Technical Note

ARC TRAINING CENTRE FOR INNOVATIVE WINE PRODUCTION

The link between cell vitality and potassium in grape berries

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Background and Aims

Previous studies indicate that berry shrinkage in the later stages of ripening is associated with the arrest of vascular inflows and the loss of cell vitality (Rogiers et al., 2006; Tilbrook & Tyerman, 2008). Shiraz was found to be prone to berry shrivelling and cell death in later stages of ripening (Rogiers & Holzapfel, 2015). A cell death associated gene, *VvBAG1*, was downregulated in the pericarp of Shiraz berries by increasing potassium (K) supply (Coetzee et al., 2019). Potassium, with essential roles such as regulation of turgor and as an enzyme cofactor (Rogiers et al., 2017), contributes to hydraulic and metabolic processes so that cell vitality is maintained. However, high berry K content is correlated with high sugar and low acidity in grape juice, resulting in an industry preference for grapes with low K content. Potassium accumulates rapidly during ripening but eventually slows once berries reach their maximum size, as a result of the arrest of vascular inflows.

Solute transport and accumulation in grape berry cells are energised by trans-membrane voltages and energy molecules such as ATP. Post-véraison berries require increased energy to accumulate high concentrations of sugar, K and other solutes. However, the increased energy demand may not be satisfied by aerobic respiration, considering the mesocarp (pulp) becomes hypoxic and fermentation ensues with low ATP production efficiency (Xiao et al., 2018). This oxygen deficiency may exacerbate mesocarp cell death in the late-ripening berries of Shiraz and Chardonnay (Xiao et al., 2018). The close association between hypoxia and cell death indicates that cell vitality may be regulated by berry energy status.

We investigated the relationship between energy status and K accumulation in berries from pre-véraison to overmature stage, aiming to explore the potential links between cell vitality and K during berry ripening at the cellular level. Our results will inform future viticultural strategies to manage berry shrivelling and regulate berry K content.

Key outcomes

- Trans-tissue and trans-membrane voltage trends in Shiraz berries across several stages of ripening inidicate a decline in energisation once berries reach physiological maturity (total soluble solid > 25 °Brix).

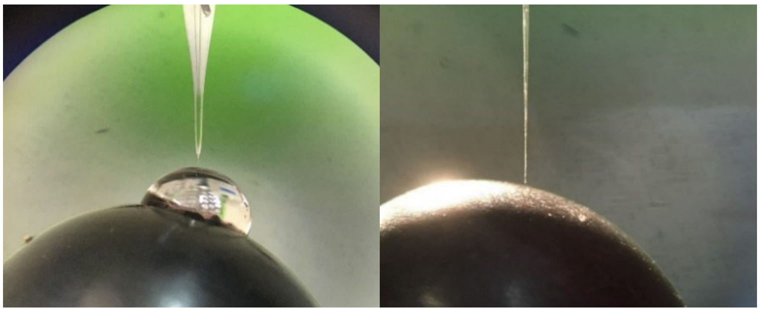

Figure 1. (Left) Submerging the tip of microelectrode into a drop of electrolyte solution placed on the exposed surface of berry flesh (after removing the skin) during the trans-tissue voltage measurement. (Right) Inserting a microelectrode into the berry flesh to measure trans-membrane voltage.

- Developmental patterns of gene expression associated with K^+ transport, membrane energisation and cell death indicate their regulation was dependent on the stage of ripening. The upregulation of cell death genes and the downregulation of vacuolar energisation genes in later ripening stages provide evidence for the loss of cell vitality and a decline in the energised state, and thus the capacity to accumulate solutes in vacuoles. The regulation of various genes responsible for K^+ transport was dependent on function and cellular location.
- Cultivar differences in the accumulation and degradation of various critical berry components were apparent, with Shiraz berries comprising progressively reduced ATP content after véraison, and elevated ethanol concentration along with a decreased ratio of K to sodium (K/Na) in later ripening stages. In contrast, Chardonnay berries continued to accumulate ATP after berries attained maximal sugar content. Flame Seedless berries contained the most stable ATP concentration and K/Na ratio during ripening.

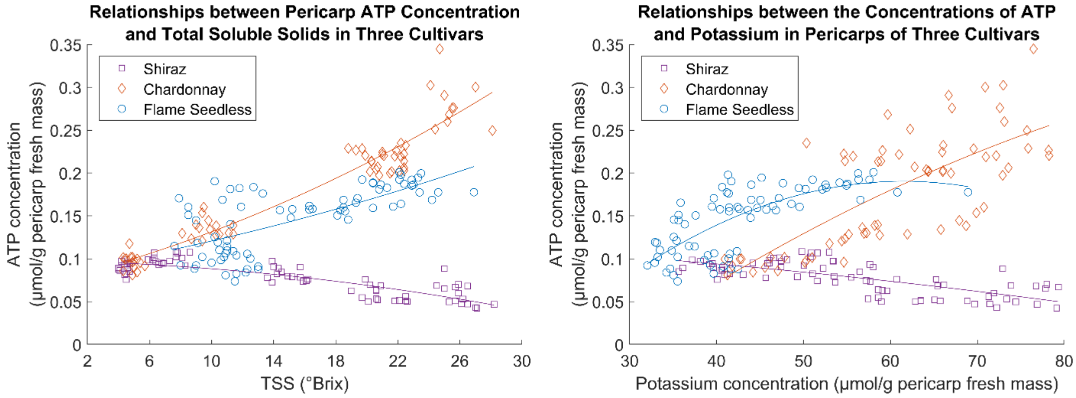

Figure 2. Relationships between berry pericarp ATP concentration and TSS (left) or K concentration (right) in Shiraz, Chardonnay and Flame Seedless. Shiraz was distinguished by the negative correlations.

- Increased K supply to Shiraz during ripening increased berry L-malic acid content in the earlier ripening stages, and increased the berry K concentration and content in later ripening stages. Berry water percentage and sugar concentration were not altered by increasing K supply from véraison to the overmature stage.
- Rootstock had an influence on berry K levels. 420 A resulted in berries with lower K than Ramsey, Ruggeri 140 or own-rooted vines.

Recommendations

Our studies provide evidence to support the hypothesis that the decline in berry energy status, that is common in cultivars such as Shiraz, is associated with the completion of K accumulation in the final ripening stages. Reducing bunch exposure and ensuring sufficient irrigation later in ripening is encouraged to alleviate berry dehydration and weight loss prior to harvest. Our results reveal that berry K content is cultivar specific and is dependent on the stage of ripening. Rootstock also has an influence and should be carefully considered. Vine nutrition should be monitored to ensure that K is not in the deficient or luxurious range. Since cell death has repercussions for berry composition, we also recommend that growers and winemakers carefully monitor berry maturity and decide on the appropiate harvest time according to the targeted wine style.

What's next?

Knowledge on the cellular and molecular mechanisms leading to changes in berry energetics are required to better understand the physiological events leading to the loss in cell vitality that is common in wine grapes. Practical approaches in the vineyard to manage berry composition during ripening may then be trialed and appropriately implemented.

Acknowledgements

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