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Study Finds Vintage and Winery Choices Leave Chemical Fingerprints on Moriles Alto Wines

Researchers analyzing two vintages from three wineries found that year-to-year conditions and cellar practices jointly shaped aroma profiles.

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A study published Monday in OENO One found that both the vintage and winery-specific winemaking decisions left distinct chemical marks on young Pedro Ximénez wines from Moriles Alto, a premium subzone within Spain’s Montilla-Moriles protected designation of origin, showing that a wine’s aroma profile is shaped by more than place alone.

The research was carried out by José Miguel Fuentes-Espinosa, Raquel Muñoz-Castells, Juan Moreno, Teresa García-Martínez, Juan Carlos Mauricio and Jaime Moreno-García. The team analyzed wines from three traditional wineries in Moriles Alto over two consecutive vintages, 2021 and 2022, to test how much of the wines’ volatile fingerprint came from year-to-year growing conditions and how much came from decisions made in the cellar. The wineries were Lagar Casablanca, Bodegas El Monte and Bodegas Doblas-Martos, all working with Pedro Ximénez grapes grown in nearby vineyards.

Moriles Alto is known for its white albariza soils, rich in calcium carbonate, and for a dry Mediterranean climate that favors Pedro Ximénez. The area has long produced distinctive wines, including biologically aged styles made without fortification. In the new study, researchers focused on young wines to isolate the effect of the harvest year and production practices before long aging could further change the aromatic profile.

To do that, the team measured standard wine parameters such as alcohol, acidity, pH and residual sugar, then quantified major and minor volatile compounds using gas chromatography and statistical modeling. The wines came from grapes harvested by hand in September of each year, when sugar levels exceeded 250g/L, enough to produce wines with alcohol levels of 14.5% or more. Fermentation was carried out at each winery with indigenous yeasts under traditional pied de cuve methods, in which an active fermenting must is used to start the main fermentation. Researchers collected three biological replicates from independent tanks for each winery and vintage and analyzed all samples in triplicate.

The statistical results showed that both vintage and winery had a strong effect on volatile compounds, and that their interaction was also significant. In practical terms, that means weather and growing conditions did not act separately from cellar choices. Instead, the aromatic profile reflected a combined effect of abiotic factors and

production decisions. The authors said this interaction confirms the multifactorial nature of wine aroma in the zone.

The study also found that standard enological measurements alone were not enough to characterize terroir. All of the wines met the Montilla-Moriles PDO rules for Fino-type wines, but those routine figures did not fully separate the effect of origin from the effect of winemaking. Vintage had a strong influence on general parameters, with higher ethanol levels in 2021 and higher absorbance at 420nm in 2022. Winery-related factors had a stronger effect on total acidity, volatile acidity and some other measures. Variation in malic and lactic acid also pointed to differences in whether malolactic fermentation occurred, another sign that cellar management can change the final profile.

The strongest markers came from volatile compounds linked to aroma. Among the major volatiles, the researchers identified acetaldehyde, ethyl acetate, isobutanol, 2-methyl-1-butanol, ethyl lactate, diethyl succinate and 2-phenylethanol as useful for distinguishing wines by both winery and vintage. A principal component analysis of the major volatiles showed a clear separation by winery along the first component, which explained 40.18% of total variance, and an additional separation by vintage along the second component, which explained 31.72%.

The pattern was also clear when the team looked at 51 minor volatile compounds. In that analysis, the first two principal components explained 70.68% of total variance, with PC1 accounting for 54.03% and PC2 for 16.65%. Wines from 2022 tended to cluster with ester compounds such as ethyl octanoate and ethyl decanoate, while 2021 wines were associated more with compounds including gamma-butyrolactone, 4-ethylguaiacol, long-chain alcohols and lactones. Differences among wineries appeared on the second axis, where furanic and carbonyl compounds pushed samples in one direction and compounds such as acetophenone, ethyl benzoate and decanal in the other.

One of the study’s main points is that no single chemical marker can explain the effect of vintage or winery on its own. Instead, the researchers argue that a broader molecular profile is needed to understand how terroir and winemaking practices

combine in a traditional production area. They said the results provide a chemical baseline for differentiating wines from Moriles Alto and for studying how specific factors modify composition within a defined appellation.

For the wine business, that kind of fingerprinting could have practical value beyond academic classification. A more precise way to separate site-related traits from cellar-driven changes could help wineries, appellation bodies and buyers improve quality control, traceability and origin verification, especially in premium markets where regional identity carries commercial weight. It could also support efforts to track how climate shifts alter grape and wine chemistry over time in protected wine regions that market authenticity as part of their value.