The uncoupling of berry ripening: what we have learned from InnoVine

Stefano Poni

Cabernet Sauvignon
Napa - 2005

Flavor intensity via sensory

Soluble solids (°Brix)

From Dokoozlian, 2005
Soft – 7-8 °Brix
Problems

- Red grapes: too fast sugar accumulation while phenolics and flavour still lag behind.
- White grapes: it is hard to maintain acidity and freshness in sparkling and spumante wine types.
- Issues of grape delivery and logistic.

Objectives

- Sugar:anthocyanins decoupling (delaying sugaring without delaying the rest of maturity is the challenge)
- Safeguard acidity without compromising adequate sugar level and aroma.
- More in general, decompress maturity by delaying the whole annual cycle?
Tools and techniques

- First, always assess if your accelerated ripening is not due to trivial reasons (i.e. maybe vines are undercropped??)
- New genetic material or drawing from existent biodiversity
- Targeted leaf removal
- Use of anti-transpirants
- Delayed winter pruning
Tempranillo somatic variants differed in their response to elevated temperature during grape sugar and anthocyanin accumulation

Objective

The aim of this study was to assess the effect of elevated temperature on the accumulation of sugars and anthocyanins of thirteen accessions of Tempranillo grapevine, which differed in their cycle length.
Experimental design

Thirteen Tempranillo Accessions with different cycle length:
86, 1052, 336, 518, 501, 349, 280, 825, 807, 814, 318, 56, and 1084 (Government of La Rioja, Spain)

Temperature regimes (from fruit set to maturity)
• 24/14ºC day/night
• 28/18ºC day/night

n=3-6

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Number of days from fruit set to veraison and from veraison to maturity of thirteen accessions of Tempranillo

**Fruit set - veraison**

- $P_{(accession)} = 0.789$
- $P_{(T)} < 0.0001$
- $P_{(accession \times T)} = 0.158$

**Veraison - maturity**

- $P_{(accession)} < 0.0001$
- $P_{(T)} = 0.015$
- $P_{(accession \times T)} = 0.237$

Accessions:
- 24/14°C
- 28/18°C

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Effect of elevated temperature on the relationship between the concentration of anthocyanins and total soluble solids in thirteen accessions of Tempranillo

![Graph showing the relationship between total skin anthocyanins and total soluble solids at different temperatures.](chart.png)

- Total skin anthocyanins (mg g⁻¹ DM) vs Total soluble solids (°Brix)
- Two temperature conditions: 24/14°C and 28/18°C
- R² = 0.92, P < 0.0001 for 24/14°C
- R² = 0.93, P < 0.0001 for 28/18°C

CSIC partner INNOVINE – Project FP7-311775
Effect of elevated temperature on the relationship between the concentration of anthocyanins and total soluble solids in thirteen accessions of Tempranillo

Short ripening cycle variants

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Total skin anthocyanins (mg g⁻¹ DM)</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/14°C</td>
<td>86</td>
<td>0.97</td>
</tr>
<tr>
<td>28/18°C</td>
<td>1052</td>
<td>0.99</td>
</tr>
<tr>
<td>24/14°C</td>
<td>336</td>
<td>0.99</td>
</tr>
<tr>
<td>28/18°C</td>
<td>518</td>
<td>0.99</td>
</tr>
<tr>
<td>24/14°C</td>
<td>501</td>
<td>0.97</td>
</tr>
<tr>
<td>28/18°C</td>
<td>280</td>
<td>0.96</td>
</tr>
<tr>
<td>24/14°C</td>
<td>825</td>
<td>0.91</td>
</tr>
<tr>
<td>28/18°C</td>
<td>318</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Total soluble solids (°Brix)

Long ripening cycle variants

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Total skin anthocyanins (mg g⁻¹ DM)</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/14°C</td>
<td>56</td>
<td>0.98</td>
</tr>
<tr>
<td>28/18°C</td>
<td>814</td>
<td>0.97</td>
</tr>
<tr>
<td>24/14°C</td>
<td>807</td>
<td>0.99</td>
</tr>
<tr>
<td>28/18°C</td>
<td>349</td>
<td>0.97</td>
</tr>
<tr>
<td>24/14°C</td>
<td>1084</td>
<td>0.99</td>
</tr>
<tr>
<td>28/18°C</td>
<td>814</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Total soluble solids (°Brix)

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Source limitation affects sugar:anthocyanins relationships

**Anthocyanin : Sugars**

**Hours** $T_{\text{berry}} > 35^\circ \text{C}$ from véraison to full maturation

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDIE</td>
<td>88</td>
<td>35</td>
</tr>
<tr>
<td>SDIW</td>
<td>112</td>
<td>48</td>
</tr>
<tr>
<td>RDIE</td>
<td>73</td>
<td>20</td>
</tr>
<tr>
<td>RDIW</td>
<td>106</td>
<td>56</td>
</tr>
</tbody>
</table>

**Cumulative water stress** (Pre-dawn water stress integral $(S\Psi_{pd} \text{ MPa day}^{-1})$ from véraison to full maturation)

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDI</td>
<td>3.75</td>
<td>5.42</td>
</tr>
<tr>
<td>RDI</td>
<td>6.43</td>
<td>6.91</td>
</tr>
</tbody>
</table>

SDI: sustained deficit irrigation 30% $\text{ET}_c$
RDI: regulated deficit irrigation 15% $\text{ET}_c$

A thermal disruption of the anthocyanin : sugar relationship east versus west berries

Decoupling due to high temperature at west side

Anthocyanin : sugar decoupling slightly larger in RDIW

RDI more susceptible to high temperature

SDIE: SDI east side
SDIW: SDI west side
RDIE: RDI east side
RDIW: RDI west side
-Highly significant correlation at the east side
- Significant but smaller correlation at the west side

high temperature at west side account for the differential modulation of these metabolites

Anthocyanin : ABA decoupling slightly larger in RDIW

RDI more susceptible to high temperature
flowering

veraison

harvest

Pn (µmol m^{-2} s^{-1})

basal

median

apical

May 1
May 15
May 31
June 15
June 30
July 15
July 31
August 15
August 31
Sept. 15
Sept. 30
October 15
October 31

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Apical to the cluster late Leaf Removal

Leaf Plucker

Detail of the fruit zone
Late leaf removal aimed at delaying ripening in cv. Sangiovese: physiological assessment and vine performance.

Australian Journal of Grape and Wine Research
Volume 19, Issue 3, pages 378-387, 12 AUG 2013
DOI: 10.1111/ajgw.12040

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Grape composition determined on Sangiovese grapevines either non-defoliated or defoliated pre- (DEF-I) and post-veraison (DEF-II) at the two different harvest dates.

<table>
<thead>
<tr>
<th></th>
<th>Soluble solids (°Brix)</th>
<th>TA</th>
<th>pH</th>
<th>Color (mg/g)</th>
<th>Phenolics (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harvest 04/09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>18.8 a</td>
<td>5.34 a</td>
<td>3.13</td>
<td>0.63</td>
<td>2.14</td>
</tr>
<tr>
<td>DEF-I</td>
<td>17.5 b</td>
<td>6.03 b</td>
<td>3.24</td>
<td>0.67</td>
<td>2.31</td>
</tr>
<tr>
<td>DEF-II</td>
<td>16.4 c</td>
<td>6.22 b</td>
<td>3.22</td>
<td>0.64</td>
<td>2.27</td>
</tr>
<tr>
<td>Sig.</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Harvest 11/09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DEF-I</td>
<td>18.9</td>
<td>6.54</td>
<td>3.19</td>
<td>0.67</td>
<td>1.90</td>
</tr>
<tr>
<td>DEF-II</td>
<td>18.0</td>
<td>6.69</td>
<td>3.18</td>
<td>0.67</td>
<td>1.98</td>
</tr>
<tr>
<td>Sig.</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>
Mechanical leaf removal: August 23 (4 weeks after veraison)

Grape harvest: September 19 (27 days after leaf removal)

Driven at 2 km/h (3-4 h/ha)

Opening of a window about 50-60 cm tall above the cluster zone
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Defoliation</th>
<th>Year</th>
<th>Sig. †</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>D</td>
<td>2011</td>
</tr>
<tr>
<td>Total leaf area/vine (m²)</td>
<td>4.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>**</td>
</tr>
<tr>
<td>Lateral leaf area/vine (m²)</td>
<td>1.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.72&lt;sup&gt;b&lt;/sup&gt;</td>
<td>**</td>
</tr>
<tr>
<td>Clusters/vine</td>
<td>10.0</td>
<td>10.3</td>
<td>ns</td>
</tr>
<tr>
<td>Yield/vine (kg)</td>
<td>2.51</td>
<td>2.63</td>
<td>ns</td>
</tr>
<tr>
<td>Cluster weight (g)</td>
<td>250.0</td>
<td>243.0</td>
<td>ns</td>
</tr>
<tr>
<td>Berry weight (g)</td>
<td>2.05</td>
<td>2.03</td>
<td>ns</td>
</tr>
<tr>
<td>Total soluble solids (°Brix)</td>
<td>23.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>*</td>
</tr>
<tr>
<td>Titratable acidity (g/L)</td>
<td>6.35</td>
<td>6.15</td>
<td>ns</td>
</tr>
<tr>
<td>Must pH</td>
<td>3.26</td>
<td>3.31</td>
<td>ns</td>
</tr>
<tr>
<td>Anthocyanins (mg/cm² skin)</td>
<td>0.419</td>
<td>0.411</td>
<td>ns</td>
</tr>
<tr>
<td>Total phenolics (mg/cm² skin)</td>
<td>0.59</td>
<td>0.57</td>
<td>ns</td>
</tr>
<tr>
<td>Leaf-to-fruit ratio (m²/kg)</td>
<td>1.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>*</td>
</tr>
</tbody>
</table>

†Means within rows designed by different superscript letters are significantly different by the Student-Newman-Keuls test. *, **. ns indicate significance at P ≤ 0.05 and 0.01 or not significant, respectively

From Palliotti et al. (2013). AJGWR 19: 369-377
Influence of mechanical postveraison leaf removal apical to the cluster zone on delay of fruit ripening in Sangiovese (*Vitis vinifera* L.) grapevines
Material and Methods

climate: moderate temperature conditions (1981-2010):

<table>
<thead>
<tr>
<th>season</th>
<th>temperature [°C]</th>
<th>precipitation [mm]</th>
<th>sunshine hours [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>winter</td>
<td>2,4</td>
<td>123</td>
<td>174</td>
</tr>
<tr>
<td>spring</td>
<td>10,4</td>
<td>125</td>
<td>509</td>
</tr>
<tr>
<td>summer</td>
<td>18,8</td>
<td>155</td>
<td>661</td>
</tr>
<tr>
<td>autumn</td>
<td>10,4</td>
<td>139</td>
<td>305</td>
</tr>
</tbody>
</table>

vegetation period | 15,2 | 336 | 1298

Varieties tested: Riesling and Müller-Thurgau

canopy manipulation treatments:

- Control [A]
- MDC: mechanically defoliated canopy [B]
- SSP: severe summer pruning [C]
- Anti-transpirant spray [D]

measurements on phenology [Coombe, 1995], physiology [A, g_s], bunch architecture and fruit components as well as fruit sanitary
The uncoupling of berry ripening:
Partner GRC (contributors: S. Tittmann, V. Stöber and M. Stoll)

Results

Phenology:

- no alteration of phenology through canopy manipulation treatments

Variation in Leaf Area to Fruit Weight (LA/FW) ratio

- control: app. 2 m²kg⁻¹
- SSP: severe summer pruning: app. 0.4 m²kg⁻¹
- MDC: mechanically defoliated canopy: app. 1.2 m²kg⁻¹
- Anti-transpirant spray: app. 1.4 m²kg⁻¹

only anti-transpirant significantly impacts on net-assimilation rate [A, µmolm⁻²s⁻¹] whilst other treatments did not significantly alter A

within canopy manipulation treatments the intensity, timing and positioning of defoliation practices are the main clues to alter berry ripening

velocity of sugar accumulation becomes reduced under restricted leaf area

similar to severe defoliation practices applying anti-transpirant spray reduces sugar accumulation or the velocity of fruit ripening drastically
The uncoupling of berry ripening: Partner GRC (contributors: S. Tittmann, V. Stöber and M. Stoll)

**Results**

- **Fruit composition:**
  - no changes in pH or total acidity
  - higher content of yeast available nitrogen using severe summer pruning
  - in Riesling: higher total phenol content under either defoliation of the bunch zone or severe summer pruning; flavanoles remain unchanged, hydroxycinnamic acid derivatives whilst flavonols increase

- **Carbohydrate allocation**
  - reduction in starch reallocation under severe summer pruning
Days after flowering

Volume dell’acino (mm$^3$)

Treatments
- Unsprayed (C)
- Sprayed pre-flowering (PF)
- Sprayed pre-veraison (PV)
- Sprayed both stages (BS)

VG spray

I

II

III

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Manipulation of ripening via antitranspirants in cv. Barbera (Vitis vinifera L.)

TSS (°Brix)

2013

2014
Manipulation of ripening via antitranspirants in cv. Barbera (*Vitis vinifera* L.)

Linear relationships between TSS and anthocyanins for (a) 2013 and (b) 2014 for the application of antitranspirant at pre-veraison (◊) and at pre-flowering and pre-veraison (□) and for the unsprayed control (●).
Field trial on Pinot Noir

Conventional winter pruning

Delayed winter pruning

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Thanks to All Contributors and to Your Attention