Research BULLETIN

WEST COAST SMOKE EXPOSURE TASK FORCE

CALIFORNIA
OREGON
WASHINGTON
IDAHO

ABOUT

In November 2024, USDA's Agricultural Research Service (ARS) and the National Grape Research Alliance hosted a workshop at Oregon State University with wine industry stakeholders and the scientific community. Dr. Arran Rumbaugh, of USDA-ARS, developed a research roadmap – **Following the Smoke Signals: Elucidating the Future of U.S. Smoke Exposure Research** – that summarized workshop outcomes and highlighted critical research priorities. The West Coast Smoke Exposure Task Force is publishing a seven-part Research Bulletin series to provide summaries of the roadmap. The full document is available at wcsetf.org.

BULLETIN NO. 2

State of the Science

Wildfire smoke releases volatile compounds that can penetrate grapes and affect the final taste of wine, potentially leading to smoke taint. These compounds—volatile phenols, thiophenols and their glycosated markers—while naturally present in grapes and wines in trace amounts, are significantly elevated after smoke exposure and contribute to undesirable taste in wine.

Researchers have identified a set of compounds that are correlated to smoke exposure and smoke taint. The select volatile phenols and their glycoconjugates are now routinely analyzed in grapes and wines to determine the level of smoke impact, while methods to quantify thiophenols are still being developed.

Early and accurate detection of these compounds is essential for winegrape growers and winemakers to assess the extent of smoke contamination and make informed decisions about fruit selection, harvest and processing.

What follows is a summary of the current state of the science and knowledge gaps of the five critical research priorities contained in the research roadmap.

1. THRESHOLD LEVELS AND BASELINE ANALYSIS

Establishment of threshold levels of smoke marker compounds in grapes that correlate with altered sensory perceptions in wine is needed to assess the risk of smoke taint early in the growing season. Several laboratories have collected baseline data on the natural levels of volatile phenol compounds and found minor variations across vintages and vineyard locations, with differences primarily related to cultivar. A standardized, comprehensive database of baseline concentrations across different cultivars and environmental conditions, built over multiple years and regions, would help distinguish typical concentrations of smoke marker compounds in grapes from those elevated due to smoke exposure and facilitate management of smoke exposure.

Determining sensory odor thresholds for smoke marker compounds in wine is also needed to better understand consumer acceptance. Current research has identified concentration ranges of volatile phenols, thiophenols and glycoconjugates in wine that are linked to smoke taint, revealing significant variation in odor thresholds based on factors such as grape cultivar, wine style and consumer sensitivity.

2. RAPID DETECTION AND RISK ASSESSMENT

Liquid chromatography (LC) and gas chromatography (GC) are established methods for detecting smoke marker compounds in grapes and wine under laboratory settings. These methods are impractical for routine field use because they are expensive, require specialized equipment and trained personnel and have long turnaround times. Another risk assessment tool is nanofermentation, which simulates the winemaking process at a smaller scale and is being explored for rapid detection of smoke taint in grapes. It shows promise for moderately quick, low-cost evaluations, enabling rapid screening of grapes for smoke-related com-

pounds and is a faster alternative to traditional laboratory analyses.

3. ATMOSPHERIC MODELING

Atmospheric modeling can help evaluate the impact of wildfire smoke on vineyards by tracking the movement, deposition and transformation of airborne compounds – such as volatile organic compounds (VOCs) and particulate matter (PM) – that contribute to smoke taint in wine. Existing models are not yet fully optimized for viticulture, and they often lack the specificity needed for growers to make timely decisions. While progress has been made, there is a gap between atmospheric modeling and the chemical understanding of how key compounds, like volatile phenols and thiophenols, degrade and interact with the environment.

4. PREVENTION STRATEGIES

Research on preventing smoke taint in grapes has focused on spray-based treatments and genetic improvements, both of which face considerable challenges. Barrier sprays are being studied, although their effectiveness remains uncertain due to limited knowledge of how smoke-marker compounds interact with grape tissues, as well as practical challenges of application, coverage and need to remove sprays from fruit after smoke exposure. Genetic approaches to developing smoke-resistant grape varieties show promise as a long-term solution, but progress is slow and regulatory issues related to genetically modified organisms (GMOs) may arise. Additionally, there is a significant gap in knowledge regarding how different grapevine genotypes respond to smoke exposure. Collaboration within the research community is vital for the development of integrated solutions. A more comprehensive understanding of the chemistry of smoke exposure is essential for creating effective prevention methods.

5. MITIGATION TECHNIQUES

Efforts to mitigate smoke taint in wine currently focus on removing or altering the smoke marker compounds that negatively impact wine quality through different treatments, though their projected feasibility varies. There is no consensus on key factors, such as which methods should be used based on the timing and duration of smoke exposure, what compounds (like thiophenols and phenols) to target for removal, and the thresholds for sensory and chemical detection of smoke taint.

There is a clear need for immediate practical solutions and exploration and investment in longer-term strategies, such as removal of smoke markers via microbial enzymes, zeolites and molecularly imprinted polymers (MIPs) for smoke marker degradation. Creation of a shared database for winemakers and growers to exchange data and development of tiered mitigation methods based on the severity of smoke exposure would be useful. Economic and sustainable evaluation of these solutions is essential, as is research into alternative markets, consumer education and engagement to better manage market perceptions of smoke-tainted wines.

RESEARCH GAPS

Standardization of Testing and Risk Assessment Methods

Inconsistent sampling methods and analytical tools across the industry make it difficult to generate comparable datasets. Needed: Ring testing and standardized laboratory performance.

Thresholds and Variability in Smoke Taint

Industry lacks established baseline or threshold levels for acceptable smoke taint in grapes that accounts for cultivar, smoke exposure intensity and wine style. Needed: Understand sensitivity of different grape varieties to smoke exposure.

Chemical Understanding of Smoke Impact

Needed: Better understanding of degradation and environmental interactions of smoke compounds (e.g., guaiacol, thiophenols) and how they accumulate and affect grape quality over time. Also, comprehensive understanding of the full range of volatile compounds responsible for smoke taint and their sensory impacts.

Data Gaps and Model Integration

Lack of long-term, high-resolution data to validate atmospheric models makes it difficult to predict smoke exposure impact on grape quality. Needed: Integration of vineyard sensor data with predictive models.

Phenolic Binding and Prevention

Needed: Understanding of how phenolic compounds from smoke bind to grape skins could help develop effective barrier sprays.

Genetic Resistance

Identification and development of grapevine cultivars that are genetically resistant to smoke taint would provide a long-term and sustainable solution.

Mitigation

Timing and effectiveness of mitigation strategies during winemaking needed for winemakers, as well as assessment of mitigation tools like zeolites, molecularly imprinted polymers and genetically engineered yeast.

Industry Collaboration and Market Development

Improved communication and data sharing between researchers and the viticulture industry would advance prevention and mitigation strategies. Needed: Exploration of alternative markets for smoke-affected wines and consumer education.

The full roadmap, which includes explanatory figures/graphics, is available at wcsetf.org.

The **West Coast Smoke Exposure Task Force** is a coalition of industry leaders committed to providing timely communications, resources and best practices to help winegrape growers and vintners navigate the challenges of wildfire smoke. The task force serves as a central hub for updates, education and collaboration to support industry resilience and informed decision-making.