

## ABSTRACT

The field of sparkling wines is in a state of perpetual transformation and development. The foundations of this domain were established by Pierre Pérignon (1638–1715), who employed three grape varieties—Pinot Noir, Pinot Meunier, and Chardonnay—thus laying the basis for sparkling wine. Outside the Champagne region, other sparkling wines have developed, such as Cava in Spain, produced from Macabeo, Xarel·lo, Parellada, and Chardonnay, and Asti in Italy, made from Moscato Bianco.

The production of sparkling wine begins with the harvest of grapes at technological maturity, defined by an alcoholic potential of 10–11% vol. and a pH as low as possible. Once brought to the winery, the must is extracted by gentle pressing in order to minimize the impact on pH values. Following clarification and yeast inoculation, the fermenting must is monitored until the dry stage is reached, thereby completing primary fermentation. Subsequent operations include racking and prolonged contact of the wine with lees in suspension. The next stages involve filtration and tartaric stabilization of the base wine, after which a methodological dichotomy in sparkling wine production emerges.

The *Champenoise method*—also known as the traditional method—entails secondary fermentation directly in glass bottles, followed by maturation, riddling, and disgorgement. This technique is intended for sparkling wines requiring extended lees aging after secondary fermentation, thereby conferring complexity and finesse to the final product.

The second technique, *Charmat–Martinotti*, is characterized by secondary fermentation in isobaric tanks. Its main advantage lies in the possibility of filtering the resulting sparkling wine using isobaric processing equipment. This approach shortens production time and increases efficiency while preserving freshness and fruit expression.

In addition to these two main methods, subsequent innovations include the *ancestral method*, which involves transferring fermenting wine into bottles for completion under pressure, and the *Asti method*, which processes the must and carries out only a single fermentation in isobaric tanks.

The diversity of grape varieties employed in sparkling wine production has expanded considerably, with non-traditional cultivars being adopted. In Brazil, varieties such as Moscato Embrapa, Villenave, Nigaramm Goethe, and Manzini Bianco are used; in Italy, Maresco and Grillo; in Spain, Albariño; in France, Voltis; and in China, Meili.

From a microbiological perspective, yeast selection in sparkling wine production has diversified in order to meet evolving consumer and market demands. While alcoholic fermentation is traditionally carried out by yeasts of the

*Saccharomyces cerevisiae* genus, recent research has focused on alternative yeasts, either in co-inoculation or as standalone fermenters. Biocapsules have been employed as a means to study co-inoculation (Peinado et al., 2006, pp. 79–84).

The use of non-*Saccharomyces* yeasts is an area of active development. Strains such as *Torulaspora delbrueckii*, *Metchnikowia pulcherrima*, and *Pichia kluyveri* have been co-inoculated with *Saccharomyces cerevisiae*, yielding higher concentrations of total alcohols, lactones, and both major and minor esters, while producing lower levels of acetaldehyde, ethyl lactate, and ethyl decanoate/octanoate (Comitini et al., 2017, pp. 44–49). When used together with *S. cerevisiae*, *T. delbrueckii* increases protein content and enhances foam properties (Velázquez et al., 2019, pp. 134–144). Moreover, volatile compounds such as ethyl propionate, isobutyric acid, and butanoic acid were found in higher concentrations under this yeast combination. *T. delbrueckii* has also been tested as a yeast derivative to accelerate maturation, showing that after 9–18 months, fruity notes in Chardonnay-based sparkling wines in Chile were preserved, although protein content declined after 18 months without causing browning of the final product.

Similarly, *Saccharomyces ludwigii* has been used with *S. cerevisiae* due to its high sulfur dioxide tolerance and its ability to generate significant amounts of glycerol, isoamyl acetate, polysaccharides, and  $\beta$ -glucosidases (Ivit et al., 2018, p. 73).

The experimental trials were carried out using Romanian native grape varieties: Fetească regală, Tămâioasă românească, and Fetească albă, from Dealu Mare region. These followed a standardized vinification protocol and comparable use of oenological products in both composition and dosage. Samples were subjected to different maturation periods, including one variant maintained on lees (without riddling and disgorgement), allowing a more comprehensive assessment of the final product.

Physicochemical analyses of must samples revealed a calculated alcoholic potential between 10.70–11.58% vol., total acidity between 7.21–7.90 g/L, and pH values ranging from 2.92 to 3.31. After primary fermentation and stabilization, the base wines exhibited alcoholic concentrations of 11.20–11.95% vol., with acidity reduced to 6.37–6.85 g/L tartaric acid.

Following secondary fermentation, riddling, and disgorgement where applicable, the sparkling wines obtained contained 13.03–13.53% vol. alcohol, falling within the optimal range for quality sparkling wines, ensuring both balance and finesse. Total acidity ranged from 6.00–6.53 g/L tartaric acid, providing freshness and aging potential. These values comply with OIV standards, guaranteeing liveliness and balance. The pH values, between 3.03 and 3.39, indicate an acidic environment conducive to freshness, oxidative stability, and aromatic development.

Overall, the combination of moderate alcohol, high acidity, and balanced pH demonstrates that the samples met technological and quality requirements for sparkling wines, resulting in harmonious sensory profiles with freshness, fine bubbles, and aromatic complexity.

Quantitative profiling of volatile compounds revealed significant differences between the three wine groups, each displaying a distinct chemical signature. Group FA exhibited a unique fermentative profile, with nearly absent tetrahydro-5-methyl-2-furanmethanol, elevated isobutyl alcohol, and medium-chain fatty acids (octanoic and decanoic). Group FR, by contrast, showed markers of controlled oxidative maturation, with elevated solerone, acetaldehyde, and 3-methylbutanal, corresponding to spicy, malty, and chocolate-like notes. Group TR was the most heterogeneous, with TR19 resembling FR's oxidative style and TR21 exhibiting aromatic intensity marked by floral and citrus monoterpenes such as linalool and terpinolene.

Principal Component Analysis (PCA) of chemical data identified the first component (F1) as the dominant axis, positively associated with fruity esters, floral monoterpenes, and medium-chain fatty acids. Sensory PCA aligned closely, with F1 correlating positively with “toasted bread” and “yeast” and negatively with “apple” and “vegetal” descriptors. Integration of chemical and sensory PCA confirmed the consistency of oxidative markers in FR19 and the aromatic vibrancy of TR21.

This combined approach—quantitative chemical profiling coupled with multivariate statistics—provides critical insights into the determinants of composition, typicity, and quality in sparkling wines, linking chemical variation to perceptible sensory differences, thereby advancing both scientific understanding and practical winemaking applications.