Investigating Peduncle Colour Evolution and Chemistry During Ripening in Vitis vinifera L. cv Shiraz

A thesis presented in fulfilment of the requirements for the degree of

Doctor of Philosophy

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September 2014

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Abstract

This thesis describes an investigation of how the various sections of the grape stem (peduncle and rachis) in *Vitis vinifera* L. cv Shiraz evolve in terms of their colour and chemical attributes during the ripening period and is compared to the prototypical berry ripeness parameters (^{o}Brix, pH, TA, etc) over three seasons. The grape peduncles turned from green at veraison, to predominantly brown at harvest, whilst the rachises remained green during the maturation period. Certain peduncle and rachis chemical changes were also uncovered during these studies and shed light on the relationships between peduncle colour and chemical composition. Statistical modelling was conducted to examine the relationship between the peduncle colour and chemical composition, and a clear co-development was observed between peduncle evolution (colour and moisture) and the berry ripening continuum. Such observations are yet to be reported and provide for the opportunity to develop a new simple platform to assist in predicting grape berry ripeness and therefore aid in harvest decisions.

Chapter 1 of this thesis comprises a detailed introduction of our current understanding on how both grape berries and their stems evolve over the ripening period and sets the scene by pinpointing key aspects for this exciting research journey.

Chapter 2 details a large study on how the change in morphology (size and colour) of both the grape peduncles and rachises evolve in eight distinct patches of Shiraz from the same vineyard over two seasons. A semi-automatic method was developed to quantify the peduncle morphological details exploiting digital image analysis. The berries associated with the peduncles from the same bunches were also analysed for their prototypical berry ripeness parameters, namely the sugar content (^{o}Brix), acidity (pH and TA), total anthocyanins and total phenolics. The image analysis showed that the overall peduncle colour evolution from green to brown was well reflected in the change of *a** and *b** values in the CIE*L*a*b** colour system coupled with their polar parameters hue and chroma. Importantly, the change in the colour coordinates of the peduncles was found to be in parallel with the change in berry ripeness parameters thus providing a new means to assist in harvest decisions. This work was submitted to the *Australian Journal of Grape and Wine Research* in 2014.

Chapter 3 evaluates a range of key chemical changes in Shiraz peduncles and rachises from veraison to harvest over two seasons. During ripening, peduncles experienced significant decrease in moisture and pigment (chlorophylls and carotenoids) levels while the total phenolics and antioxidant capacity (DPPH) levels did not change significantly. The levels of these chemical traits were always higher in the rachises than the peduncles; an observation yet to be reported. Moreover, it was found that the peduncle moisture content was correlated with the peduncle colour hue value in a strong linear fashion and was negatively associated with the pigments ratio (total chlorophylls / total carotenoids). Finally, the results showed that peduncle moisture content also co-developed with the prototypical berry ripeness parameters during ripening, an observation which excitingly provides for a new hitherto unknown approach to predicting berry ripeness and harvest date via peduncle moisture detection. This work was submitted to the *Journal of Agricultural and Food Chemistry* in 2014.

Chapter 4 evaluates the spatial and temporal variation of peduncle colour in five Shiraz patches from the same vineyard during the 2013/14 season. Peduncles were collected from the same positions based on a regular grid sampling design for each patch of Shiraz; an enormous but fulfilling task! The within-patch variation among individual peduncle colour was found to be mostly driven by the berry maturation stages. It was found that at veraison, the peduncle colour was more homogeneous and displayed a green state, then the peduncle colour became more variable during ripening whilst less heterogeneous at harvest with the majority of peduncles in brownish colour. We also observed that actual fruit harvesting within these vineyard patches began when over 40% of the sampled peduncles appeared visually predominantly brown, providing the sample size was no less than 100 from that particular patch. Thus a simple visual assessment of the proportion of brown peduncles could be used as an easy and quick way to help predict time for harvest. Moreover, the linear relationship between peduncle colour hue value and moisture content was verified and extended to the individual bunch level during the 2014 vintage. Again these observations strengthen the potential use of monitoring peduncle colour evolution to predict harvest date, and pave the way for the development of non-destructive methods of measuring peduncle colour in the field. This work has been prepared in publication style for the *Australian Journal of Grape and Wine Research* in 2014.

Chapter 5 completes these exhilarating research works by summarising the key new findings and their potential benefits to the wine industry and provides suggestions for future research directions.

List of publications

1. Fang, Y.; Kravchuk, O.; Fuentes, S.; Skouroumounis, G. K.; Cotsaris, D.; Taylor, D. K. Assisting Harvest Decisions via the Relationship between Peduncle Colour and Berry Ripeness in *Vitis vinifera* L. cv Shiraz. *Australian Journal of Grape and Wine Research*. **2014**, submitted.

2. Fang, Y.; Kravchuk, O.; Taylor, D. K. Chemical Changes in Grape Stem and Their Relationship to Stem Color Throughout Berry Ripening in *Vitis vinifera* L. cv Shiraz. *Journal of Agricultural and Food Chemistry*. **2014**, submitted.

3. Fang, Y.; Kravchuk, O.; Taylor, D. K. Investigation of Within-Vineyard Variation of Peduncle Colour to Assist in Harvest Decisions in *Vitis vinifera* L. cv Shiraz**.** *Australian Journal of Grape and Wine Research*. **2014**, publication format.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Acknowledgements

Firstly I would like to express my sincerest gratitude to Professor Dennis Taylor. As my supervisor, you not only guided me through my exciting research, but you also showed your enthusiasm by coming to the vineyard with me and conducting some of the hard grape sampling work over 3 vintages. Your wisdom, enthusiasm and determination always inspired me to get through the challenges that appeared during my PhD, I really appreciate your mentoring and thank you for making me stronger.

I also wish to thank Dr Sigfredo Fuentes for aiding in the writing up of the customised code to analyse peduncle morphology; your help paved the way for my peduncle work. Also thanks to Dr Olena Kravchuk for your assistance in data analysis. You opened a new window for me to interpret the large amount of data from my research which is greatly appreciated.

A huge thanks to Dr George Skouroumounis for his helpful advice and Mr Dino Cotsaris for his generous support in allowing access to the Longview Vineyard. Thanks to Dr Tommaso Liccioli and Mariola for their help in developing the methods of the microplate chemical assays. Thanks to all members of the Taylor Group for their company and I extend my thanks to Jingyuan Li, Jiao Jiang and many other friends for their good help with sampling and sample processing during busy vintages.

Thanks to the funding support provided by the Australia's grapegrowers and winemakers through their investment body formally known as the Grape and Wine Research and Development Corporation (GWRDC) but now known as the Australian Grape and Wine Authority (AGWA). Thanks to the Australian Society of Viticulture and Oenology (ASVO) for the opportunity to present my work at the 'In the wine light' competition during the 15th AWITC and my gratitude for the awards. I also thank the China Scholarship Council and the University of Adelaide for a PhD scholarship.

Finally, I would like to thank my parents in China for their care and support along my PhD journey. Although they don't speak English and hardly understand research, their unconditional love has encouraged me continuously during my four years in Adelaide.

Abbreviations

ABA	Abscisic acid
au	Absorbance units
BSA	Berry sensory assessment
C	Chroma
Ca	Chlorophyll *a*
Cb	Chlorophyll *b*
Ca+b	Total chlorophylls
Cx+c	Total carotenoids
cm	Centimetres
DAF	Days after flowering
DPPH	1,1-Diphenyl-2-picrylhydrazyl
g	Grams
GA	Gibberellic acid
GC	Gas chromatography
GPS	Global positioning system
h	Hue
Ha	Hectare
HCl	Hydrochloric acid
HPLC	High Performance Liquid Chromatography
Hz	Hertz
JPEG	Joint Photographic Experts Group
kg	Kilogram
L	Litre
LC-MS	Liquid chromatography-mass spectrometry
m	Meter
M	Molar (moles/litre)
mg	Milligrams
MgO	Magnesium oxide
min.	Minutes
mL	Millilitre
mm	Millimeter
mmol	Millimoles

mol	Moles
MS	Mass spectrometry
NIR	Near-infrared spectroscopy
nm	Nanometres
OIV	International Organisation of Vine and Wine
P	Peduncle
pi	π (≈ 3.14)
ppm	Parts per million
R	Rachis
REML	Restricted/residual maximum likelihood
RGB	Red Green Blue
ROI	Regions of interest
ROS	Reactive oxygen species
rpm	Revolutions per minute
SH	Shiraz
SPME-GC-MS	Solid-phase microextration-Gas chromatography-Mass spectrometry
TA	Titratable acidity
Trolox	6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid
TSS	Total soluble solids
UV	Ultra-violet
μg	Micro gram
μM	Micro molar

Figures and Tables for Chapter 1.

Learning is the only thing which the mind can never exhaust, never alienate, never be tortured by, never fear or distrust, and never dream of regretting.

— T.H. White