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A hypothesis for the presence, activity, and role of potassium/hydrogen, adenosine triphosphatases in grapevines

By: Roger Boulton

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• Recent articles by Dr. Boulton demonstrated that metal cations, in particular potassium, enter the cell in direct exchange for protons derived from the acids inside the berry. This exchange leads to juices with lower TA and higher pH than would be expected from the acid content alone. The goal of this paper was to describe the mechanism considered to be responsible for this K+/H+ exchange. Additionally, the author interprets a variety of viticultural observations that are considered a direct result of the presence of this enzyme.

• But what is adenosine triphosphatase, or ATPase, anyway? It is an enzyme that can be viewed as a 'pump' or 'shuttle', and that it is embedded in the inner membrane of the cells of many plants and animals. Its function is to 'pump' potassium and sodium ions inside the cell, and to pump protons out. The energy that makes the 'pump' work is the molecule adenosine triphosphate (or ATP), which in the pumping process gets converted to adenosine diphosphate (or ADP). ADP is converted back to ATP by other pathways and cycles in the metabolism of the cell. The functioning of the 'pump', that is, the uptake of K and Na, is affected by factors such as the internal levels of ATP in the root cells, the moisture level of the soil, and the size of the root system.

• The idea that an ATPase existed in the root and berry tissues of grapevines, and that this enzyme was responsible for the exchange of potassium (or sodium) by protons, was triggered by the observation by the author that the discrepancy between the protons expected from the measure of the *organic acid content* and those measured by *titratable acidity* was essentially identical to the quantity of potassium and sodium ions present. Since neither diffusion nor active transport could account for the values observed, this suggested an exchange mechanism. ATPases had previously been reported to perform this type of exchange in many other species.

• Dr. Boulton devotes a good portion of the article to review real cases in which the presence of an ATPase can explain the observed changes of pH. Briefly, here are some examples (please refer to the original text for a full explanation):

_ *high crop situations:* the higher TA observed would be associated with a lower ATPase activity, potentially due to K being depleted by the large crop, as well as an increase in tartrate due to smaller berries.
_ *soil nutritional composition:* generally, there is no significant correlation between soil K and berry K, implying that the ATPase uptake is independent of the external K concentration. This, however, is not the case when soil K is deficient, in which case the vine does respond to K fertilization. In situations of K

deficiency, the presence of ATPase activity would be expected to translate into higher K in the berry, and lower TA and higher pH in the must, all of which have been observed. In the event that considerable sodium is present in the soil (high salinity), additional sodium would enter the vine in place of potassium. Higher petiole sodium was observed in high-salinity sites, as it would be expected from the presence of ATPase activity.

_ *sugar accumulation*: data from cool growing regions with delayed sugar accumulation tend to show also high K levels. This is considered to be a competition for available ATPase between K^+ and sugars.

_ *rootstock:* differences in K absorption of various rootstocks would be due in part to different selectivity between K and Na by the different stocks. However, cropping level, root development, and water uptake would also play a role.

_ *water status/irrigation:* Dr. Boulton reports a study on Riesling in which the observed changes in the irrigated treatment –higher TA and lower pH – could be explained by a 'reversal' of the ATPase exchange, causing an efflux of K and an influx of H+. This would be expected to occur in the presence of an excess of cytoplasmatic ADP. Based on the pH values observed in Riesling juices – rarely greater than pH 3.5 - the ATPase activity in this cultivar is supposed to be limited.

In conclusion, in this study Dr. Boulton proposes the presence of a K+/H+ adenosine triphosphatase in grapevines. Even though this finding does not have practical application for the grower or winemaker, invoking the presence of this enzyme allowed the author to explain some of the acidity measurements observed in a number of situations that we face everyday, like those involving various rootstocks, cropping levels, irrigation and mineral nutrition levels.

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