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Key facts about rotundone and practical ways to pepper your wine with this fascinating aroma compound

>>> In 2008, the sesquiterpene, rotundone, was identified as the main contributor to the aroma of black pepper in wine. Since then, this potent aroma compound has been detected in several grape varieties. In most cases, rotundone is positively perceived by consumers. One of the most fascinating facts about this molecule is probably that 20 to 25 % of the general population is anosmic to it. This technical review provides key facts about rotundone and practical ways to manipulate its concentration in wine using oenological and viticultural techniques. <<<

■ (3S, 5R, 8S) -5-isopropenyl-3,8-dimethyl-3,4,5,6,7,8-hexahydro-1 (2H) -azulenone, better known as rotundone

Rotundone, an oxygenated sesquiterpene also known as (3S, 5R, 8S) -5-isopropenyl-3,8-dimethyl-3,4,5,6,7,8-hexahydro-1 (2H) -azulenone (Figure 1), owes its name to *Cyperus rotundus*, the plant species in which it was first discovered in the 1960s. Rotundone flew under the analytical radar for about 40 years until it was detected for the first time in 2008 in pepper, in many Mediterranean aromatic species (rosemary, thyme, marjoram and basil), and in Australian Syrah grapes and wines[1]. Since this "rediscovery", rotundone has also been found at concentrations above twice its odor threshold in cultivars such as Castets (Maturana tinta), Cot (Malbec), Duras, Gamay, Grüner Veltliner, Mondeuse, Mourvèdre, Noiret, Pineau d'Aunis, Schiopettino and Vespolina[2]. Rotundone has also been identified in many spirits (bourbon, tequila, rum, whiskey, and brandy).

■ A potent and positive aroma compound for which 20 to 25 % of specific anosmia has been reported

Together with other grape-derived aroma compounds such as varietal thiols or alkyl-methoxypyrazines, rotundone is one of the most potent odorants to have been identified in wine. It has an odor threshold of 8 ng/L in water and 16 ng/L in red wine[1]. A specific anosmia (smell blindness) has been reported for this compound, as during the first sensory tests 20 to 25 % of the panelists were unable to detect rotundone in water, even at very high concentrations (>4000 ng/L)[1]. This fact is not trivial, as it may involve a complete distinct sensory experience between anosmic and non-anomic panelists enjoying the same glass of wine containing a substantial level of rotundone. For non-anosmic respondents, a significant positive correlation between the intensity of peppery notes at tasting and rotundone concentration in wine was highlighted (Figure 2)[3].

However, it cannot be completely discarded that other compounds may also participate in the peppery character of wine. Studies have been conducted to assess the appreciation of peppery notes by consumers. It has emerged that consumers appreciating peppery wines were generally those connoisseurs who pay more for a bottle of wine than the average consumer[3]. Furthermore, no concentration at which the molecule becomes undesirable (consumer rejection threshold) could be determined for rotundone[2]. Four clusters of consumers have been identified and the response of consumers to rotundone appear complex. However, in most cases rotundone was neutrally or positively perceived, apart from by the young panelists.

■ None of the studied winemaking techniques have proved to be effective in enhancing rotundone

Rotundone is a free aroma compound mainly located in the berry skin produced through enzymatic oxidation of its precursor, α-guaiene. It is a hydrophobic compound with only 10 % the rotundone present in grapes being extracted during fermentation[4]. The impact of several winemaking techniques and fermentation variables on rotundone was investigated[2].

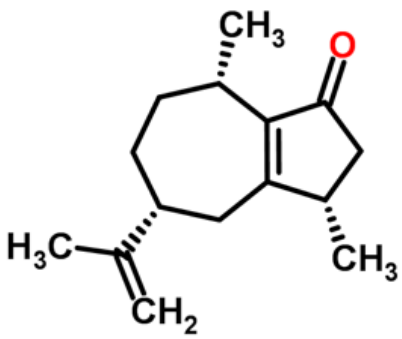

Figure 1. Chemical structure of rotundone.

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None of the techniques, including the addition of pectolytic enzymes during maceration or a cold pre-fermentation maceration ("cold soak"), have made it possible to enhance rotundone in comparison with a control wine fermented at 25 °C for 8 days. However, a decrease of 20 % has been observed for the semi-carbonic maceration treatment, for the wines fermented with *Saccharomyces uvarum* and when maceration was extended for 6 days after fermentation, indicating practical opportunities for reducing the pepper aroma in wine. Due to the pre-ferment removal of skins, the rotundone concentration in thermovinified and rosé wines was as low as 20 % and 13 % in comparison to that of the control wine. These findings indicate that it is crucial to harvest grapes with a substantial rotundone level in order to enhance rotundone in finished wine.

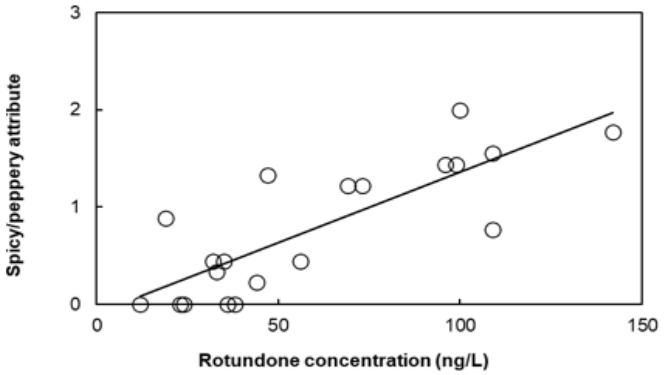

Figure 2. Relationship between rotundone concentration in wines and their spicy/peppery score rated on a five-point scale (n = 21). $R^2 = 0.66$[3].

■ Enhancing rotundone concentration in berries using common viticultural levers

Cool and wet vintages are particularly favorable for obtaining wines with higher rotundone levels[4]. Beside the cultivar, the clone is another lever to consider as clonal variations in rotundone have been reported for Duras, Syrah and Grüner Veltliner[2]. Biotic stresses also have a great impact on rotundone. While powdery mildew (*Erysiphe necator*) may stimulate rotundone accumulation as a result of the sesquiterpenic nature of the compound (Figure 3)[5], *Botrytis cinerea* has a depreciative effect[6]. As rotundone accumulates late during maturation before reaching a plateau[4], it is key to harvesting fully ripe grapes. Conflicting results have been observed for defoliation[2]. Indeed, it has been demonstrated that temperatures above 25 °C negatively affected rotundone accumulation[7] and light might stimulate the production of rotundone[6]. Therefore, defoliation is recommended only on the side of the row exposed to less sun radiation (i.e., east or north). Crop load and grape thinning have no impact on rotundone which is in accordance with the *in situ* production of the compound[2]. Preveraison irrigation is an effective strategy for enhancing rotundone, which can be combined with 'Passerillage Eclaircissage sur Souche' (PES) to mitigate its depreciative effect on wine phenolic compounds[2]. The PES technique consists in cutting the fruit-bearing cane on a Guyot-trained vineyard two to three weeks prior to harvest. Large intra-block variability in rotundone content has been described which makes it possible to organize differential harvesting, with the aim of producing wine with distinct levels of rotundone concentration from the same vineyard block[8]. To approximate rotundone spatial distribution, trunk circumference can be used[2].

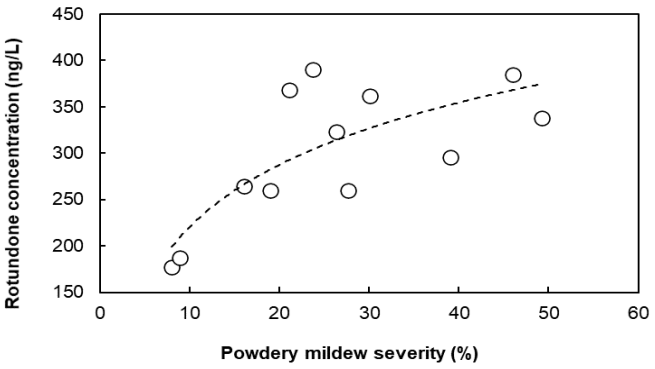

Figure 3. Relationship between rotundone concentration in wines and powdery mildew severity on grapes at harvest (n = 12). $R^2 = 0.58$[5].

■ Next challenge?

Climate change which in most cases takes the form of an altered precipitation regime and higher temperatures during the grapes ripening, already has a depreciatory effect on rotundone accumulation. In this context, one of the main issues for researchers is to provide the wine industry with more sustainable strategies than irrigation to enhance rotundone. ■

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