0.14 a	3.05 ± 0.23 a	5.59 ± 0.19 ab	6.10 ± 1.35 ab	5.48 ± 0.10 a	7.30 ± 0.45 ab	8.98 ± 1.24 b
DMS	1.34 ± 0.09 a	1.31 ± 0.05 a	1.17 ± 0.05 a	1.28 ± 0.09 a	1.16 ± 0.13 a	3.42 ± 0.17 a	3.92 ± 0.55 a	3.53 ± 0.64 a	3.70 ± 0.20 a	3.34 ± 0.38 a
DES	0.10 ± 0.01 ab	0.08 ± 0.02 ab	0.05 ± 0.01 a	0.19 ± 0.02 b	0.09 ± 0.00 ab	0.73 ± 0.09 a	0.82 ± 0.07 a	0.65 ± 0.16 a	0.76 ± 0.19 a	0.69 ± 0.07 a
DMDS	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Sum of VSC	4.49 ± 0.21 a	4.35 ± 0.03 a	4.20 ± 0.09 a	4.62 ± 0.22 a	4.30 ± 0.44 a	12.5 ± 0.72 a	14.2 ± 1.82 ab	14.5 ± 3.29 ab	14.4 ± 0.37 ab	17.0 ± 2.52 b
1-Butanol	39.4 ± 2.16 a	39.0 ± 2.19 a	39.4 ± 1.16 a	37.8 ± 3.47 a	36.1 ± 3.81 a	64.6 ± 4.52 ab	57.9 ± 3.18 ab	56.3 ± 6.56 ab	50.8 ± 3.88 a	131 ± 10.3 b
1-Pentanol	145 ± 59.9 a	133 ± 41.2 a	123 ± 55.4 a	139 ± 63.8 a	143 ± 14.2 a	531 ± 55.4 b	508 ± 29.4 ab	518 ± 43.8 ab	264 ± 23.8 a	498 ± 62.1 ab
Isoamyl alcohol	184,684 ± 6213 a	176,442 ± 19,332 a	184,779 ± 2773 a	188,788 ± 17,804 a	191,057 ± 8486 a	72,667 ± 3105 a	70,376 ± 9426 a	66,438 ± 8279 a	59,974 ± 1199 a	69,878 ± 5926 a
Methionol	166 ± 9.38 a	164 ± 11.1 a	167 ± 9.47 a	149 ± 4.79 a	164 ± 9.87 a	177 ± 18.9 a	197 ± 19.6 a	183 ± 11.8 a	176 ± 16.5 a	188 ± 20.6 a
Phenylethyl Alcohol	17,206 ± 1636 a	18,120 ± 1085 a	16,407 ± 914 a	17,984 ± 1458 a	17,747 ± 110 a	7208 ± 632 a	6949 ± 186 a	6955 ± 402 a	7376 ± 478 a	6951 ± 691 a
Benzyl Alcohol	38.9 ± 1.75 ab	62.1 ± 2.63 b	38.5 ± 2.77 a	40.1 ± 6.36 ab	46.2 ± 1.75 ab	54.5 ± 2.53 a	88.9 ± 9.31 ab	148 ± 8.76 ab	61.3 ± 5.95 ab	179 ± 15.3 b
Sum of higher alcohol	202,279 ± 7755 a	194,960 ± 19,777 a	201,554 ± 3450 a	207,137 ± 19,334 a	209,194 ± 8587 a	80,703 ± 3730 a	78,178 ± 9657 a	74,299 ± 8733 a	67,903 ± 1727 a	77,827 ± 6722 a
1-Hexanol	384 ± 4.54 a	384 ± 13.2 a	397 ± 14.6 a	381 ± 25.0 a	383 ± 18.6 a	499 ± 17.8 a	483 ± 55.8 a	491 ± 27.0 a	486 ± 70.2 a	506 ± 39.0 a
cis-3-Hexen-1-ol	7.75 ± 0.24 a	7.94 ± 0.43 a	8.18 ± 0.29 a	7.86 ± 0.42 a	7.84 ± 0.46 a	8.21 ± 0.98 a	8.33 ± 0.78 a	7.99 ± 0.67 a	8.42 ± 0.71 a	8.08 ± 0.73 a
trans-3-Hexen-1-ol	121 ± 2.17 a	124 ± 3.96 a	123 ± 4.16 a	119 ± 8.63 a	121 ± 5.30 a	124 ± 13.0 a	127 ± 10.9 a	133 ± 12.8 a	122 ± 13.3 a	140 ± 8.92 a
cis-2-hexen-1-ol	4.72 ± 0.24 a	4.71 ± 0.35 a	4.89 ± 0.36 a	4.82 ± 0.34 a	4.78 ± 0.23 a	13.4 ± 1.30 a	14.4 ± 1.76 a	14.5 ± 0.22 a	12.6 ± 1.45 a	14.4 ± 1.09 a
Sum of C6 alcohols	517 ± 6.53 a	521 ± 17.8 a	533 ± 19.3 a	512 ± 34.4 a	517 ± 24.5 a	644 ± 32.7 a	633 ± 69.2 a	647 ± 40.6 a	629 ± 85.7 a	668 ± 48.3 a
Isoamyl acetate	2255 ± 137 a	2162 ± 53.8 a	2159 ± 276 a	2127 ± 468 a	2125 ± 88.1 a	1598 ± 115 a	1600 ± 136 a	1608 ± 204 a	1597 ± 146 a	1553 ± 177 a
n-Hexyl acetate	52.4 ± 10.3 a	55.6 ± 4.57 a	45.6 ± 18.2 a	49.0 ± 10.8 a	51.6 ± 9.40 a	40.2 ± 3.79 ab	46.7 ± 2.17 ab	45.5 ± 3.80 ab	48.7 ± 5.08 b	39.3 ± 2.46 a
2-Phenethyl acetate	258 ± 31.8 a	267 ± 9.97 a	235 ± 60.4 a	242 ± 72.5 a	252 ± 27.3 a	168 ± 12.8 ab	177 ± 14.2 ab	185 ± 8.35 ab	201 ± 12.3 b	164 ± 23.1 a
Sum of acetates	2564 ± 179 a	2484 ± 67.2 a	2440 ± 354 a	2417 ± 562 a	2428 ± 124 a	1807 ± 128 a	1823 ± 151 a	1838 ± 216 a	1847 ± 162 a	1756 ± 202 a
Ethyl butanoate	225 ± 3.22 a	224 ± 9.30 a	226 ± 4.63 a	226 ± 24.0 a	221 ± 2.89 a	243 ± 9.74 a	237 ± 19.3 a	231 ± 14.5 a	230 ± 14.5 a	234 ± 8.20 a
Ethyl hexanoate	684 ± 135 a	746 ± 46.1 a	590 ± 25.6 a	655 ± 267 a	688 ± 104 a	679 ± 61.6 a	718 ± 33.2 a	703 ± 76.9 a	724 ± 68.3 a	712 ± 84.7 a
Ethyl octanoate	500 ± 159 a	598 ± 131 a	403 ± 85.3 a	500 ± 272 a	563 ± 179 a	355 ± 48.1 a	519 ± 25.0 ab	499 ± 7.64 ab	630 ± 44.1 b	513 ± 35.4 ab
Ethyl decanoate	65.0 ± 15.9 a	66.5 ± 10.5 a	59.1 ± 8.40 a	76.0 ± 9.58 a	80.0 ± 27.6 a	34.4 ± 4.00 a	58.1 ± 6.36 ab	68.4 ± 5.59 ab	102 ± 7.65 b	80.5 ± 6.21 ab
Sum of ethyl esters of straight-chain fatty acids	1474 ± 308 a	1634 ± 208 a	1278 ± 566 a	1456 ± 600 a	1553 ± 306 a	1312 ± 123 a	1532 ± 79.2 ab	1501 ± 103 ab	1686 ± 132 b	1540 ± 130 ab
Ethyl-2-methylbutanoate	2.80 ± 0.18 a	2.86 ± 0.24 a	2.56 ± 0.42 a	2.63 ± 0.55 a	2.81 ± 0.08 a	5.33 ± 0.52 ab	5.63 ± 0.45 b	4.28 ± 0.40 a	4.88 ± 0.42 ab	4.79 ± 0.26 ab
Ethyl 3-methylbutanoate	4.11 ± 0.71 a	4.20 ± 0.47 a	4.93 ± 0.38 a	5.00 ± 0.42 a	3.01 ± 0.76 a	10.5 ± 1.32 ab	12.1 ± 1.14 b	11.5 ± 0.87 ab	9.22 ± 0.87 a	9.75 ± 0.79 ab
Ethyl 3-hydroxybutyrate	65.9 ± 2.79 a	70.9 ± 1.66 a	69.8 ± 4.10 a	72.4 ± 8.62 a	70.3 ± 2.31 a	64.3 ± 4.83 a	67.4 ± 5.75 a	65.1 ± 4.25 a	56.3 ± 7.21 a	65.2 ± 5.51 a
Ethyl di-2-hydroxyhexanoate	0.48 ± 0.01 a	0.48 ± 0.02 a	0.49 ± 0.02 a	0.47 ± 0.04 a	0.48 ± 0.01 a	0.97 ± 0.09 a	0.92 ± 0.05 a	0.86 ± 0.09 a	0.87 ± 0.06 a	0.89 ± 0.09 a
Sum of ethyl esters of branched fatty acids	73.3 ± 2.94 a	78.4 ± 1.45 a	77.7 ± 4.84 a	80.5 ± 9.60 a	76.6 ± 3.15 a	81.1 ± 6.57 a	86.0 ± 7.23 a	81.8 ± 5.5 a	71.3 ± 8.5 a	80.6 ± 6.64 a
3-Methylbutanoic acid	196 ± 4.66 a	194 ± 5.07 a	195 ± 8.29 a	194 ± 14.8 a	199 ± 8.38 a	266 ± 22.2 a	257 ± 19.4 a	267 ± 34.5 a	269 ± 11.5 a	261 ± 22.9 a
Hexanoic acid	5922 ± 434 a	5733 ± 185 a	6045 ± 279 a	5900 ± 468 a	5904 ± 261 a	4547 ± 318 a	4255 ± 407 a	4063 ± 247 a	4189 ± 293 a	3923 ± 468 a
Octanoic acid	10,317 ± 645 a	10,281 ± 233 a	10,547 ± 123 a	10,314 ± 670 a	10,321 ± 240 a	7282 ± 442 a	7410 ± 687 a	7468 ± 224 a	7912 ± 678 a	7107 ± 971 a
Sum of fatty acids	16,435 ± 1077 a	16,209 ± 421 a	16,788 ± 381 a	16,407 ± 1153 a	16,424 ± 506 a	12,095 ± 781 a	11,921 ± 1108 a	11,798 ± 504 a	12,370 ± 960 a	11,291 ± 1458 a
α-Phellandrene	0.02 ± 0.00 a	0.03 ± 0.01 a	0.04 ± 0.01 a	0.03 ± 0.00 a	0.03 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.01 a	0.01 ± 0.00 a
α-Terpinene	<LOQ	<LOQ	0.04 ± 0.00	<LOQ	0.03 ± 0.00	<LOQ	<LOQ	<LOQ	0.03 ± 0.01	0.03 ± 0.01
γ-Terpinene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
β-Pinene	0.00 ± 0.00 a	0.03 ± 0.00 a	0.02 ± 0.01 a	0.02 ± 0.01 a	0.01 ± 0.00 a	0.01 ± 0.01 a	0.01 ± 0.01 a	0.01 ± 0.00 a	0.01 ± 0.01 a	0.01 ± 0.00 a
3-Carene	<LOQ	<LOQ	<LOQ	<LOQ	0.03 ± 0.00	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
β-Myrcene	0.07 ± 0.01 a	0.10 ± 0.01 a	0.12 ± 0.03 a	0.11 ± 0.03 a	0.09 ± 0.01 a	0.10 ± 0.03 ab	0.14 ± 0.02 b	0.09 ± 0.01 ab	0.08 ± 0.03 a	0.08 ± 0.00 a

Table 4. Cont.

	Control	A	T1 B	C	D	Control	A	T2 B	C	D
Limonene	0.34 ± 0.01 a	0.34 ± 0.03 a	0.37 ± 0.01 a	0.35 ± 0.03 a	0.36 ± 0.01 a	0.34 ± 0.00 a	0.35 ± 0.01 a	0.35 ± 0.01 a	0.35 ± 0.02 a	0.35 ± 0.01 a
1,4-Cineole	0.02 ± 0.01 a	0.01 ± 0.01 a	<LOQ	<LOQ	<LOQ	0.10 ± 0.01 a	1.11 ± 0.09 ab	1.85 ± 0.02 b	1.11 ± 0.11 ab	0.21 ± 0.06 ab
1,8-Cineole	0.01 ± 0.01	<LOQ	<LOQ	0.01 ± 0.01	0.01 ± 0.01	<LOQ	<LOQ	<LOQ	0.01 ± 0.00	<LOQ
p-Cymene	<LOQ	0.08 ± 0.01	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Terpinolene	0.07 ± 0.03 a	0.10 ± 0.01 a	0.09 ± 0.02 a	0.07 ± 0.02 a	0.09 ± 0.01 a	0.05 ± 0.01 a	0.07 ± 0.01 ab	0.09 ± 0.01 ab	0.10 ± 0.04 b	0.10 ± 0.01 b
Linalool	2.63 ± 0.42 a	3.24 ± 0.15 a	2.98 ± 0.22 a	3.00 ± 0.23 a	3.06 ± 0.23 a	2.36 ± 0.09 ab	3.28 ± 0.26 b	2.25 ± 0.06 ab	2.26 ± 0.81 ab	1.98 ± 0.47 a
Terpinen-4-ol	0.19 ± 0.04 ab	0.27 ± 0.03 b	0.19 ± 0.02 ab	0.08 ± 0.02 a	0.10 ± 0.01 ab	0.30 ± 0.02 a	0.28 ± 0.01 a	0.30 ± 0.01 a	0.33 ± 0.03 a	0.28 ± 0.01 a
α-Terpineol	1.13 ± 0.26 a	1.73 ± 0.05 a	1.62 ± 0.40 a	1.37 ± 0.12 a	1.54 ± 0.02 a	1.55 ± 0.28 ab	1.63 ± 0.10 ab	1.50 ± 0.14 a	2.77 ± 0.76 b	2.22 ± 0.09 ab
β-Citronellol	1.24 ± 0.36 a	2.07 ± 0.56 ab	1.43 ± 0.19 ab	1.67 ± 0.36 ab	2.56 ± 0.92 b	1.48 ± 0.96 b	1.28 ± 0.14 ab	0.95 ± 0.16 ab	0.96 ± 0.16 ab	0.82 ± 0.06 a
Nerol	0.19 ± 0.07 a	0.18 ± 0.01 a	0.40 ± 0.09 a	0.32 ± 0.01 a	0.33 ± 0.03 a	0.46 ± 0.04 a	0.52 ± 0.03 ab	0.78 ± 0.10 ab	0.74 ± 0.29 ab	1.38 ± 0.20 b
Geraniol	2.01 ± 0.10 a	2.14 ± 0.17 a	2.95 ± 0.57 a	2.21 ± 0.46 a	1.96 ± 0.66 a	0.92 ± 0.20 a	2.19 ± 0.47 b	1.17 ± 0.11 ab	1.43 ± 0.32 ab	1.01 ± 0.35 ab
Linalyl acetate	0.16 ± 0.06 a	0.27 ± 0.02 a	0.15 ± 0.07 a	0.18 ± 0.04 a	0.23 ± 0.08 a	0.18 ± 0.01 a	0.11 ± 0.06 a	0.30 ± 0.09 a	0.15 ± 0.03 a	0.17 ± 0.02 a
Geranyl acetate	0.07 ± 0.04 a	0.08 ± 0.01 a	0.12 ± 0.00 a	0.12 ± 0.02 a	0.09 ± 0.01 a	0.08 ± 0.01 a	0.09 ± 0.01 a	0.10 ± 0.01 a	0.09 ± 0.01 a	0.09 ± 0.01 a
Geranyl acetone	0.91 ± 0.02 b	0.10 ± 0.02 a	0.10 ± 0.01 a	0.16 ± 0.06 ab	0.90 ± 0.03 b	0.10 ± 0.03 ab	0.12 ± 0.03 ab	0.08 ± 0.01 a	1.45 ± 0.17 b	0.08 ± 0.03 a
Sum of monoterpenoids	9.14 ± 1.27 a	11.0 ± 1.65 a	10.7 ± 1.77 a	9.80 ± 1.09 a	11.5 ± 1.37 a	8.00 ± 1.13 a	11.29 ± 1.00 a	9.95 ± 2.77 a	12.0 ± 3.03 a	8.91 ± 1.80 a
β-Damascenone	1.39 ± 0.34 a	1.59 ± 0.18 a	1.48 ± 0.46 a	1.72 ± 0.21 a	1.57 ± 0.20 a	1.21 ± 0.02 a	1.37 ± 0.17 a	1.46 ± 0.13 a	1.34 ± 0.15 a	1.39 ± 0.17 a
α-Ionol	0.01 ± 0.00 a	0.02 ± 0.02 a	0.01 ± 0.01 a	0.03 ± 0.00 a	0.02 ± 0.02 a	0.01 ± 0.01 a	0.01 ± 0.00 a	0.02 ± 0.01 a	0.01 ± 0.00 a	0.01 ± 0.01 a
4-Oxoisophorone	5.21 ± 1.79 a	6.60 ± 0.87 ab	9.77 ± 0.83 ab	14.3 ± 0.76 b	8.73 ± 2.24 ab	0.44 ± 0.05 a	0.49 ± 0.10 ab	0.65 ± 0.06 ab	0.73 ± 0.24 ab	0.82 ± 0.13 b
Vitispirane 1	0.06 ± 0.02 a	0.08 ± 0.01 a	0.08 ± 0.01 a	0.06 ± 0.02 a	0.07 ± 0.00 a	24.6 ± 3.75 a	31.5 ± 3.13 ab	49.2 ± 3.9 ab	79.5 ± 17.4 b	63.5 ± 13.7 b
Vitispirane 2	0.08 ± 0.00 a	0.11 ± 0.02 a	0.12 ± 0.03 a	0.08 ± 0.02 a	0.10 ± 0.00 a	24.7 ± 5.05 a	30.1 ± 3.88 ab	53.1 ± 0.93 ab	94.2 ± 13.4 b	71.5 ± 16.8 ab
TPB	0.00 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	0.01 ± 0.00 a	1.87 ± 0.11 a	2.03 ± 0.27 ab	2.62 ± 0.37 ab	3.98 ± 0.55 b	3.82 ± 0.19 ab
TDN	0.06 ± 0.02 a	0.07 ± 0.01 a	0.08 ± 0.01 a	0.07 ± 0.02 a	0.06 ± 0.04 a	29.9 ± 9.12 a	29.7 ± 3.22 a	41.5 ± 3.73 ab	55.1 ± 16.4 b	58.3 ± 9.13 b
3-hydroxy-β-damascone	0.00 ± 0.00 a	0.23 ± 0.05 b	0.11 ± 0.00 ab	0.09 ± 0.00 ab	0.09 ± 0.00 ab	0.00 ± 0.00 a	0.00 ± 0.00 a	0.15 ± 0.01 ab	0.07 ± 0.00 ab	0.18 ± 0.01 b
Sum of norisoprenoids	6.82 ± 2.12 a	8.71 ± 1.01 ab	11.7 ± 8.29 ab	16.3 ± 0.62 b	10.7 ± 2.05 ab	82.7 ± 17.2 a	95.2 ± 10.3 ab	149 ± 8.1 ab	235 ± 88.2 b	200 ± 39.6 b
Farnesol 1	0.47 ± 0.09 a	0.55 ± 0.07 a	0.36 ± 0.09 a	0.72 ± 0.23 a	0.68 ± 0.04 a	0.25 ± 0.10 a	1.64 ± 0.23 ab	1.78 ± 0.34 ab	0.25 ± 0.08 a	5.25 ± 0.82 b
Nerolidol 1	0.02 ± 0.01 a	0.01 ± 0.01 a	0.05 ± 0.00 a	0.02 ± 0.01 a	0.02 ± 0.01 a	1.78 ± 0.16 a	2.78 ± 0.27 a	2.89 ± 0.34 a	2.87 ± 0.80 a	2.94 ± 0.64 a
Bisabolol	0.01 ± 0.01 a	0.12 ± 0.00 ab	0.19 ± 0.05 b	0.02 ± 0.01 a	0.02 ± 0.01 a	0.04 ± 0.01 a	0.02 ± 0.02 a	0.16 ± 0.01 a	0.04 ± 0.01 a	0.04 ± 0.02 a
Sum of sesquiterpenes	0.50 ± 0.29 a	0.69 ± 0.52 a	0.60 ± 0.13 a	0.76 ± 0.23 a	0.71 ± 0.04 a	2.06 ± 0.07 a	4.44 ± 3.42 ab	4.83 ± 2.51 ab	3.17 ± 0.74 ab	8.23 ± 5.3 b
Methyl salicylate	2.08 ± 0.27 a	2.57 ± 0.22 ab	3.33 ± 0.50 b	2.22 ± 0.10 ab	2.49 ± 0.09 ab	1.69 ± 0.05 a	2.35 ± 0.27 ab	1.79 ± 0.17 ab	3.34 ± 0.85 b	2.13 ± 0.11 ab
Benzaldehyde	1.70 ± 0.16 a	2.08 ± 0.27 a	2.17 ± 0.30 a	2.31 ± 0.19 a	1.92 ± 0.36 a	1.47 ± 0.04 ab	1.16 ± 0.05 a	1.37 ± 0.12 ab	1.29 ± 0.14 ab	1.61 ± 0.10 b
2,6-Dimethoxyphenol	3.88 ± 0.73 a	4.07 ± 0.33 a	4.17 ± 0.02 a	4.24 ± 0.06 a	3.87 ± 0.73 a	2.96 ± 0.12 a	3.01 ± 0.35 a	2.99 ± 0.44 a	4.47 ± 0.63 a	2.95 ± 0.35 a
Vanillin	34.5 ± 0.91 a	36.0 ± 1.50 a	35.0 ± 1.06 a	35.5 ± 2.78 a	34.3 ± 1.88 a	22.2 ± 0.81 ab	25.3 ± 2.18 ab	1.99 ± 0.10 a	27.0 ± 2.49 b	24.4 ± 3.02 ab
Eugenol	2.02 ± 0.08 ab	3.10 ± 0.06 b	2.14 ± 0.11 ab	1.47 ± 0.08 a	2.16 ± 0.09 ab	0.23 ± 0.01 ab	0.23 ± 0.01 ab	0.22 ± 0.02 a	0.60 ± 0.08 b	0.67 ± 0.08 b
Ethyl cinnamate	0.19 ± 0.03 a	0.40 ± 0.05 b	0.23 ± 0.06 ab	0.22 ± 0.05 ab	0.18 ± 0.04 a	0.12 ± 0.02 a	0.28 ± 0.05 ab	0.16 ± 0.02 ab	0.25 ± 0.03 ab	0.33 ± 0.03 b
Sum of benzenoids	44.4 ± 0.64 a	48.1 ± 1.12 a	47.0 ± 1.29 a	46.0 ± 3.95 a	45.0 ± 2.72 a	28.7 ± 1.02 ab	32.3 ± 2.82 ab	8.52 ± 0.72 a	42.1 ± 9.94 b	32.1 ± 3.68 ab

Different letters in the same row denote statistically significant differences as obtained by the Kruskal–Wallis test ($\alpha = 0.05$) and Dunn's test.

At T1, in wines fermented with CGC62, the addition of enzymes promoted the production of higher alcohols, ethyl esters from straight-chain fatty acids, norisoprenoids, and sesquiterpenes. In contrast, for VSC, enzyme addition had the opposite effect, resulting in significantly lower levels compared to the control. Wines treated with enzyme A (pectinolytic and glycosidic enzymes) exhibited higher alcohol levels, similar to those of the control, while the other enzymes led to a decrease. However, enzyme A significantly reduced ethyl esters from straight-chain fatty acids and sesquiterpenes. Enzyme C (β -glucanase) enhanced the presence of varietal compounds, yielding the highest levels of sesquiterpenes and the norisoprenoid 4-oxoisophorone, while simultaneously reducing VSC and higher alcohol levels. Wines treated with enzyme B (pectinolytic enzymes with β -glucanase) displayed significantly higher concentrations of ethyl esters from straight-chain fatty acids.

A greater enzyme effect was observed after three months of aging (T2) in wines fermented with CGC62, where significant differences were found in most compound families, except for VSC, ethyl esters from branched-chain fatty acids, and sesquiterpenes. In general, enzyme addition increased the concentrations of aroma compounds compared to the control, except for C6 alcohols, acetate esters, and benzenoids. Enzyme C led to the highest levels of monoterpenoids and norisoprenoids, while enzyme D increased higher alcohol concentrations. Enzymes A and B promoted the accumulation of fatty acids and ethyl esters from straight-chain fatty acids, respectively. Notably, enzyme A resulted in the lowest levels of most compounds compared to the control and other enzyme treatments. The control wines had the lowest fatty acid concentrations, whereas enzyme D did not favor the formation of monoterpenoids.

Unlike CGC62, no significant differences were observed in SP665 wines at T1. The composition and structure of β -glucans and mannoproteins can vary significantly between *Saccharomyces cerevisiae* strains [38], affecting their susceptibility to exogenous glucanases. A strain with a more rigid or differently structured β -glucan layer might be less accessible to enzyme hydrolysis, explaining the more limited effect observed for SP665. However, at T2, significant variations were found in VSC, ethyl esters from straight-chain fatty acids, benzenoids, norisoprenoids, and sesquiterpenes. The control wines exhibited significantly lower levels of these compounds, indicating that the addition of the enzyme had a positive impact. Among the enzyme treatments, enzymes C and D showed the best performance, yielding the highest concentrations of these aroma compounds (Table 4). The results demonstrated a non-uniform effect of the enzymes. The effect of the enzymes on the aromatic profile of Prosecco wines also seemed to depend on the yeast strain. The increase in VSC could be linked to the degradation of amino acids released into the wine or to the chemical transformation of VSC produced during fermentation, as has been suggested for CS₂ and MeSH [39]. By accelerating cell lysis, the enzymes could promote the release of sulfur-containing amino acids into the wine which, subsequently degrading chemically, lead to the formation of VSCs.

It should be noted, however, that the differences observed between the methods, although significant, were not wide. Prosecco wine is characterized primarily by fermentative aromas [5]. The variations in concentrations of terpenes, sesquiterpenes, norisoprenoids, and benzenoids are on the order of a few micrograms per liter, insufficient or far from the olfactory thresholds (Table S1) [40–58], and therefore unlikely to significantly impact the aroma of the wines. This could be positive if the purpose of using glucanase enzymes is merely flavor. The observed increase in the concentration of monoterpenoids and norisoprenoids, particularly in CGC62 wines treated with enzyme C (a preparation containing β -glucanase and glycosidase activities; EC 232-885-6; EC 263-462-4), can be attributed to the specific enzymatic activities of this formulation. β -glucanases target yeast cell wall

β -glucans primarily, potentially accelerating autolysis and the release of intracellular compounds or cell-wall-bound enzymes into the wine matrix [10,17,19]. More importantly, the glycosidase activity present in this preparation is known to hydrolyze glycosidic precursors of varietal aroma compounds, such as terpenes and norisoprenoids, thereby increasing the concentration of their free, odor-active forms [35]. This synergistic action, enhancing both the liberation of yeast-derived components and the cleavage of grape-derived glycosidic precursors, likely explains the significant enhancement of these compound families. In contrast, the more limited impact of enzyme A (pectinolytic and glycosidic enzymes) or enzyme B (pectinolytic with β -glucanase) suggests that the specific combination and balance of β -glucanase and glycosidase activities in enzyme C were particularly effective under the conditions of this study, especially in interaction with the CGC62 yeast strain. These mechanisms are consistent with previous literature on the role of exogenous glycosidases in wine aroma development and the impact of yeast cell wall-degrading enzymes on the release of intracellular metabolites during lees aging [35]. Enzyme A was reported to have glucosidase activity and, therefore, was suitable for aroma release; however, it was found to be less effective in aroma release than other enzymes, such as enzyme C. It could be that enzyme A has greater substrate specificity (aglycone and glycosidic moiety) and is therefore less effective in the presence of heterogeneous and complex precursors present in wine.

The results obtained indicate that the use of glucanase enzymes combined with a short (3-month) sur-lies aging of Prosecco wine does not significantly affect the wine's aromatic profile. However, a greater effect cannot be excluded if the aging period were extended for a larger number of months. The use of these relatively expensive enzymes in this wine style could be justified when aiming to enhance perlage and mouthfeel by accelerating cell lysis to promote the release of polysaccharides and proteins.

4. Conclusions

This study highlighted the significant influence of yeast strain and aging time on the fermentation kinetics and aroma composition of sparkling wines. The two yeast strains, SP665 and CGC62, exhibited markedly different refermentation behaviors and aroma profiles. SP665 showed faster fermentation kinetics and higher-pressure development, while CGC62 demonstrated a slower, more gradual fermentation. Aroma analysis revealed that both the yeast strain and aging period played a key role in shaping the volatile profile, with distinct differences in compound families, including volatile sulfur compounds, esters, and varietal aromas.

Glucanase enzyme addition showed variable effects on wine aroma depending on both the yeast strain and aging time. The influence was more pronounced in CGC62 wines, particularly after three months of aging, where enzyme treatments generally enhanced the concentration of several aroma compound families. In contrast, SP665 wines exhibited fewer significant changes, with only a few compounds affected by enzyme treatments at T2.

While enzyme use led to statistically significant differences in certain aroma compounds, these variations were often below sensory thresholds and thus unlikely to have a strong impact on the overall aroma of the wines. This suggests that glucanase enzymes may be used to enhance the mouthfeel and stability of wine without substantially altering the characteristic aroma profile of Prosecco. These findings are valuable for optimizing winemaking strategies in sparkling wine production without compromising the typical aromatic profile of Prosecco.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/beverages12010008/s1>, Table S1: Odor thresholds of analyzed compounds.

Author Contributions: Conceptualization, D.S., J.A.S.S., A.B., A.D.C., V.Z. and G.L.; methodology, J.A.S.S., D.S., A.B., A.D.C., V.Z. and G.L.; validation, D.S.; formal analysis, N.P.B., O.M., V.Z. and J.A.S.S.; data curation, G.L., D.S. and J.A.S.S.; writing—original draft preparation, J.A.S.S. and D.S.; writing—review and editing, N.P.B., O.M., M.U., J.A.S.S. and G.L.; visualization, D.S.; project administration, D.S.; funding acquisition, D.S., A.B., A.D.C., M.U. and V.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The work was funded by Joint Project 2019 developed by the University of Verona and Masi Agricola S.p.a., JPVR19WJAC titled “Influenza di pratiche enologiche sull’aroma di vini Prosecco, studio dell’utilizzo di enzimi durante la rifermentazione in autoclave”.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors have reviewed and edited the output and take full responsibility for the content of this publication.

Conflicts of Interest: D.S., O.M., J.A.S.S., M.U., G.L., and N.P.B. declare no conflict of interest. Authors A.B., A.D.C., and V.Z. were employed by the company Masi Agricola, the funder of the project. They participated in the conceptualization, the development of the experimental plan, and the procurement of raw materials to carry out the experiment. The company has no interest in promoting the results for commercial or corporate purposes.

References

1. Eurostat. 2024. Available online: <https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20241230-1> (accessed on 3 November 2025).
2. Luchian, C.E.; Grosaru, D.; Scutarașu, E.C.; Colibaba, L.C.; Scutarașu, A.; Cotea, V.V. Advancing Sparkling Wine in the 21st Century: From Traditional Methods to Modern Innovations and Market Trends. *Fermentation* **2025**, *11*, 174. [CrossRef]
3. Zimmerman, L.B. Champagne vs. Sparkling—The Shrinking Gap. *Wine Business Monthly*. 2018. Available online: <https://www.winebusiness.com/wbm/article/193495> (accessed on 3 November 2025).
4. Rossetto, L.; Gastaldello, G. The Loyalty Structure of Sparkling Wine Brands in Italy. *J. Wine Econ.* **2018**, *13*, 409–418. [CrossRef]
5. Tomasi, D.; Gaiotti, F.; Jones, G.V. *The Power of the Terroir: The Case Study of Prosecco*; Wine Springer: Basel, Switzerland, 2013.
6. Slaghenau, D.; Luzzini, G.; Borgato, M.; Boscaini, A.; Dal Cin, A.; Zandonà, V.; Ugliano, M. Characterization of the Aroma Profile of Commercial Prosecco Sparkling Wines. *Appl. Sci.* **2023**, *13*, 3609. [CrossRef]
7. Martínez-García, R.; García-Martínez, T.; Puig-Pujol, A.; Mauricio, J.C.; Moreno, J. Changes in sparkling wine aroma during the second fermentation under CO₂ pressure in sealed bottle. *Food Chem.* **2017**, *237*, 1030–1040. [CrossRef]
8. Ubeda, C.; Kania-Zelada, I.; del Barrio-Galán, R.; Medel-Marabolí, M.; Gil, M.; Peña-Neira, Á. Study of the changes in volatile compounds, aroma and sensory attributes during the production process of sparkling wine by traditional method. *Food Res. Int.* **2019**, *119*, 554–563. [CrossRef]
9. Charpentier, C.; Feuillat, M. Yeast autolysis. In *Wine Microbiology and Biotechnology*; Fleet, G.H., Ed.; Harwood Academic Publishers: Chur, Switzerland, 1993; pp. 225–242.
10. Alexandre, H.; Guilloux-Benatier, M. Yeast autolysis in sparkling wine—A review. *Aust. J. Grape Wine Res.* **2006**, *12*, 119–127. [CrossRef]
11. Vincenzi, S.; Crapisi, A.; Curioni, A. Foamability of Prosecco wine: Cooperative effects of high molecular weight glycoproteins and wine PR-proteins. *Food Hydrocoll.* **2014**, *34*, 202–207. [CrossRef]
12. Le Menn, N.; Marchand, S.; de Revel, G.; Demarville, D.; Laborde, D.; Marchal, R. N,S,O-Heterocycles in Aged Champagne Reserve Wines and Correlation with Free Amino Acid Concentrations. *J. Agric. Food Chem.* **2017**, *65*, 2345–2356. [CrossRef]
13. Sun, N.; Zhao, L.; Liu, A.; Su, L.; Shi, K.; Zhao, H.; Liu, S. Role of amino acids in flavor profiles and foam characteristics of sparkling wines during aging. *J. Food Compos. Anal.* **2024**, *126*, 105903. [CrossRef]
14. Wang, Q.J.; Spence, C. Is complexity worth paying for? Investigating the perception of wine complexity for single varietal and blended wines in consumers and experts. *Aust. J. Grape Wine Res.* **2018**, *25*, 243–251. [CrossRef]

15. Fedrizzi, B.; Magno, F.; Finato, F.; Versini, G. Variation of Some Fermentative Sulfur Compounds in Italian “Millesimè” Classic Sparkling Wines during Aging and Storage on Lees. *J. Agric. Food Chem.* **2010**, *58*, 9716–9722. [[CrossRef](#)]
16. Pinheiro, S.S.; Campos, F.; Cabrita, M.J.; da Silva, M.G. Exploring the Aroma Profile of Traditional Sparkling Wines: A Review on Yeast Selection in Second Fermentation, Aging, Closures, and Analytical Strategies. *Molecules* **2025**, *30*, 2825. [[CrossRef](#)]
17. Gnoinski, G.B.; Schmidt, S.A.; Close, D.C.; Goemann, K.; Pinfold, T.L.; Kerslake, F.L. Novel Methods to Manipulate Autolysis in Sparkling Wine: Effects on Yeast. *Molecules* **2021**, *26*, 387. [[CrossRef](#)] [[PubMed](#)]
18. Dubourdieu, D.; Villetaz, J.C.; Desplanques, C.; Ribéreau Gayon, P. Dégradation enzymatique du glucane de *Botrytis cinerea*. Application à l’amélioration de la clarification des vins issus de raisins pourris. *J. Int. Sci. Vigne Vin.* **1981**, *15*, 161–177. [[CrossRef](#)]
19. Torresi, S.; Frangipane, M.T.; Garzillo, A.M.V.; Massantini, R.; Contini, M. Effects of a β -glucanase enzymatic preparation on yeast lysis during aging of traditional sparkling wines. *Food Res. Int.* **2014**, *55*, 82–92. [[CrossRef](#)]
20. Alessandrini, M.; Gaiotti, F.; Belfiore, N.; Matarese, F.; D’Onofrio, C.; Tomasi, D. Influence of vineyard altitude on Glera grape ripening (*Vitis vinifera* L.): Effects on aroma evolution and wine sensory profile. *J. Sci. Food Agric.* **2016**, *97*, 2695–2705. [[CrossRef](#)] [[PubMed](#)]
21. Liger-Belair, G.; Religieux, J.-B.; Fohanno, S.; Vialatte, M.-A.; Jeandet, P.; Polidori, G. Visualization of Mixing Flow Phenomena in Champagne Glasses under Various Glass-Shape and Engraving Conditions. *J. Agric. Food Chem.* **2007**, *55*, 882–888. [[CrossRef](#)] [[PubMed](#)]
22. Slaghenau, D.; Guardini, S.; Tedeschi, R.; Ugliano, M. Volatile terpenoids, norisoprenoids and benzenoids as markers of fine scale vineyard segmentation for Corvina grapes and wines. *Food Res. Int.* **2019**, *125*, 108507. [[CrossRef](#)]
23. Cisilotto, B.; Scariot, F.J.; Schwarz, L.V.; Mattos Rocha, R.K.; Longaray Delamare, A.P.; Echeverrigaray, S. Differences in yeast behaviour during ageing of sparkling wines made with Charmat and Traditional methods. *Food Microbiol.* **2023**, *110*, 104171. [[CrossRef](#)]
24. Antalick, G.; Perello, M.-C.; de Revel, G. Esters in Wines: New Insight through the Establishment of a Database of French Wines. *Am. J. Enol. Vitic.* **2014**, *65*, 293–304. [[CrossRef](#)]
25. Díaz-Maroto, M.C.; Schneider, R.; Baumes, R. Formation Pathways of Ethyl Esters of Branched Short-Chain Fatty Acids during Wine Aging. *J. Agric. Food Chem.* **2005**, *53*, 3503–3509. [[CrossRef](#)]
26. Luzzini, G.; Slaghenau, D.; Ugliano, M. Approaches to the classification of wine aroma ageing potential. Applications to the case of terpenoids in Valpolicella red wines. *OENO One* **2022**, *56*, 221–232. [[CrossRef](#)]
27. Slaghenau, D.; Ugliano, M. Norisoprenoids, Sesquiterpenes and Terpenoids Content of Valpolicella Wines During Aging: Investigating Aroma Potential in Relationship to Evolution of Tobacco and Balsamic Aroma in Aged Wine. *Front. Chem.* **2018**, *6*, 66. [[CrossRef](#)]
28. Francioli, S.; Torrens, J.; Riu-Aumatell, M.; López-Tamames, E.; Buxaderas, S. Volatile Compounds by SPME-GC as Age Markers of Sparkling Wines. *Am. J. Enol. Vitic.* **2003**, *54*, 158–162. [[CrossRef](#)]
29. Muñoz-Redondo, J.M.; Ruiz-Moreno, M.J.; Puertas, B.; Cantos-Villar, E.; Moreno-Rojas, J.M. Multivariate optimization of headspace solid-phase microextraction coupled to gas chromatography-mass spectrometry for the analysis of terpenoids in sparkling wines. *Talanta* **2020**, *208*, 120483. [[CrossRef](#)] [[PubMed](#)]
30. Luzzini, G.; Bicego, R.; Slaghenau, D.; Ugliano, M. Variations in sensorially-relevant metabolites and indices in PDO wines of common ampelographic background: A case study on commercial Lambrusco wines. *J. Food Compos. Anal.* **2025**, *140*, 107300. [[CrossRef](#)]
31. Barbagallo, R.N.; Spagna, G.; Palmeri, R.; Restuccia, C.; Giudici, P. Selection, characterization and comparison of β -glucosidase from mould and yeasts employable for enological applications. *Enzym. Microb. Technol.* **2004**, *35*, 58–66. [[CrossRef](#)]
32. Bertazzoli, G.; Pelizza, E.; Luzzini, G.; Felis, G.E.; Ugliano, M.; Torriani, S. Influence of Fermentation Temperature and *Metschnikowia pulcherrima*/*Saccharomyces cerevisiae* Multi-Starter Cultures on the Volatile Compounds of Lugana Wine. *Foods* **2025**, *14*, 3538. [[CrossRef](#)]
33. Luzzini, G.; Slaghenau, D.; Pasetto, F.; Ugliano, M. Influence of grape composition and origin, yeast strain and spontaneous fermentation on aroma profile of Corvina and Corvinone wines. *LWT* **2021**, *143*, 111120. [[CrossRef](#)]
34. Parker, M.; Capone, D.L.; Francis, I.L.; Herderich, M.J. Aroma Precursors in Grapes and Wine: Flavor Release during Wine Production and Consumption. *J. Agric. Food Chem.* **2018**, *66*, 2281–2286. [[CrossRef](#)] [[PubMed](#)]
35. Sarry, J.; Gunata, Z. Plant and microbial glycoside hydrolases: Volatile release from glycosidic aroma precursors. *Food Chem.* **2004**, *87*, 509–521. [[CrossRef](#)]
36. Sumby, K.M.; Grbin, P.R.; Jiranek, V. Microbial modulation of aromatic esters in wine: Current knowledge and future prospects. *Food Chem.* **2010**, *121*, 1–16. [[CrossRef](#)]
37. Yuan, T.T.; Chen, Q.Q.; Zhao, P.J.; Zeng, Y.; Liu, X.Z.; Lu, S. Identification of enzymes responsible for the reduction of geraniol to citronellol. *Nat. Prod. Bioprospect.* **2011**, *1*, 108–111. [[CrossRef](#)]
38. Klis, F.M.; Mol, P.; Hellingwerf, K.; Brul, S. Dynamics of cell wall structure in *Saccharomyces cerevisiae*. *FEMS Microbiol. Rev.* **2002**, *26*, 239–256. [[CrossRef](#)]

39. Kinzurik, M.; Deed, R.C.; Herbst-Johnstone, M.; Slaghenaufi, D.; Guzzon, R.; Gardner, R.C.; Larcher, R.; Fedrizzi, B. Addition of volatile sulfur compounds to yeast at the early stages of fermentation reveals distinct biological and chemical pathways for aroma formation. *Food Microbiol.* **2020**, *89*, 103435. [\[CrossRef\]](#)
40. Ailer, Š.; Jakabová, S.; Benešová, L.; Ivanova-Petropulos, V. Wine faults: State of knowledge in reductive aromas, oxidation and atypical aging, prevention, and correction methods. *Molecules* **2022**, *27*, 3535. [\[CrossRef\]](#)
41. Spedding, D.; Raut, P. The influence of dimethyl sulphide and carbon disulphide in the bouquet of wines. *VITIS—J. Grapevine Res.* **1982**, *21*, 240–246.
42. Francis, L.; Newton, J. Determining wine aroma from compositional data. *Aust. J. Grape Wine Res.* **2005**, *11*, 114–126. [\[CrossRef\]](#)
43. Mestres, M.; Busto, O.; Guasch, J. Analysis of organic sulfur compounds in wine aroma. *J. Chromatogr. A* **2000**, *881*, 569–581. [\[CrossRef\]](#) [\[PubMed\]](#)
44. Goniak, O.J.; Noble, A.C. Sensory study of selected volatile sulfur compounds in white wine. *Am. J. Enol. Vitic.* **1987**, *38*, 223–227. [\[CrossRef\]](#)
45. Sánchez-Palomo, E.; Trujillo, M.; García Ruiz, A.; González Viñas, M.A. Aroma profile of malbec red wines from La Mancha region: Chemical and sensory characterization. *Food Res. Int.* **2017**, *100*, 201–208. [\[CrossRef\]](#)
46. Etiévant, P.X. Volatile compounds in foods and beverages. In *Wine*; Maarse, H., Ed.; Marcel Dekker: New York, NY, USA, 1991; pp. 483–546.
47. Culleré, L.; Escudero, A.; Cacho, J.; Ferreira, V. Gas Chromatography–Olfactometry and Chemical Quantitative Study of the Aroma of Six Premium Quality Spanish Aged Red Wines. *J. Agric. Food Chem.* **2004**, *52*, 1653–1660. [\[CrossRef\]](#)
48. Moyano, L.; Zea, L.; Moreño, J.; Medina, M. Analytical study of aromatic series in Sherry wines subjected to biological aging. *J. Agric. Food Chem.* **2002**, *50*, 7356–7361. [\[CrossRef\]](#)
49. Marais, J. Terpenes in the aroma of grapes and wines: A review. *S. Afr. J. Enol. Vitic.* **1983**, *4*, 49–58. [\[CrossRef\]](#)
50. Ferreira, V.; López, R.; Cacho, J.F. Quantitative determination of the odorants of young red wines from different grape varieties. *J. Sci. Food Agric.* **2000**, *80*, 1659–1667. [\[CrossRef\]](#)
51. Lytra, G.; Cameleyre, M.; Tempere, S.; Barbe, J.C. Distribution and organoleptic impact of ethyl 3-hydroxybutanoate enantiomers in wine. *J. Agric. Food Chem.* **2015**, *63*, 10484–10491. [\[CrossRef\]](#) [\[PubMed\]](#)
52. Song, M.; Xia, Y.; Tomasino, E. Investigation of a quantitative method for the analysis of chiral monoterpenes in white wine by HS-SPME-MDGC-MS of different wine matrices. *Molecules* **2015**, *20*, 7359–7378. [\[CrossRef\]](#)
53. Antalick, G.; Tempère, S.; Suklje, K.; Blackman, J.; Deloire, A.; De Revel, G.; Schmidtke, L.M. Investigation and sensory characterization of 1,4-cineole: A potential aromatic marker of Australian Cabernet Sauvignon wine. *J. Agric. Food Chem.* **2015**, *63*, 9103–9111. [\[CrossRef\]](#)
54. Versini, G.; Schneider, R.; Carlin, S.; Depentori, D.; Nicolini, G.; Dalla Serra, A. Characterisation of Some Northern Italian Passiti-Wines through Aroma and Stable Isotope Analysis. In Proceedings of the 12th International Oenological Symposium, Montreal, QC, Canada, 29 May–2 June 1999; Lemperle, E., Ed.; International Association for Enology, Management and Wine Marketing: Breisach, Germany, 1999; pp. 544–571.
55. Janusz, A.; Capone, D.L.; Puglisi, C.J.; Perkins, M.; Elsey, G.M.; Sefton, M.A. (E)-1-(2,3,6-Trimethylphenyl)buta-1,3-diene: A potent grape-derived odorant in wine. *J. Agric. Food Chem.* **2003**, *51*, 7759–7763. [\[CrossRef\]](#)
56. Sacks, G.L.; Gates, J.M.; Ferry, F.X.; Lavin, E.H.; Kurtz, A.J.; Acree, T.E. Sensory Threshold of 1,1,6-Trimethyl-1,2-dihydronaphthalene (TDN) and Concentrations in Young Riesling and Non-Riesling Wines. *J. Agric. Food Chem.* **2012**, *60*, 2998–3004. [\[CrossRef\]](#) [\[PubMed\]](#)
57. Carlin, S.; Vrhovsek, U.; Lonardi, A.; Landi, L.; Mattivi, F. Aromatic complexity in Verdicchio wines. A case study. *OENO One* **2019**, *53*, 597–610. [\[CrossRef\]](#)
58. López, R.; Aznar, M.; Cacho, J.; Ferreira, V. Determination of minor and trace volatile compounds in wine by solid-phase extraction and gas chromatography with mass spectrometric detection. *J. Chromatogr. A* **2002**, *966*, 167–177. [\[CrossRef\]](#) [\[PubMed\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.