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Research Article

Application of commercial wine yeast strains in beer production: effects on fermentation performance, volatile metabolites, and sensory profile

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Abstract

The use of non-conventional yeast strains has emerged as a promising approach for diversifying beer sensory profiles. In this study, the potential of five commercial active dry wine yeasts for beer production was evaluated in comparison with two brewing control strains. Fermentation was conducted at 20°C, and fermentation dynamics, physicochemical parameters, and the production of key volatile metabolites (higher alcohols, esters, and aldehydes) were monitored. In addition, sensory analysis and principal component analysis (PCA) were performed to assess the impact of yeast strain on aroma and taste profiles. The results revealed clear strain-dependent differences in fermentation performance and metabolite production. Brewing strains exhibited higher attenuation and alcohol production, whereas wine yeasts showed more diverse metabolic behavior. Among the tested strains, Lalvin DV-10 demonstrated the highest fermentation efficiency, while Zymaflore XAROM and Zymaflore RX-60 showed enhanced ester production, contributing to more complex fruity and floral sensory profiles. Sensory evaluation and PCA confirmed that wine yeast strains significantly modified both aroma and taste characteristics, with some strains producing profiles similar to the control samples, while others induced distinct sensory differentiation. Overall, the findings demonstrate that commercial wine yeasts can be successfully applied in brewing to develop beers with novel sensory profiles.

Keywords

wine yeast, beer fermentation, fermentation dynamics, volatile metabolites, sensory analysis

Abbreviations

ANOVA – one-way analysis of variance; FAN – free amino nitrogen; PCA – principal component analysis;

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Introduction

Beer – one of the oldest beverages in the world – is produced from four main raw materials: malt, water, hops, and yeast. Among these, yeast is the primary contributor to beer aroma. During alcoholic fermentation, yeast synthesizes a wide range of metabolites (e.g., higher alcohols, esters, ethers, aldehydes, and ketones) that significantly influence the aroma profile of beer. The concentrations of these metabolites vary considerably and are strongly influenced by wort composition, fermentation conditions and the yeast strain used (Palombi et al. 2023; Castro et al. 2022).

Traditionally, alcoholic fermentation in brewing is carried out using strains of *Saccharomyces cerevisiae* and *Saccharomyces pastorianus*. However, their widespread use has encouraged the search for alternative yeasts capable of generating novel aromatic and flavour characteristics. Therefore, numerous studies have investigated the application of both *Saccharomyces* and non-*Saccharomyces* yeasts for aroma diversification and flavour enhancement (Capece et al. 2018; Satora et al. 2023; Canonico et al. 2023; Palombi et al. 2023). The ability of many non-conventional yeasts to express a broader range of enzymatic activities enables the biotransformation of aroma precursors through pathways that differ from those of traditional brewing strains (Postigo et al. 2022).

Among the alternative yeasts evaluated for brewing applications, wine-associated yeasts have attracted increasing attention. Although wine and ale brewing strains belong predominantly to the same species, *Saccharomyces cerevisiae*, genomic and phenotypic studies have shown that they represent distinct domesticated lineages adapted to different fermentation environments. Wine strains generally exhibit increased tolerance to ethanol, low pH, sulfur dioxide, and osmotic stress, reflecting their adaptation to grape must fermentations (Su et al. 2025). In addition, considerable differences have been reported in aroma compound production and precursor biotransformation. Particular attention has recently been given to β-lyase activity, which facilitates the release of volatile thiols and contributes to the formation of fruity and floral aroma characteristics (Costantini et al. 2025). Besides *S. cerevisiae*, *Saccharomyces bayanus* has also attracted interest because of its cryotolerance, stress resistance, and distinct metabolite production patterns, which may provide additional opportunities for sensory diversification in fermented beverages (Alexa et al. 2025; Legras et al. 2007).

Recent studies have demonstrated wine-associated *Saccharomyces* strains to produce beers with enhanced aromatic complexity and distinctive sensory characteristics. Wine-derived *Saccharomyces* strains have been reported to increase fruity and floral attributes through altered ester formation and distinct metabolic behaviour during fermentation (Rossi et al. 2018; Postigo et al. 2021). Furthermore, both wine and non-*Saccharomyces* wine yeasts have been investigated for the production of specialty and experimental beers with differentiated flavour profiles (Postigo et al. 2022). These findings suggested that wine yeasts represented a promising source of phenotypic diversity that could be exploited for the development of novel beer styles.

Despite the growing interest in wine yeasts for brewing applications, most published studies have focused on a limited number of strains or on non-commercial isolates. Commercial active dry wine yeasts are particularly attractive for brewing applications because they are readily available, technologically robust, and already optimized for industrial fermentation processes. Nevertheless, comparative information regarding their fermentation performance, metabolite production, and sensory impact in beer remains limited. Therefore, the aim of the present study was to evaluate the brewing potential of five commercial active dry wine yeast strains and assess their effects on fermentation dynamics, volatile metabolite formation, and the sensory characteristics of the beers produced.

Materials and Methods

Microorganisms. The yeasts used in this study included 7 commercial active dry yeast strains – 5 wine and 2 brewing strains (Table 1). Brewing strains – 1 ale and 1 lager – were used as control samples.

Table 1. Yeast strains used for the experiments. Yeast strains

Yeast strains	Manufacturer
Wine yeasts	
Saccharomyces cerevisiae Zymaflore Xarom	Laffort, France
Saccharomyces cerevisiae Zymaflore RX-60	Laffort, France
Saccharomyces cerevisiae Vitielevure Chardonnay	Martin Vialatte, France
Saccharomyces cerevisiae Vitielevure 58W3	Martin Vialatte, France
Saccharomyces cerevisiae var. bayanus Lalvin DV-10	Lallemand, Canada
Brewing yeasts /Control fermentations/	
Saccharomyces pastorianus Saflager W-34/70	Fermentis by Lesaffre, France
Saccharomyces cerevisiae Safale US-05	Fermentis by Lesaffre, France

Wort production. Hopped wort with an initial extract of 12.6±0.1°P, pH 6.04±0.05 and a free amino nitrogen (FAN) content of 196.82±0.75 $mg.L^{-1}$ was used for fermentation. The wort was prepared under laboratory conditions using a Braumeister brewing system. A total of 4.5 kg of Pilsner malt grist (Best Malt, Germany) was mixed with pre-heated water in a liquor-to-grist ratio of 1:5. The mashing regime included the following rests: at 45°C for 10 min, 52°C for 20 min, 63°C for 30 min, 72°C for 20 min, and 78°C for 5 min. Lautering and wort boiling were carried out in the same Braumeister. Hopping was performed 10 min after boiling start using Magnum hop (12.6 % α-acids) at a dosage corresponding to 90 $mg.L^{-1}$ α-acids. After 60 min of boiling, hot trub was removed and wort was frozen at -18°C until experiments.

Fermentation. Fermentations were carried out in 330 ml glass bottles, equipped with airlock systems, filled with concentrated sulphuric acid. Bottles were filled with 200 ml of hopped wort and were sterilized by means of a Koch steam sterilizer. After cooling to 20°C, wort was inoculated with 1 ml of suspension of pre-rehydrated yeast. The active dry yeasts were rehydrated according to the manufacturer's instructions prior to inoculation. Fermentations were performed in triplicate as independent biological replicates. Since viable cell concentration was not determined, this limitation was considered when interpreting strain-dependent differences in fermentation kinetics. The bottles were placed in a thermostat FOC 200i (VELP Scientific, Italy). Fermentation was carried out at 20°C under static conditions. Fermentation dynamics were monitored through measurements of fermentation parameters such as extract, ethanol, and pH and secondary metaboites accumulation such as higher alcohols, esters, and aldehydes.

Analytical methods. The analyses of basic wort and beer parameters (original, real and apparent extract, alcohol, and FAN) were conducted according to the EBC methods of analysis (Analytica EBC 2010). The pH was determined by WTWinolab Ph7110 (Xylem analytics, Weiheim, Germany).

Higher alcohols were measured using the p-dimethylaminobenzaldehyde method according to AOAC methods (Official Methods of Analysis of AOAC International 2007). Ester concentration was determined according to ester saponification with sodium hydroxide after simple distillation of the beer (Marinov 2010). The aldehyde concentration was determined according to the bisulphite method after simple distillation of the beer (Marinov 2010). These methods allow the evaluation of strain-dependent trends in metabolite production but do not provide identification and quantification of individual volatile compounds. Therefore, the results should be interpreted at the level of compound groups rather than specific aroma-active molecules.

Sensory analysis. Sensory evaluation was performed by a panel of 10 assessors (5 male and 5 female, age 22-63) with prior experience in beer sensory analysis. The panellists were familiarized with the methodology and the objectives of the

study. Each participant evaluated the aroma and taste of the samples using a 5-point scale, where 1 indicated barely perceptible and 5 indicated very strong. The evaluated aroma descriptors included fruity, citrus, spicy, malty, hoppy, and alcoholic notes, while taste attributes included malty, sour, bitter, astringent, and sweet. Tastings were conducted in a sensory evaluation room, with samples poured into clean, transparent glasses. Each sample was assigned a number and evaluated in triplicate. Panelists were provided with flat mineral water and plain white bread to cleanse the palate between samples. All tastings were performed using cold beverages (4°C). All sensory data were expressed as mean values of the panel scores, reported with a precision of 0.1.

Statistical methods. All fermentations were performed in triplicate as independent biological replicates, and analytical measurements were conducted on each replicate. Statistical analyses were performed using one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test for pairwise comparisons. Differences were considered statistically significant at $p < 0.05$.

Principal component analysis (PCA) was applied to the sensory dataset in order to compare the overall organoleptic profiles of the experimental yeast strains with those of the two controls. The analysis included 11 sensory variables describing aroma and taste, as given in Sensory analysis section. The data were centered and standardized to unit variance (z-score transformation) so that all variables contributed equally to the multivariate model regardless of their original scale. PCA was then performed on the standardized data matrix, and the sample distribution was interpreted using the first two principal components. Distances between each strain and the control samples were additionally evaluated using Euclidean distances calculated in both the PC1-PC2 score space and the full standardized variable space. The analysis and visualization were performed in Python 3.13.5 (CPython) using standard numerical and multivariate analysis libraries.

Results and Discussion

Fermentation dynamics. The results for fermentation dynamics, measured by changes in apparent extract, alcohol content, and pH are presented in Fig. 1 - 3.

All yeast strains were able to ferment the wort, as evidenced by the continuous decrease in apparent extract; however, the extent and rate of extract utilization varied considerably among strains (Fig. 1). Vitilevure 58W3 exhibited the most rapid decrease in apparent extract within the first 48 h. In contrast, Vitilevure Chardonnay showed a slower apparent extract reduction, maintaining the highest residual extract throughout the entire fermentation period. At 96 h, the most pronounced extract consumption was recorded for Zymaflore XAROM. By 168 h, most strains approached stabilization, with Lalvin DV-10, Zymaflore RX60, and Zymaflore XAROM reaching similarly low levels of apparent extract. At the end of fermentation, the lowest apparent extract values were observed for Lalvin DV-10 and the Zymaflore strains, whereas Vitilevure Chardonnay retained the highest residual extract. These results indicate clear strain-dependent differences in fermentation performance.

The fermentation temperature applied in this study (20°C) likely contributed to the observed differences in strain performance. This temperature is generally favorable for *S. cerevisiae*, supporting efficient fermentation kinetics and sugar utilization. The relatively low extract consumption observed for Vitilevure Chardonnay may be explained by its typical application in white wine fermentations conducted at lower temperatures. In contrast, Lalvin DV-10 (S. cerevisiae var. bayanus), known for its robustness and broad temperature tolerance, maintained high fermentation efficiency, resulting in the lowest residual extract. The differences in alcohol production (Fig. 2) closely correspond to the trends observed in apparent extract reduction, confirming strain-dependent variation in fermentation efficiency. Strains such as Lalvin DV-10 and Zymaflore XAROM, which demonstrated rapid extract consumption, also exhibited higher alcohol production, indicating efficient conversion of fermentable sugars into ethanol. The early peak in alcohol production observed for Zymaflore XAROM suggested high metabolic activity during

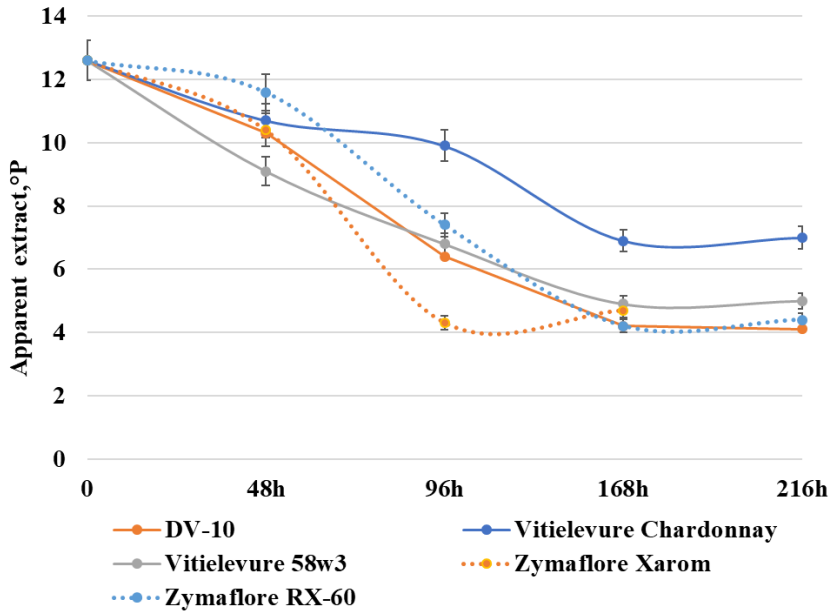


Figure 1. Changes in apparent extract during laboratory-scale beer fermentation with five commercial wine yeast strains at 20°C. Values are presented as mean ± SD from three parallel

the initial stages of fermentation, whereas Lalvin DV-10 showed a more sustained fermentation profile, resulting in the highest final alcohol concentration. In contrast, Vitilevure Chardonnay consistently exhibited lower alcohol production, which is in agreement with its higher residual extract values. The results demonstrate close correspondence between sugar consumption and alcohol production, highlighting the importance of strain selection and fermentation conditions in determining fermentation performance.

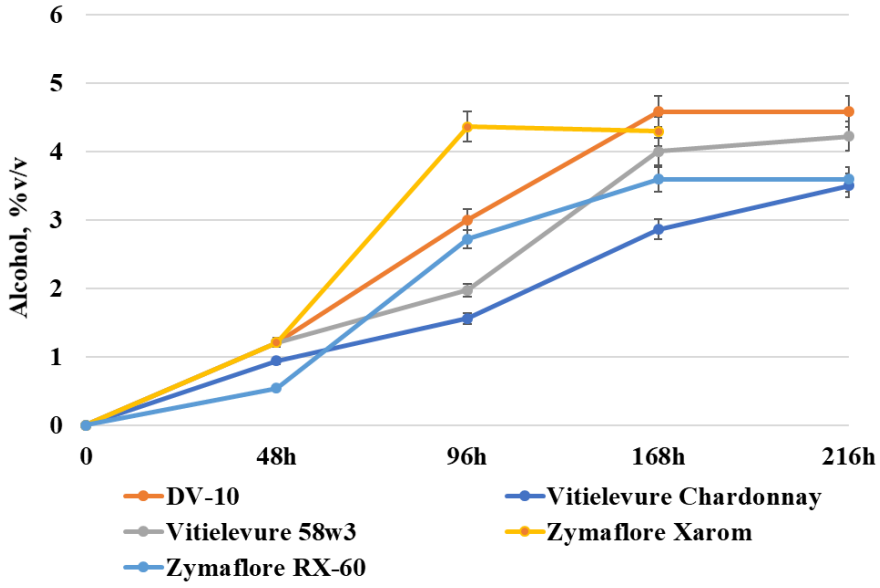


Figure 2. Changes in ethanol formation during laboratory-scale beer fermentation with five commercial wine yeast strains at 20 °C. Values are presented as mean ± SD from three parallel measurements

The observed decrease in pH (Fig. 3) during the first 48–96 h corresponds to the period of highest fermentation activity, as also indicated by rapid extract consumption and increased alcohol production. Zymaflore XAROM, which demonstrated rapid sugar utilization, also exhibited a stronger initial pH decrease, suggesting more intensive metabolic activity during the early fermentation phase. In contrast, Vitilevure Chardonnay showed a more moderate pH decline, which aligns with its slower fermentation kinetics, lower alcohol production, and higher residual extract. The stabilization of pH values after 96 h indicated a transition to the later stages of fermentation, where metabolic activity slowed and fewer organic acids were produced. The pH evolution supports the presence of strain-dependent variation in fermentation behavior observed for extract consumption and alcohol production, highlighting the close relationship between yeast metabolism, acid production, and fermentation efficiency.

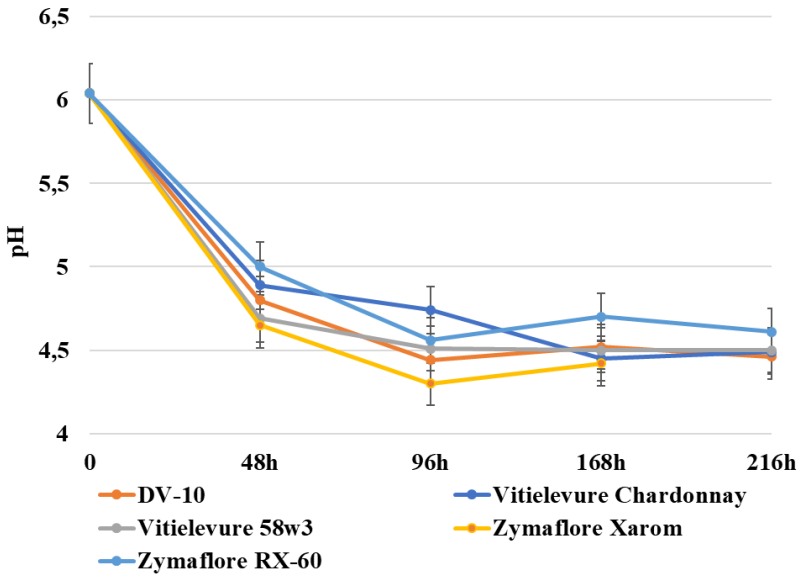


Figure 3. Changes in pH during laboratory-scale beer fermentation with five commercial wine yeast strains at 20°C. Values are presented as mean ± SD from three parallel measurements

Secondary metabolites production. The results for the synthesis of higher alcohols, esters, and aldehydes by the studied wine yeasts are shown on Fig. 4-6, respectively.

Higher alcohols are formed by yeast during fermentation via the catabolic (Ehrlich) and the anabolic (amino acid metabolism) pathways (Hazelwood et al. 2008). These compounds constitute an important group of volatile metabolites that significantly contribute to the aroma profile of fermented beverages also as precursors for esters formation (Nasuti and Solieri 2024).

Strains such as Lalvin DV-10 and Zymaflore XAROM, which exhibited higher fermentation activity and more efficient sugar utilization, also produced higher concentrations of higher alcohols (Fig. 4). These observations are consistent with the known influence of nitrogen metabolism on higher alcohol formation.

Aldehydes are key intermediates in yeast metabolism and are primarily formed during the early stages of fermentation as part of central carbon metabolism, particularly in the conversion of pyruvate to ethanol. Their subsequent reduction to alcohols reflects active fermentation and the maintenance of redox balance within yeast cells (Stewart 2017). The initial increase in aldehyde concentration observed for all strains corresponds to the phase of intense metabolic activity, as also indicated by rapid extract consumption and increasing alcohol production (Fig. 5).

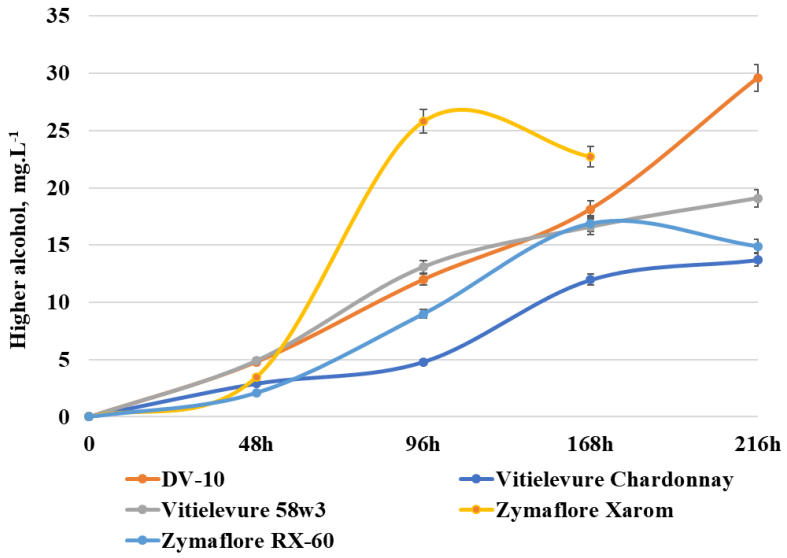


Figure 4. Changes in total higher alcohols formation during laboratory-scale beer fermentation with five commercial wine yeast strains at 20°C. Values are presented as mean ± SD from three parallel measurements

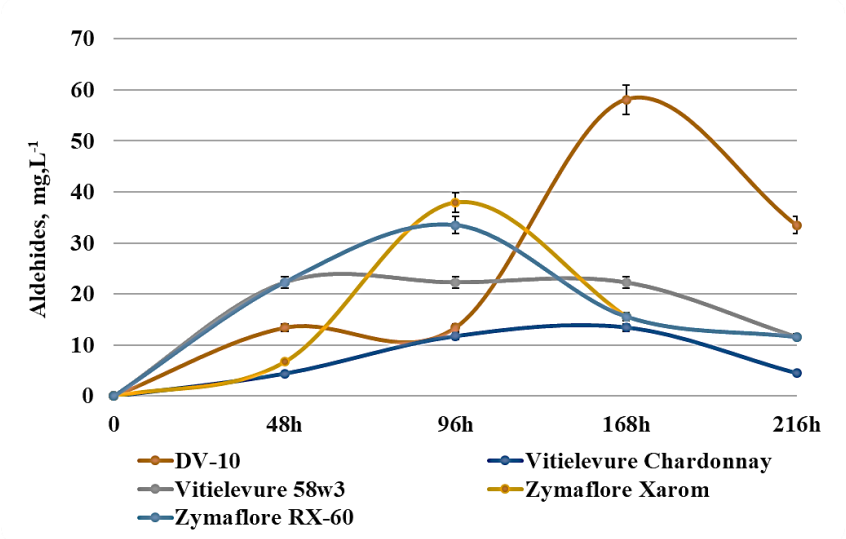


Figure 5. Changes in total aldehydes formation during laboratory-scale beer fermentation with five commercial wine yeast strains at 20°C. Values are presented as mean ± SD from three parallel measurements

The subsequent decrease, particularly evident after 96-168 h, was consistent with the progressive reduction of aldehydes to their corresponding alcohols as fermentation proceeded. Lalvin DV-10 exhibited the most pronounced increase, reaching the highest concentration at 168 h (~58 $mg.L^{-1}$), followed by a decrease at 216 h. Zymaflore XAROM also showed a rapid increase, peaking at 96 h (~38 $mg.L^{-1}$), after which a decline was observed. Vitilevure 58W3 and Zymaflore RX60 demonstrated moderate aldehyde production, with peak values at 96 h and a gradual decrease thereafter. In contrast, Vitilevure Chardonnay consistently exhibited the lowest aldehyde concentrations throughout the fermentation process, which correlates with its lower fermentation

activity. The observed trends also highlighted the close relationship between aldehyde metabolism and higher alcohol formation. As aldehydes act as intermediates in amino acid catabolism and alcohol synthesis, their temporal dynamics reflect the balance between formation and reduction processes within yeast cells.

Esters are formed during fermentation by the enzymatic condensation of alcohol and organic acid (Stewart 2017). Ester production increased during the early and mid-stages of fermentation, reaching maximum levels between 96 h and 168 h, followed by a gradual decrease or stabilization (Fig. 6).

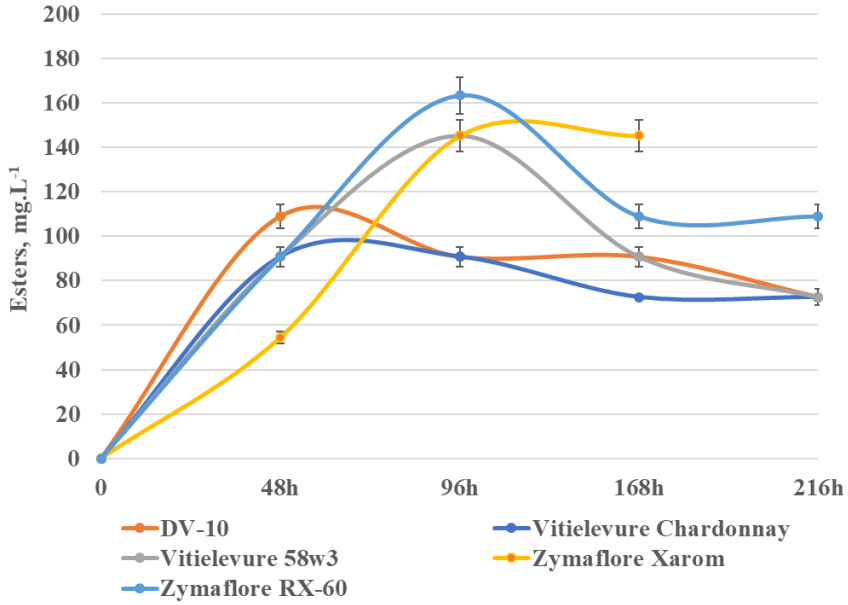


Figure 6. Changes in total esters formation during laboratory-scale beer fermentation with five commercial wine yeast strains at 20°C. Values are presented as mean ± SD from three parallel measurements

Zymaflore RX60 exhibited the highest ester concentration at 96 h, followed by a decline in the later stages of fermentation. Similar trend was demonstrated by Vitilevure 58W3. Zymaflore XAROM also showed a pronounced increase, reaching peak values at 96–168 h. Lalvin DV-10 showed a more moderate ester production profile, with a peak at 48–96 h and a gradual decline thereafter. In contrast, Vitilevure Chardonnay exhibited lower ester concentrations throughout fermentation, with a steady decrease after 48 h. The decrease in ester concentration may be attributed to hydrolysis, volatilization, or reduced enzymatic activity during the later stages of fermentation. The differences observed among the studied strains confirm that ester production is strongly strain-dependent and influenced by metabolic regulation and fermentation conditions (Yoshimoto and Bogaki 2023).

Comparison with ale and lager beers. Beers produced with wine yeasts were compared with lager and ale beers, produced under the same conditions and the results for main fermentation parameters are presented in Table 2. One-way ANOVA revealed significant differences among yeast strains with respect to apparent extract, real extract, alcohol content, and pH ($p < 0.001$). Post-hoc comparison using Tukey's HSD test confirmed that most strains differed significantly from one another, highlighting the strong influence of yeast strain on fermentation performance. The superior fermentation performance of the brewing strains (Saflager W-34/70 and SafAle US-05) was expected, as these yeasts have been specifically selected for efficient utilization of wort carbohydrates. In contrast, the wine yeasts exhibited variable attenuation levels, suggesting differences in their ability to metabolize brewing-relevant

sugars. Similar variability among wine-associated *Saccharomyces* strains has been reported previously, highlighting the influence of strain-specific physiological characteristics on fermentation performance in brewer's wort (Rossi et al. 2018; Postigo et al. 2021). Regarding pH, the lager strain showed the highest final values, while all wine yeast strains resulted in lower pH values (4.42–4.61), suggesting differences in acid production and metabolic activity. Interestingly, there is no significant difference between pH of beers, produced with ale yeast and Zymaflore RX-60.

The concentrations of higher alcohols, aldehydes, and esters in the beers produced with the investigated yeast strains are presented in Table 3.

Table 2. Main fermentation parameters of beer produced

Strain	Apparent extract, °P	Real extract, °P	Alcohol, %v/v	pH -
Saflager W-34/70 (Control lager)	3.2±0.1^{a}	5.1±0.2^{a}	5.39±0.05^{a}	5.17±0.02^{a}
Safale US-05 (Control ale)	3.5±0.1^{b}	5.2±0.1^{a}	5.16±0.02^{b}	4.60±0.05^{b}
Lalvin DV-10	4.1±0.2^{c}	6.1±0.2^{b}	4.58±0.06^{c}	4.46±0.01^{cd}
Zymaflore RX-60	4.4±0.1^{d}	6.4±0.1^{bc}	3.59±0.01^{e}	4.61±0.03^{b}
Zymaflore Xarom	4.7±0.0^{d}	6.6±0.2^{bc}	4.29±0.03^{d}	4.42±0.06^{d}
Vitielevure 58W3	5.0±0.1^{e}	7.2±0.1^{c}	4.22±0.04^{d}	4.50±0.03^{c}
Vitielevure Chardonnay	7.0±0.2^{f}	8.7±0.3^{d}	3.50±0.05^{e}	4.49±0.00^{c}

Values are presented as mean ± SD (n = 3). Different superscript letters within the same column indicate statistically significant differences among yeast strains according to Tukey's HSD test ($p < 0.05$).

Table 3. Secondary metabolites concentration in beers produced

Strain	Higher alcohols, mg.L^{-1}	Aldehydes, mg.L^{-1}	Esters, mg.L^{-1}
Saflager W-34/70 (Control lager)	43.7±0.5^{b}	13.4±2.2^{b}	89.8±8.8^{ab}
Safale US-05 (Control ale)	71.8±0.8^{a}	6.7±1.0^{c}	72.2±5.3^{b}
Lalvin DV-10	29.6±1.0^{c}	33.5±2.9^{a}	72.6±9.2^{b}
Vitielevure Chardonnay	13.7±0.2^{f}	4.5±0.5^{c}	72.6±9.6^{b}
Vitielevure 58W3	19.1±0.9^{e}	11.6±0.9^{b}	72.6±10.0^{b}
Zymaflore Xarom	22.7±0.7^{d}	15.6±1.8^{b}	145.2±17.6^{a}
Zymaflore RX-60	14.9±0.6^{f}	11.6±0.2^{b}	108.9±13.5^{a}

Values are presented as mean ± SD (n = 3). Different superscript letters within the same column indicate statistically significant differences among yeast strains according to Tukey's HSD test ($p < 0.05$).

One-way ANOVA revealed significant differences among strains with respect to all analyzed metabolite groups ($p < 0.001$). Tukey's HSD test demonstrated that SafAle US-05 produced significantly higher concentrations of higher alcohols than all other strains, whereas Vitilevure Chardonnay and Zymaflore RX-60 exhibited the lowest values. In regard to aldehydes, Lalvin DV-10 produced significantly higher amounts than the other strains, while in beers produced with Vitielevure Chardonnay and Safale US-05 aldehydes concentration was the lowest. In the present study, Zymaflore Xarom and Zymaflore RX-60 were characterized by the highest ester concentrations, indicating distinct metabolic behaviour compared to the remaining strains. Similar strain-dependent differences in volatile metabolite production have been reported previously for wine-associated *Saccharomyces* strains (Rossi et al. 2018; Tufariello et al. 2018; Postigo et al. 2021). The observed differences in volatile metabolite production suggest that the investigated yeast strains may contribute differently to the sensory characteristics of the resulting beers, which was further evaluated by sensory analysis

Sensory analysis. Sensory evaluation was performed to determine how the strain-dependent differences in volatile metabolite production influenced the aroma and flavor characteristics of the resulting beers. The analysis included key aroma descriptors (fruity, citrus, spicy, malty, hoppy, and alcoholic) as well as taste attributes (bitterness, sweetness, sourness, and astringency). The sensory evaluation revealed distinct differences in aroma profiles among the beers produced with the wine yeast strains compared to the lager and ale beers (Fig. 7 and 8).

The control lager sample exhibited a predominantly hoppy character, with relatively low intensity of fruity, citrus, and spicy notes (Fig. 7). The control ale beer aroma was characterized by pronounced malty notes and bitterness, complemented by well-integrated fruity and citrus nuances, while spicy notes were only weakly expressed (Fig. 8).

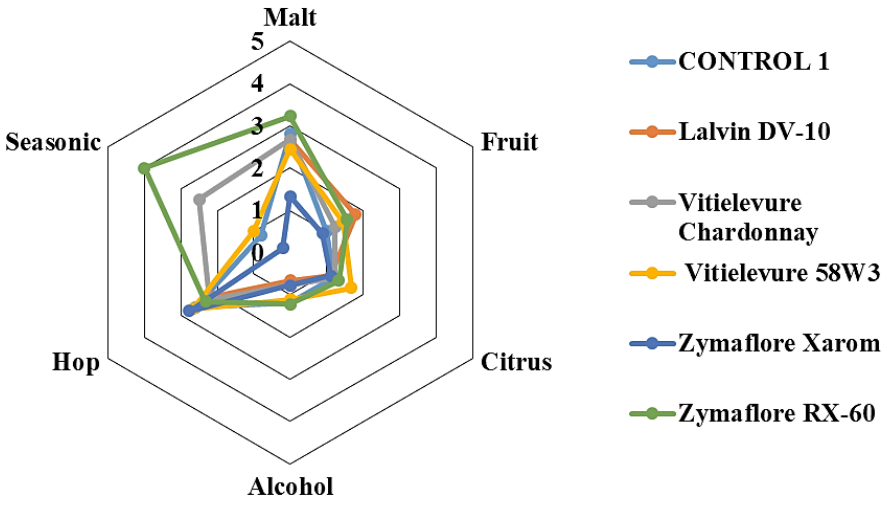


Figure 7. Sensory evaluation of aroma of beers, produced with wine yeast compared to the control lager beer

Lalvin DV-10 was characterized by a balanced profile, with moderate fruity and malty attributes and low intensity of spicy and alcoholic notes. Vitilevure Chardonnay showed enhanced malty and moderately spicy characteristics, while maintaining relatively low fruity and citrus notes. Vitilevure 58W3 demonstrated a more pronounced citrus profile, accompanied by moderate fruity and malty attributes. Zymaflore XAROM exhibited a relatively balanced profile with moderate intensity across most descriptors, without a dominant sensory attribute. In contrast, Zymaflore RX-60 displayed the most distinctive profile, characterized by the highest intensity of spicy and malty notes, along with moderate citrus and fruity attributes. The observed differences in sensory profiles are consistent with the variations in volatile metabolite production among the yeast strains.

The enhanced fruity and citrus notes detected in samples such as Vitilevure 58W3 and Zymaflore strains can be associated with increased ester formation, as esters are key contributors to these sensory attributes. In contrast, the control sample, which exhibited higher levels of higher alcohols but lower ester concentrations compared to Zymaflore XAROM, showed a more pronounced hoppy character, suggesting a lower contribution of yeast-derived aroma compounds relative to hop-derived ones. The relatively neutral sensory profile of Vitilevure Chardonnay corresponded well with its lower production of volatile metabolites, particularly higher alcohols and aldehydes, indicating reduced metabolic activity under the applied conditions.

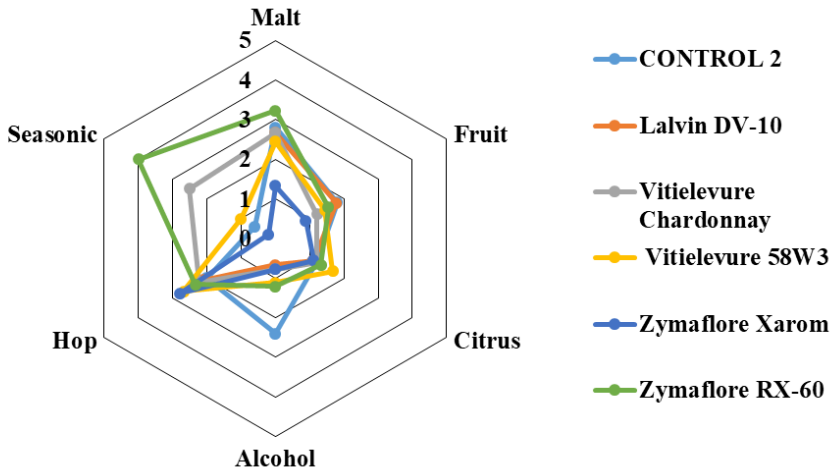


Figure 8. Sensory evaluation of aroma of beers, produced with wine yeast compared to the control ale beer

The sensory evaluation of taste attributes revealed clear differences among the beers produced with the different yeast strains (Fig. 9 and 10). The control lager sample was characterized by the highest bitterness intensity, accompanied by relatively low sweetness and moderate astringency (Fig. 9). Although the control ale beer was shown pronounced bitterness, the relatively low levels of acidity and astringency contributed to a less complex and not fully balanced sensory profile (Fig. 10). Lalvin DV-10 also exhibited pronounced bitterness, although slightly lower than the control, combined with moderate sweetness and low sourness and astringency. Vitilevure Chardonnay showed a taste profile dominated by malt-derived sweetness, with reduced bitterness and low astringency, indicating a softer overall perception. Vitilevure 58W3 demonstrated the highest sweetness among all samples, along with moderate bitterness and low astringency. Zymaflore XAROM exhibited a balanced taste profile, characterized by relatively high bitterness and moderate sweetness and sourness. In contrast, Zymaflore RX-60 showed lower bitterness and sweetness, with slightly elevated sourness compared to the other samples.

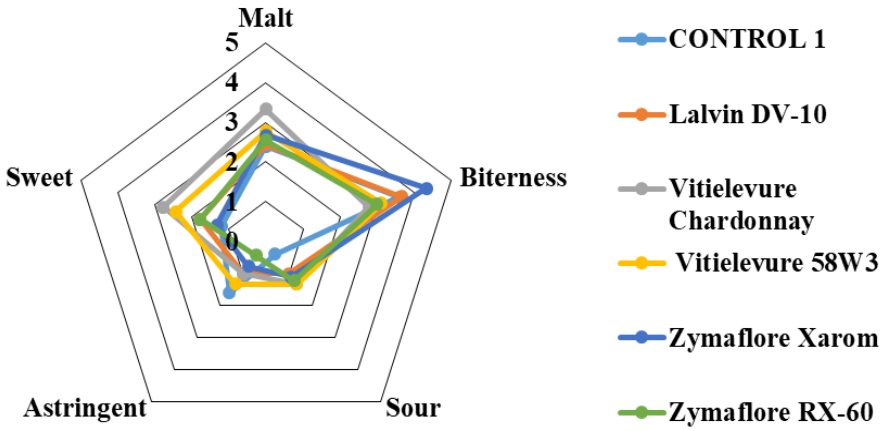


Figure 9. Sensory evaluation of taste of beers, produced with wine yeast compared to the control lager beer

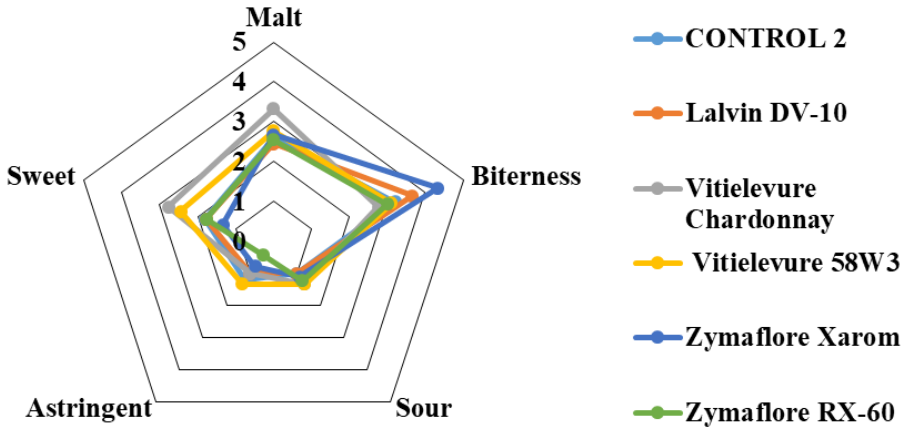


Figure 10. Sensory evaluation of taste of beers, produced with wine yeast compared to the control lager beer

The observed differences in taste perception were consistent with the physicochemical characteristics of the samples. The higher bitterness intensity in the control sample and Lalvin DV-10 correlates with their lower residual extract and higher attenuation, which enhance the perception of hop-derived bitterness. In contrast, the increased sweetness observed in Vitilevure Chardonnay and Vitilevure 58W3 is consistent with their higher residual extract and lower fermentation efficiency, leading to a greater contribution of unfermented sugars. The balanced taste profile observed for Zymaflore XAROM reflects its intermediate fermentation performance and metabolite production, while the slightly higher sourness in Zymaflore RX-60 may be associated with differences in acid metabolism and pH.

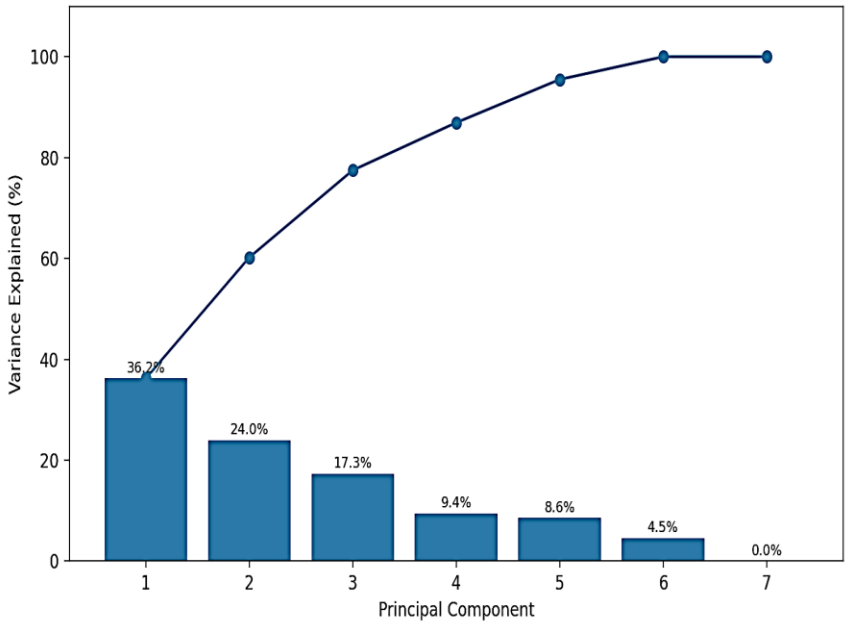


Figure 12. Scree plot showing the proportion of variance explained by each principal component

Principal component analysis. PCA provided an exploratory multivariate visualization of sensory differentiation among the samples. The first principal component (PC1, 36.2%) accounted for the largest proportion of variance and primarily described the contrast between samples characterized by higher bitterness and hop-related attributes (positive loadings) and those associated with sweeter, fruitier, maltier, more sour, and spicier profiles (negative loadings). The second principal component (PC2, 24.0%) further differentiated the samples, mainly in relation to variations in taste attributes (malty, sour, and sweet) and hop aroma. As PC1 and PC2 together explained 60.2% of the total variability, the two-dimensional score plot can be considered sufficiently representative for interpreting the sensory relationships among the samples (Fig. 12).

An important outcome of the analysis is that two control samples were not superimposed in the PCA space but were separated from each other. This indicated that the baseline sensory profiles of the two controls were not identical and that the effects of the tested strains should be interpreted relative to both controls rather than a single reference point.

The lager strain (Control 1) was positioned on the positive side of PC1 and the negative side of PC2, whereas the ale strain (Control 2) was located on the negative side of both components. The positioning of each strain in the score plot reflected not only absolute sensory differences but also the direction and magnitude of the shift in sensory profile relative to these two distinct control states (Fig. 13).

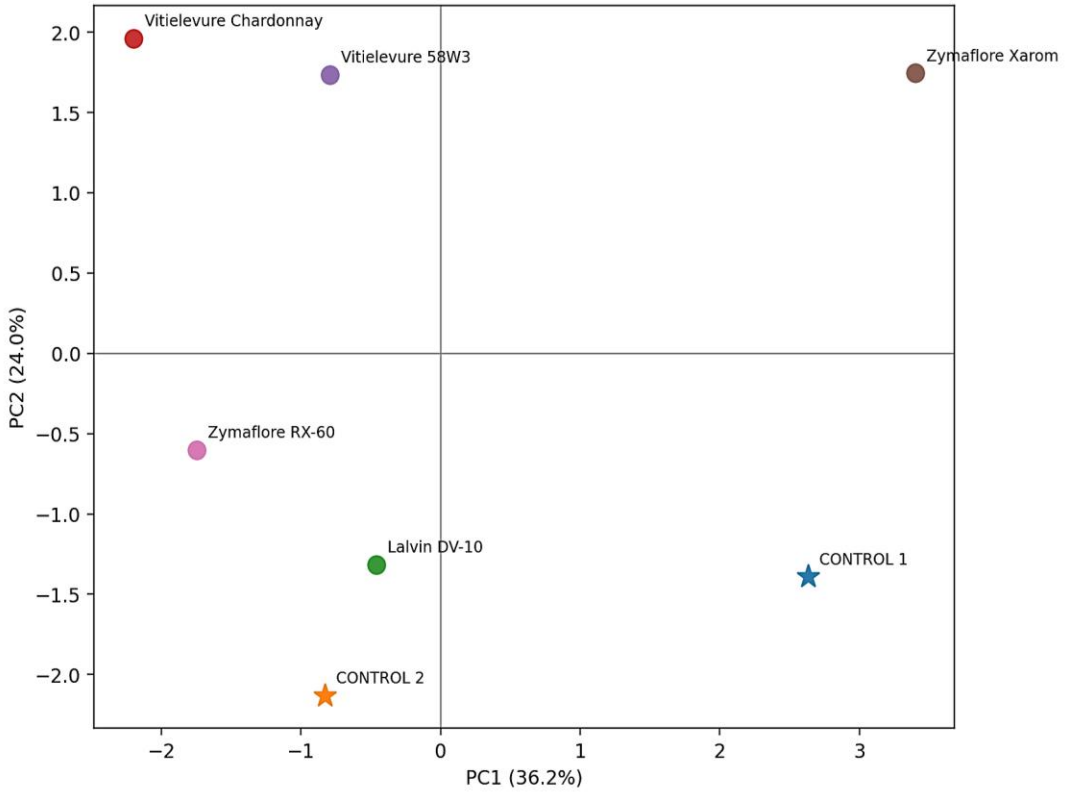


Figure 13. PCA score plot showing the distribution of the two controls and five yeast strains.

Among the experimental strains, Lalvin DV-10 showed the closest proximity to ale strain (Control 2) in the PC1-PC2 plot. This suggests that the overall aroma and taste profile generated by Lalvin DV-10 appeared closest to CONTROL 2 in the PC1–PC2 space, suggesting a sensory profile more similar to this control under the conditions of the present study. Zymaflore RX-60 also grouped closer to ale than lager (Control 1) strain, although the distance was greater than that observed for Lalvin DV-10, indicating partial but not complete similarity. Zymaflore Xarom was positioned closer

to Control 1 and apart from Control 2, which indicated that this strain drove the sensory profile in a different direction and may be associated with a profile closer to the first control condition. Such differences are valuable from a technological perspective, because they show which strains preserve a familiar sensory balance and which ones shift the product toward a new descriptive space. The most distinctive strains were Vitilevure Chardonnay and Vitilevure 58W3, both of which were positioned away from the control samples. Their displacement from the controls indicated that they generated broader changes across the sensory descriptor set rather than only minor adjustments of one or two attributes. Vitilevure Chardonnay occupied the negative PC1 and positive PC2 quadrant, suggesting a profile associated with reduced bitterness and stronger contribution of those variables loading negatively on PC1, combined with the sensory dimensions positively associated with PC2. Vitilevure 58W3 was also located in the positive PC2 region, but with a less extreme negative PC1 value, indicating that its effect differed from Chardonnay while still remaining separated from the controls. Within the exploratory PCA framework, these strains were associated with the greatest sensory separation from the control samples (Fig. 13).

The loading structure supports these interpretations. Taste bitter and aroma hop had the highest positive loadings on PC1 and therefore were major drivers of separation toward the positive side of this axis. In contrast, taste sweet, aroma fruit, aroma malt, taste sour, and aroma seasoning contributed strongly in the negative PC1 direction, indicating that these attributes defined the opposite sensory pole. On PC2, the strongest positive contributions were associated with taste malt and taste sour, together with aroma hop and taste sweet. Consequently, movement upward in the score plot can be interpreted as an increase in the influence of these attributes in the multivariate sensory balance (Fig. 14). The PCA demonstrated that the tested yeast strains did not affect the sensory profile uniformly. They generated differentiated multivariate patterns, ranging from strains that remained close to one of the controls to strains that substantially shifted the product into a separate sensory region.

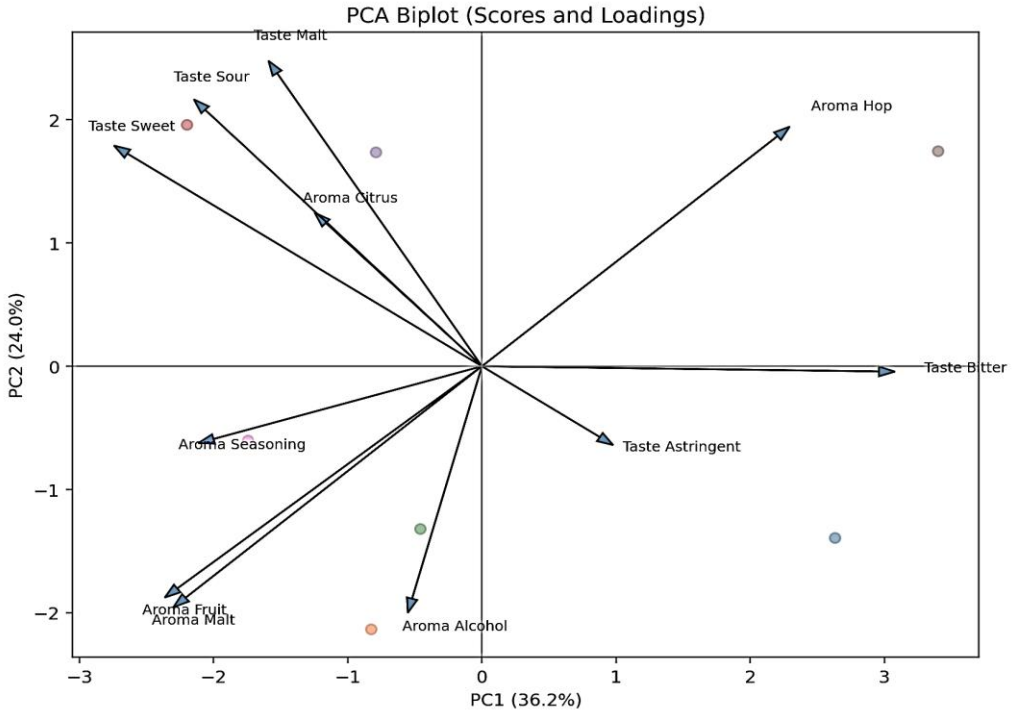


Figure 14. PCA biplot of sensory descriptors and beer samples produced with wine and brewing yeast strains. PC1 and PC2 explain 36.2% and 24.0% of the total variance, respectively. The analysis is exploratory and based on standardized mean sensory scores

Conclusions

The present study provides a laboratory-scale comparative screening of five commercial active dry wine yeast strains for beer fermentation. The results indicated clear strain-dependent differences in extract consumption, ethanol formation, group-level volatile metabolite production, and sensory profile. Among the tested strains, Lalvin DV-10 showed efficient fermentation performance, whereas Zymaflore XAROM and Zymaflore RX-60 were associated with higher ester formation and distinct sensory characteristics under the applied conditions.

The findings suggest that selected commercial wine yeasts may be useful tools for sensory diversification in beer production. However, due to the small-scale static fermentation system, group-level volatile compound analysis, and exploratory nature of the sensory PCA, the results should be interpreted as preliminary. Further studies using pilot-scale fermentations, detailed wort characterization, and chromatographic profiling of individual volatile compounds are required before definitive technological recommendations can be made.

Author Contributions

Conceptualization, G. K. and V.S.; methodology, V. S. and G.K; software, G. K.; validation, V.S; formal analysis, P.Z and S.T.; investigation, P.Z and S.T.; resources, G.K and P.Z; data curation, V.S.; writing - original draft preparation, P.Z., S.T. V.S.; writing - review and editing, G. K. and V.S.; visualization, G. K.; supervision, G.K.; project administration, G.K.; funding acquisition, G. K. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Conflicts of Interest

The authors declare no conflicts of interest.

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