

Alternatives to Oak Barrel Maturation:  
Influence on Composition, Sensory Properties  
and Consumer Acceptance of Wine

Anna Marie Crump

The University of Adelaide  
School of Agriculture, Food and Wine  
Faculty of Sciences

February 2015

A thesis submitted in fulfilment of the requirements for the degree  
of Doctor of Philosophy



THE UNIVERSITY  
*of* ADELAIDE

## Table of Contents

Table of Contents.....	ii
List of Figures.....	iv
List of Tables .....	v
Abstract .....	vi
Declaration .....	viii
Acknowledgements .....	ix
<b>Chapter 1: Introduction .....</b>	<b>1</b>
1.1 OAK VOLATILES.....	3
1.2 OAK ALTERNATIVES.....	7
1.3 CONSUMER RESEARCH.....	8
1.4 RESEARCH OBJECTIVES .....	10
<b>Chapter 2: Paper 1 - Consumers' knowledge of and attitudes toward the role of oak in     winemaking. ....</b>	<b>12</b>
2.1 STATEMENT OF AUTHORSHIP.....	13
<b>Chapter 3: Maturation of wine using barrel alternatives.....</b>	<b>25</b>
3.1 PART 1 - INTRODUCTION.....	25
3.2 MATERIALS AND METHODS.....	27
3.2.1 <i>Wine maturation</i> .....	27
3.2.2 <i>Compositional analysis of wines</i> .....	29
3.2.3 <i>Sensory analysis of wines</i> .....	29
3.2.4 <i>Statistical Analysis</i> .....	30
3.3 RESULTS AND DISCUSSION.....	32
3.3.1 <i>Compositional analysis of wines</i> .....	32
3.3.2 <i>Sensory Analysis</i> .....	37

3.4 CONCLUSIONS .....	45
3.5 FUTURE WORK.....	45
3.6 PART 2: <b>Paper 2 - Consumer acceptance, sensory properties and chemical composition of Cabernet Sauvignon wines made using alternative oak maturation regimes...</b>	47
3.7 STATEMENT OF AUTHORSHIP.....	49
<b>Chapter 4: Consumers' emotional response to oak aromas .....</b>	<b>59</b>
4.1 INTRODUCTION.....	59
4.2 MATERIALS AND METHODS.....	61
4.2.1 <i>Consumer Survey</i> .....	61
4.2.2 <i>Data Analysis</i> .....	62
4.3 RESULTS AND DISCUSSION.....	62
<b>Chapter 5: Paper 3 - Preparation of isotopically labelled volatile wine phenols using microwave assisted deuterium exchange.....</b>	<b>69</b>
5.1 STATEMENT OF AUTHORSHIP .....	70
<b>Chapter 6: Conclusions and future work .....</b>	<b>74</b>
<b>References .....</b>	<b>79</b>

## List of Figures

Figure 1. Schematic diagram of an oak-sided Stakvat.....	26
Figure 2. Stainless steel, oak and plastic-sided Stakvats. ....	28
Figure 3. Flow diagram of the experimental design. ....	28
Figure 4. Mean ratings of sensory attributes in Cabernet Sauvignon wines matured in different types of Stakvat for 12 months. ....	39
Figure 5. PCA bi-plot of the mean sensory data obtained for Cabernet Sauvignon wines aged in different types of Stakvat; PC1 versus PC2.....	41
Figure 6. Mean ratings of sensory attributes in Shiraz wines matured in different types of Stakvat for 12 months. ....	42
Figure 7. PCA bi-plot of the mean sensory data obtained for Shiraz wines aged in different types of Stakvat; PC1 versus PC2. ....	43
Figure 8. PCA bi-plot of mean consumer data obtained for emotional responses to oak aromas, PC1 versus PC2. ....	67

## List of Tables

Table 1. Cost of maturation. ....	2
Table 2. Compounds derived from oak wood important to wine sensory characteristics.....	5
Table 3. Aroma, palate and mouth-feel attributes used for descriptive analysis of wines.....	31
Table 4. Reference standards used for formal sensory analysis of wines.....	32
Table 5. Chemical composition of Cabernet Sauvignon and Shiraz wines after maturation in different types of Stakvat.....	33
Table 6. Concentrations of oak volatiles in Cabernet Sauvignon and Shiraz wines after 0, 6 and 12 months maturation in different types of Stakvat. ....	35
Table 7. Difference test scores for Cabernet Sauvignon wines matured for 12 months in different types of Stakvats against the control wine.....	38
Table 8. Terms used in an Italian consumer study to describe emotions elicited during wine consumption .....	60
Table 9. Mean consumer liking and emotion scores for eight oak-derived aroma names. ....	63
Table 10. Consumer hedonic cluster mean ratings for wine liking, aroma liking and emotional response. ....	65
Table 11. Mean aroma liking and emotion ratings of consumer clusters segmented on aroma liking. ..	66

## **Abstract**

The aim of this research was to investigate the use of oak alternatives by the wine industry, and specifically, to explore their influence on the composition, sensory properties, and consumer acceptability of wine. A detailed online consumer questionnaire was administered nationally to wine consumers to explore their knowledge of and attitudes towards the use of oak during winemaking. Within the sample population surveyed (n=1015), four distinct consumer segments were identified, each with significantly different attitudes towards the use of oak alternatives for wine maturation. A segment of more knowledgeable consumers, who appreciate and value traditional barrel maturation, held slightly negative views of wines produced with oak alternatives. However, a second cluster comprising less knowledgeable consumers were accepting of the use of oak alternatives, provided wine quality was not affected. The results from this study have advanced our understanding of consumer attitudes towards innovative oak technologies and provide justification for the use of oak alternatives by winemakers, who can now tailor their wines to better meet the expectations of specific segments of their target market.

A maturation trial was subsequently established to examine the effect of different storage vessels on wine composition and sensory properties. The specific objective of the trial was to compare vessels comprising three different panel types, i.e. stainless steel, plastic and oak wood panels, and the potential for each to produce wines of comparable composition and quality to those aged traditionally in barrels. The outcomes of the 12 month trial demonstrated that the different storage vessels each imparted oak characters to wine and therefore afford winemakers an alternative method for the oak maturation of wine. In a second maturation trial, traditional and alternative oak maturation regimes were employed to age Cabernet Sauvignon wines and the effect of each treatment on the composition, sensory properties and consumer acceptance of wine investigated. Acceptability scores from 116 consumers revealed no significant differences in consumers' overall liking of each wine, but

segmentation based on individual liking scores identified three distinct clusters comprising consumers with significantly different wine preferences. Multivariate data analysis revealed the sensory attributes driving wine preference for each consumer segment. These results further justify wine producers' use of alternative oak maturation regimes to reduce production costs and achieve wine styles that appeal to different segments of the consumer market.

To gain a holistic view of consumer preferences for oak attributes in wine, a third consumer study was undertaken to investigate the effect of key oak aromas on consumer emotions. Consumers (n=116) were asked to rate their liking of eight oak-derived aromas and to then consider how different oak aromas make them feel. Consumers scored each aroma favourably, but spice and chocolate were liked most, and smoky and coconut aromas were liked least. Segmentation of consumer liking scores revealed three segments which differed in their liking of and emotional response to different oak aromas, but differences were subtle. This study showed oak aromas generally elicited positive emotions, but broader classes of aromas, e.g. oak derived aromas versus fruit aromas (e.g. citrus, berry or tropical fruit), may elicit stronger emotional responses than individual oak aromas.

An additional study reporting the convenient, low-cost preparation of isotopically labelled volatile wine phenols, using microwave-assisted deuterium exchange, was also conducted. The development of a method that incorporates deuterium atoms on the aromatic ring offers significant benefits for quantitative GC-MS analysis by stable isotope dilution analysis, i.e. improved accuracy and reproducibility, and this study complemented the aforementioned consumer research.

## Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, 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 in my name, 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.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Anna Crump

18/2/15  
.....

Date



## **Acknowledgements**

First and foremost I would like to thank my principal supervisor, Dr. Kerry Wilkinson for encouraging me to make the move from Brisbane to pursue a PhD at The University of Adelaide. Over the past 5 years you have gone above and beyond for me, your encouragement and support has been unwavering and has resulted in so many fantastic opportunities for both my personal and professional development. Your ability to always look at challenges positively is inspiring.

Thank you to my co-supervisors Dr. Mark Sefton, Dr. Sue Bastian and Dr. Heather Smyth, for the opportunity to work under your supervision and for your valuable support and advice throughout my PhD.

I would also like to acknowledge The University of Adelaide and the Australian Grape and Wine Authority for financial support in the form of a research scholarship and travel grants that enabled me to present my research at conferences in Australia and overseas.

Thank you to the many industry partners who also provided support towards this research, in particular Matthew and Peter Warren (Ausvat Pty. Ltd.), Louisa Rose (Yalumba Wine Company), Sam Brooke (Treasury Wine Estates) and Greg Clack (Haselgrove).

For their valued assistance and guidance I would like to thank all members of the Wilkinson, Bastian and Taylor research groups. I would particularly like to thank Dr. Renata Ristic, Dr. Trent Johnson, Sandra Olarte, Dr. Kerry Pinchbeck, Dr. Jo Giaccio, Jade Haggerty, Anthea Fudge, Yaelle Saltman, Mariola Kwiatkowski, Dr. Peter Valente and Dr. Josh Hixson. Thank you also to the Wine Science staff and students at The University of Adelaide for their friendship and involvement as sensory panellists.

I would like to thank my parents, Colin Crump and Meryl Dodge, for their unconditional love and support. I would especially like to thank my Dad, Colin Crump, for providing many opportunities for me to be the best that I can be. Lastly, I would like to thank my partner, Mark Haase, who gave me the strength to keep going on the PhD journey. You continued to listen and love me (even when I was completely stressed and unlovable), I am so grateful for your support in all that I do.