

A wine glass filled with red wine is shown in a dynamic, splashing pose. The wine is captured mid-air, creating a dramatic arc. The background is a light, neutral color. Overlaid on the wine and glass are several text labels representing common wine faults: VSCs, ethyl acetate, oxidation, TCA, house cage, peanut, H₂S, and wet sack. The main title 'WINE FAULTS AND FLAWS' is written in large, bold, red capital letters, and the subtitle 'A PRACTICAL GUIDE' is in smaller, black capital letters to the right.

WINE FAULTS AND FLAWS

A PRACTICAL GUIDE

KEITH GRAINGER

WILEY Blackwell

Wine Faults and Flaws: A Practical Guide

Wine Faults and Flaws: A Practical Guide

Keith Grainger

Consultant in Wines and Wine Technology
Broadway, UK

WILEY Blackwell

This edition first published 2021
© 2021 John Wiley & Sons Ltd

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Keith Grainger to be identified as the author of this work has been asserted in accordance with law.

Registered Offices

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Limit of Liability/Disclaimer of Warranty

The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting scientific method, diagnosis, or treatment by physicians for any particular patient. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Cataloging-in-Publication Data

Names: Grainger, Keith, author.

Title: Wine faults and flaws : a practical guide / Keith Grainger.

Description: Hoboken, NJ, USA : Wiley-Blackwell, 2021. | Includes bibliographical references and index.

Identifiers: LCCN 2021001638 (print) | LCCN 2021001639 (ebook) | ISBN 9781118979068 (cloth) | ISBN 9781118979099 (adobe pdf) | ISBN 9781118979075 (epub)

Subjects: LCSH: Wine and wine making--Gaging and testing.

Classification: LCC TP511 .G73 2021 (print) | LCC TP511 (ebook) | DDC 641.2/2--dc23

LC record available at <https://lcn.loc.gov/2021001638>

LC ebook record available at <https://lcn.loc.gov/2021001639>

Cover Design: Wiley

Cover Image: © RomanKozhin/Shutterstock

Set in 9.5/12.5pt STIXTwoText by SPi Global, Chennai, India

To Paula

Contents

Acknowledgements *xxix*

Preface *xxxi*

Introduction *xxxv*

1	Faults, Flaws, Off-Flavours, Taints, and Undesirable Compounds	1
1.1	Introduction	1
1.2	Advances in Wine Technology in Recent Decades	1
1.3	Changes in Markets and the Pattern of Wine Consumption in Recent Decades	3
1.4	The Possible Impact of Some Fault Compounds Upon Human Health	4
1.5	Sulfur Dioxide and Other Possible Allergens	5
1.6	Faults and Taints	6
1.7	Distinguishing Between Faults and Flaws	7
1.8	Sensory Detection (Perception) Thresholds and Sensory Recognition Thresholds	8
1.8.1	Sensory Detection Thresholds	8
1.8.2	Sensory Identification (Recognition) Thresholds	8
1.8.3	Odour Activity Values	9
1.9	Consumer Rejection Thresholds (CRTs)	9
1.10	Basic Categories of Wine Faults	10
1.10.1	The Origin of Wine Faults	10
1.10.2	Microbiological Faults	10
1.10.2.1	Types of Microorganisms Involved	10
1.10.2.2	Examples of Microbiological Faults	13
1.10.2.3	Minimising the Occurrence Microbiological Faults	13
1.10.3	Chemical Nature Faults	14
1.10.3.1	Examples of Chemical Faults	14
1.10.3.2	Minimising the Occurrence Chemical Faults	14
1.10.4	Physical Faults, Contamination, and Packaging Damage	15
1.11	Flaws	15
1.11.1	Poor Wines, as a Consequence of Adverse Weather, Sub-standard Viticulture, Careless Winemaking, or Inappropriate Additives	15
1.11.2	The Presence of 'Fault' Compounds at Low Concentrations	16

1.12	The Incidence of Wine Faults	16
1.13	'Faulty' Wines that Exude Excellence	18
1.14	Final Reflections	18
	References	19
2	Wine Tasting	22
2.1	Introduction	22
2.2	Anosimics, Fatigue Effect, and Supertasters	23
2.2.1	Anosimics and Fatigue Effect	23
2.2.2	Supertasters	24
2.3	Tasting Conditions, Equipment, and Glassware	24
2.3.1	The Tasting Room	24
2.3.2	Appropriate Equipment	25
2.3.2.1	Tasting Glasses	25
2.3.2.2	Glass Washing and Storage	25
2.3.2.3	Water	26
2.3.2.4	Spittoons	26
2.3.3	When to Taste	26
2.4	The Use of a Structured Tasting Technique and Detection of Faults	27
2.5	Appearance	27
2.5.1	The Appearance Assessment	27
2.5.2	Clarity and Brightness	28
2.5.3	Intensity	29
2.5.4	Colour	30
2.5.4.1	White Wines	31
2.5.4.2	Rosé Wines	31
2.5.4.3	Red Wines	31
2.5.4.4	The Rim and Core	32
2.5.5	Other Observations	32
2.5.5.1	Bubbles or Petillance	33
2.5.5.2	Legs	33
2.5.5.3	Deposits	34
2.6	Nose	34
2.6.1	Condition	35
2.6.2	Intensity	35
2.6.3	Aroma Types, Development, and Characteristics	35
2.6.3.1	Primary Aromas	36
2.6.3.2	Secondary Aromas	37
2.6.3.3	Tertiary Aromas	37
2.6.3.4	Aroma Characteristics	38
2.7	Palate	41
2.7.1	Palate Sensations	41
2.7.2	Sweetness/Bitterness/Acidity/Saltiness/Umami/Trigeminal Sensations	42
2.7.3	Dryness/Sweetness	43
2.7.4	Acidity	44

2.7.5	Tannins	44
2.7.6	Alcohol	45
2.7.7	Body	46
2.7.8	Flavour Intensity	47
2.7.9	Flavour Characteristics	47
2.7.10	Other Observations	47
2.7.10.1	Texture	47
2.7.10.2	Balance	50
2.7.11	Finish – Length	50
2.8	Assessment of Quality	51
2.8.1	Quality Level	51
2.8.2	Reasons for Assessment of Quality	51
2.9	Assessment of Readiness for Drinking/Potential for Ageing	52
2.9.1	The Life-Cycle of a Wine	52
2.9.2	Level of Readiness for Drinking/Potential for Ageing	53
2.10	Grading Wine – The Award of Points	53
2.10.1	Is the Awarding of Points Appropriate for Wines?	53
2.10.2	The Systems in Use	53
2.10.3	Nothing but a Snapshot Reflecting a Moment in Time	54
2.11	Blind Tasting	54
2.11.1	Why Taste Blind?	54
2.11.2	Blind or Sighted?	54
2.11.3	Tasting for Quality	55
2.12	Final Reflections	55
	References	55
3	Chloroanisoles, Bromoanisoles, and Halophenols	57
3.1	Introduction	57
3.2	Haloanisole Contaminations in the Food, Drinks, Water, and Pharmaceutical Industries	58
3.2.1	Haloanisole Contamination of Pharmaceutical Products	58
3.2.2	Haloanisole Contamination of Food and Non-Alcoholic Drinks	59
3.2.3	Haloanisoles in Tap Water and Bottled Water	59
3.3	Haloanisole Contamination of Wines	60
3.4	The Economic and Reputational Costs to Wine Producers and the Wine Industry	60
3.4.1	The Economic Cost to the Industry at Large	60
3.4.2	The Economic and Reputational Cost to Individual Wine Producers	61
3.4.3	The Nightmare of Haloanisole Contaminated Wineries and Cellars	61
3.4.3.1	California Pays a High Price	61
3.4.3.2	Affluence and Crisis in Bordeaux	62
3.4.3.3	Cellar Contaminations in South America	64
3.5	Sensory Characteristics and Detection of Haloanisoles in Wine	64
3.5.1	The Odours and Tastes of Haloanisoles in Wine	65

3.5.2	Variance in Sensory Detection Thresholds and Consumer Rejection Thresholds	65
3.6	The Haloanisoles Responsible and Their Detection Thresholds	66
3.6.1	The Main Haloanisoles Responsible	66
3.6.2	2,4,6-Trichloroanisole (TCA)	67
3.6.3	2,3,4,6-Tetrachloroanisole (TeCA)	68
3.6.4	Pentachloroanisole (PCA)	69
3.6.5	2,4,6-Tribromoanisole (2,4,6-TBA)	69
3.7	The Formation Pathways of Haloanisoles from Halophenols	70
3.7.1	Origins	70
3.7.1.1	Chlorophenols	70
3.7.1.2	Bromophenols	71
3.7.2	The Biological Transformation of Halophenols into Haloanisoles	71
3.7.3	The Role of the Pesticides, Herbicides, and Fungicides	72
3.7.3.1	Chlorophenol-Based Products	72
3.7.3.2	Bromophenol-Based Products	72
3.7.3.3	Restrictions on Usage of Chlorophenols and Bromophenols	73
3.7.3.4	The Advent of Chloroanisole and Bromoanisole Wine Contamination	74
3.7.3.5	Other Halophenol Formation Pathways	74
3.7.4	The Fungi that Convert Halophenols into Haloanisoles	74
3.8	Contamination of Cork with TCA and Other Chloroanisoles	75
3.8.1	Cork Production and How Cork Becomes Contaminated	75
3.8.2	The Transmission of TCA from Corks to Wine	76
3.8.3	The Historic Incidences of So-Called ‘Cork Taint’ and the Role of the Cork Industry	77
3.8.4	The Rise in Incidences of So-Called ‘Cork Taint’	77
3.9	The Cork Industry in the Dock	79
3.9.1	The Industry in Denial	79
3.9.2	Hostile Coverage in the Wine Press	80
3.9.3	Alternative Closures to the Fore	80
3.10	The Cork Industry Begins to Address the Issues	81
3.10.1	Cork Producers Fight Back	81
3.10.2	Many Wine Professionals Remain Hostile to Cork	82
3.11	The Cork Industry’s Recent Initiatives for Haloanisole Prevention and Extraction	83
3.11.1	Investment and Initiatives by the Stakeholders	83
3.11.2	Symbiosis	84
3.11.3	Methods to Extract TCA During Cork Production	84
3.11.3.1	Analysis and Rejection of Bark Affected by Chloroanisoles	84
3.11.3.2	Changes in Boiling Systems	84
3.11.3.3	Chloroanisole Removal by Steam Vaporisation	84
3.11.3.4	Extraction with Supercritical Carbon Dioxide	85
3.11.3.5	NDtech	85
3.11.3.6	Other Companies’ Non-Detectable TCA’ Guarantees	87
3.12	Winery and Cooperage Sources of Haloanisole Contamination in Wines	87

- 3.12.1 Winery Environment, Structure, Sundry Items, and Routine Processes as Sources of Contamination 87
- 3.12.2 Oak Barrels as a Source of Haloanisole Contamination of Wine 88
- 3.12.3 Processing Aids and Additives as Sources of Contamination 90
- 3.13 Laboratory Analysis for TCA and Other Haloanisoles in Corks and Wine 91
- 3.13.1 Haloanisoles in Wine and Releasable and Total TCA in Corks 91
- 3.13.2 Laboratory Methods of Analysis 92
- 3.13.2.1 Sample Preparation 92
- 3.13.2.2 Separation and Quantification 92
- 3.13.2.3 Bioanalytical Methods 93
- 3.13.3 Inexpensive Alternatives 94
- 3.14 Prevention of Haloanisole Contamination of Wineries and Wines 94
- 3.14.1 Implementation of an HACCP System 94
- 3.14.2 In the Vineyard 94
- 3.14.3 In the Winery 94
- 3.14.3.1 Cleaning and Sanitising 95
- 3.14.3.2 Avoidance of Chlorine and Bromine 95
- 3.14.3.3 Monitoring of Tap Water 95
- 3.14.3.4 Air Renewal and Humidity Control 96
- 3.14.3.5 Prohibition of PCP and 2,4,6-TBP 96
- 3.14.3.6 Diligence with Regard to Oenological Products and Processing Aids 96
- 3.14.3.7 Periodic Inspections and Testing of Production and Storage Areas 97
- 3.14.3.8 Attention to the Barrel Room, Cellar, and Storage 97
- 3.14.3.9 Regular Sensory Analysis of Wine Stock 97
- 3.14.3.10 Training Cellar Staff for Haloanisole Detection 98
- 3.14.4 Cork Screening and Group Cork Soaks 98
- 3.15 Treatment of Wines Contaminated with Haloanisoles 99
- 3.15.1 Fining with Half and Half 99
- 3.15.2 Filtration Using Zeolites Y-Faujasites 100
- 3.15.3 Absorption/Adsorption/Filtration Using Polymeric Media 100
- 3.15.3.1 Use of Polythene Resin Beads and Polymer 'Fining' 100
- 3.15.3.2 Filtration Using Adsorbing Polymers 100
- 3.15.3.3 Adsorption by Polyvinylidene Chloride (PVdC) 100
- 3.15.4 Adsorbing by Yeast Hulls 101
- 3.15.5 Filtration Through Cork Dust 101
- 3.15.6 Deodorising with Mustard Seeds 101
- 3.16 Chlorophenols and Bromophenols as Taints 101
- 3.16.1 The Odours of Chlorophenols and Bromophenols 101
- 3.16.2 2,4-Dichlorophenol 102
- 3.16.3 2,6-Dichlorophenol 102
- 3.16.4 2,4,6-Trichlorophenol 102
- 3.16.5 6-Chloro-*o*-cresol 102
- 3.16.6 2-Bromophenol 102
- 3.16.7 2,6-Dibromophenol 103
- 3.16.8 2,4,6-Tribromophenol 103

- 3.17 'Musty' Taints Unrelated to Halophenols and Haloanisoles 103
- 3.17.1 Other Musty Taints in Wine 103
- 3.17.2 2-Methoxy-3,5-dimethylpyrazine (MDMP) or 'Fungal Must Taint' 103
- 3.17.3 2-Isopropyl-3-methoxypyrazine 104
- 3.17.4 2-Methoxy-3-isopropylpyrazine 104
- 3.17.5 2-Methylisoborneol (MIB) 104
- 3.17.6 1-Octen-3-ol 105
- 3.17.7 1-Octen-3-one 105
- 3.17.8 1-Octen-2-one 105
- 3.17.9 *cis*-1,5-Octadien-3-one 105
- 3.17.10 *cis*-1,5-Octadien-3-ol 105
- 3.17.11 Geosmin 105
- 3.17.12 'Musty' Monoterpenes and Sesquiterpenes 106
- 3.17.13 Guaiacol 106
- 3.17.14 Treatment of Musty Taints Unrelated to Halophenols and Haloanisoles 106
- 3.18 Final Reflections 107
- References 107

4 *Brettanomyces* (Dekkera) and Ethyl Phenols 117

- 4.1 Introduction 117
- 4.2 Background and History 119
- 4.3 The Brett Controversy 120
- 4.3.1 *Brettanomyces* Paranoia? 120
- 4.3.2 The Role of *Brettanomyces* in Craft and Lambic Beer Production 121
- 4.3.3 *Brettanomyces*: An Extension of Terroir? 122
- 4.3.4 Artisans Choosing *Brettanomyces* for Wine Fermentations 123
- 4.3.5 Some Wines with a Notable Brett Influence 124
- 4.3.6 An Old World/New World Divide? 125
- 4.3.7 Good Brett/Bad Brett? 127
- 4.4 Sensory Characteristics and Detection of *Brettanomyces*-Related Compounds in Wine 128
- 4.4.1 The Odours Associated with *Brettanomyces*-Related Compounds 128
- 4.4.2 Sensory Detection Thresholds 129
- 4.4.3 4-Ethylphenol (4-EP) 130
- 4.4.4 4-Ethylguaiacol (4-EG) 130
- 4.4.5 Isovaleric Acid and Isobutyric Acid 130
- 4.4.6 4-Ethylcatechol 131
- 4.4.7 Tetrahydropyridines Particularly 2-Acetyltetrahydropyridine (ATHP) and 2-Ethyltetrahydropyridine (ETHP) 131
- 4.4.8 Guaiacol 131
- 4.4.9 The Impact of the Wine Matrix 131
- 4.5 The Origins of *Brettanomyces* and Formation of Related Compounds in Wines 132
- 4.5.1 Microflora on Grapes and Present in Wineries 132
- 4.5.2 The Formation Pathways of *Brettanomyces*-Related Compounds 133

- 4.5.2.1 Hydroxycinnamic Acids Precursors 133
- 4.5.2.2 The Formation of Vinyl Phenols 133
- 4.5.2.3 The Formation of Ethyl Phenols 134
- 4.6 The Danger Periods and Favourable Conditions for the Growth of *Brettanomyces* 135
 - 4.6.1 The Danger During Winemaking and Cellar Maturation 135
 - 4.6.2 Growth in Bottle 136
- 4.7 Why Are *Brettanomyces*-Related Compounds Found Mostly in Red Wines? 137
- 4.8 Prevention: Formulation and Implementation a Brett Control Strategy 137
 - 4.8.1 HACCP 137
 - 4.8.2 The Vineyard 138
 - 4.8.3 Harvest 138
 - 4.8.4 The Winery 138
 - 4.8.5 Winemaking Practices 138
 - 4.8.5.1 Approaches to *Brettanomyces* Management 138
 - 4.8.5.2 Pre-fermentation 139
 - 4.8.5.3 Cold Soaks and Hot Pre-fermentation Maceration 139
 - 4.8.5.4 Yeast Starters, Nutrients, and Enzymes 139
 - 4.8.5.5 The Alcoholic Fermentation (AF), Post-Fermentation Period, and Pressing 141
 - 4.8.5.6 The Pre-MLF Lag Phase and the MLF 141
 - 4.8.6 Maturation, Barrel Ageing, and Barrel Care 142
 - 4.8.6.1 Barrel Maturation 142
 - 4.8.6.2 Barrel Cleaning and Sanitising 142
 - 4.8.6.3 Methods of Barrel Cleaning 143
 - 4.8.6.4 Topping Up Barrels 144
 - 4.8.6.5 Temperature of the Barrel Store 144
 - 4.8.7 Maintaining Appropriate Molecular Sulfur Dioxide Levels 145
 - 4.8.7.1 The Sulfur Dioxide Quandary 145
 - 4.8.7.2 Appropriate Levels of Molecular Sulfur Dioxide 145
 - 4.8.8 Racking 147
 - 4.8.9 Fining 147
 - 4.8.10 Filtration 148
 - 4.8.11 Bottling 148
 - 4.8.12 Storage 149
- 4.9 Laboratory Analysis for *Brettanomyces* and Volatile Phenols 149
 - 4.9.1 When Analysis Should Be Undertaken 149
 - 4.9.2 Analysis for Viable Yeast Cells 150
 - 4.9.2.1 Plate Cultures 150
 - 4.9.2.2 Fluorescence Microscopy 152
 - 4.9.2.3 Polymerase Chain Reaction (qPCR) 152
 - 4.9.2.4 Flow Cytometry and Fluorescence In Situ Hybridisation 153
 - 4.9.2.5 Raman Spectroscopy 153
 - 4.9.2.6 Experimental Technologies for Detection of *Brettanomyces* 153
 - 4.9.3 Analysis for Volatile Phenols Using Gas Chromatography with Detection by Mass Spectroscopy (GC-MS) 153

- 4.10 Treatment of Affected Wines 153
 - 4.10.1 Reduction or Removal of *Brettanomyces* Cells 154
 - 4.10.1.1 Racking 154
 - 4.10.1.2 Fining 154
 - 4.10.1.3 Filtration 154
 - 4.10.1.4 Heat Treatments 155
 - 4.10.1.5 Chemical Treatments 155
 - 4.10.2 Reduction in Volatile Phenols 157
 - 4.10.3 Future Possibilities for Physical Brett Inactivation 157
- 4.11 What the Future Might Hold for Microbiological Methods to Inhibit *Brettanomyces*? 158
- 4.12 Final Reflections 159
- References 160

- 5 Oxidation, Premox, and Excessive Acetaldehyde 171**
 - 5.1 Introduction 171
 - 5.1.1 Oxygen: The Enemy and the Friend 171
 - 5.1.2 The Importance of Oxygen in Winemaking 172
 - 5.1.3 Oxygenation Is Not Oxidation 172
 - 5.1.4 Good and Bad Oxidation? 173
 - 5.2 Oxidation in Must and Wine 173
 - 5.2.1 Oxidation Defined 173
 - 5.2.2 Types of Oxidation 173
 - 5.3 Sensory Characteristics and Detection of Excess Acetaldehyde and Oxidation in Wine 174
 - 5.3.1 Excess Acetaldehyde 174
 - 5.3.1.1 Background 174
 - 5.3.1.2 Detection 174
 - 5.3.1.3 Appearance 174
 - 5.3.1.4 Nose 174
 - 5.3.1.5 Palate 175
 - 5.3.1.6 Sensory Detection Threshold 175
 - 5.3.2 Oxidation 175
 - 5.3.2.1 Appearance 175
 - 5.3.2.2 Nose 175
 - 5.3.2.3 Palate 175
 - 5.4 Deliberately Oxidised and Highly Oxygenated Wines 176
 - 5.4.1 Fortified and Speciality Wines 176
 - 5.4.1.1 Speciality Unfortified Wines 176
 - 5.4.1.2 Fortified Wines 176
 - 5.4.2 Deliberate Oxidation in High-Quality 'Table' Wines 176
 - 5.4.3 The Strange Case of Orange Wines 177
 - 5.4.4 Grape Varieties Susceptible to Oxidation 177
 - 5.5 Metal Ions and Substrates for Oxidation 178
 - 5.5.1 The Role of Metal Ions 178

5.5.2	Substrates for Oxidation	178
5.5.3	Classes of Phenolics	178
5.5.3.1	Flavonoids	178
5.5.3.2	Non-flavonoids	179
5.6	Enzymatic Oxidation	179
5.6.1	Substrates	179
5.6.2	Polyphenol Oxidases, Tyrosinase, and Laccase	179
5.6.3	Glutathione and Grape Reaction Product (GRP)	180
5.6.4	Prevention of Tyrosinase-Catalysed Enzymatic Oxidation	180
5.6.5	Laccase	180
5.6.6	Hydroxylation	181
5.7	Chemical Oxidation	182
5.7.1	Substrates	182
5.7.2	Chemical Oxidation Pathways	182
5.8	Microbial Oxidation	182
5.9	Acetaldehyde	183
5.9.1	Biological Production	183
5.9.2	Chemical Production	184
5.9.3	Acceptable and Unacceptable Levels of Acetaldehyde	184
5.9.4	Binding of Sulfur Dioxide	185
5.10	Sotolon	185
5.11	Oxygen Management in Winemaking	185
5.11.1	The Role of Oxygen During Fermentation	186
5.11.2	Post-fermentation Oxygenation	186
5.11.3	Barrel Maturation	187
5.11.4	Lees Ageing	187
5.12	Oxygen Uptake During Cellar Operations	187
5.13	Containers and Closures	188
5.14	Pinking	188
5.15	Premature Oxidation (Premox)	189
5.15.1	Premature Oxidation Rears Its Head	189
5.15.2	Reversible Oxidation?	190
5.15.3	Causes of Premature Oxidation	191
5.15.3.1	Possible Causes	191
5.15.3.2	Clonal Selection	191
5.15.3.3	The Phenolic Ripeness and High pH of Fruit	191
5.15.3.4	Low Levels of Glutathione in Grapes	192
5.15.3.5	The Use of Pneumatic Presses	192
5.15.3.6	The Increased Use of New Oak Barrels	193
5.15.3.7	Bâtonnage	193
5.15.3.8	Insufficient Free Sulfur Dioxide Levels	193
5.15.3.9	Interventionist Operations Undertaken to Speed the Wine to Market	194
5.15.3.10	Ingress of Oxygen When Bottling	194
5.15.3.11	Low-Quality Cork Closures and Corks Washed with Peroxide	195
5.15.4	Prune Aroma	195

- 5.16 Prevention of Excess Acetaldehyde and Oxidation 196
 - 5.16.1 Basic Principles 196
 - 5.16.2 Picking at Appropriate Ripeness 196
 - 5.16.3 Harvesting and Transporting Fruit 197
 - 5.16.4 Sorting 198
 - 5.16.5 Crushing 198
 - 5.16.6 Pressing (for White Wines) 198
 - 5.16.7 Juice Clarification (White Must) 199
 - 5.16.8 Inoculate with Commercial Strains of *Saccharomyces* 199
 - 5.16.9 Fermentation 199
 - 5.16.10 Post-fermentation Maceration 199
 - 5.16.11 Malolactic Fermentation (MLF) 200
 - 5.16.12 Avoiding Ullage in Tanks and Barrels 200
 - 5.16.13 Reducing Oxygen Uptake in Cellar Operations Including Rackings and Transfers 200
 - 5.16.14 Maintaining Appropriate Levels of Free SO₂ 201
 - 5.16.15 Reducing Heavy Metals 202
 - 5.16.16 Controlling Cellar Temperature and Humidity 202
 - 5.16.17 Barrel Ageing and/or the Addition of Ellagitannins 202
 - 5.16.18 Lees Ageing 203
 - 5.16.19 Cold Stabilisation 203
 - 5.16.20 Ultrafiltration Before Bottling 203
 - 5.16.21 Bottling 204
 - 5.16.21.1 A Major Source of Oxygen Uptake 204
 - 5.16.21.2 Total Package Oxygen (TPO) 204
 - 5.16.21.3 Dissolved Oxygen in the Wine 204
 - 5.16.21.4 Oxygen in the Empty Bottle Pre-filling 204
 - 5.16.21.5 Headspace Oxygen 204
 - 5.16.21.6 Oxygen Content of the Closure 205
 - 5.16.21.7 Addition of Glutathione Prior to Bottling 205
 - 5.16.22 Storage 205
 - 5.16.22.1 Oxygenation During Storage 205
 - 5.16.22.2 Oxidation Due to Poor Storage 205
- 5.17 Additions of Ascorbic Acid: Antioxidant or Oxidising Agent? 206
- 5.18 Laboratory Analysis 207
 - 5.18.1 Acetaldehyde 207
 - 5.18.2 Dissolved Oxygen 208
 - 5.18.3 Oxidation 208
- 5.19 Treatments 208
 - 5.19.1 Acetaldehyde 208
 - 5.19.2 Oxidation 209
- 5.20 Final Reflections 209
 - References 210

6	Excessive Sulfur Dioxide, Volatile Sulfur Compounds, and Reduced Aromas	218
6.1	Introduction	218
6.1.1	Volatile Sulfur Compounds	218
6.1.2	Thiols	219
6.2	The Presence and Role of Sulfur, Sulfur Dioxide, Sulfite, and Sulfate in Wine Production	219
6.2.1	Sulfur Contained in Grapes	219
6.2.2	Sulfur-Containing Fungicides	220
6.2.3	Sulfur Dioxide Generated by Yeast During Fermentation	221
6.2.3.1	Sulfur-Containing Amino Acid	221
6.2.4	Additions of Sulfur Dioxide During the Winemaking Process	221
6.2.4.1	The Use of Sulfur Dioxide in Winemaking	221
6.2.4.2	Total, Bound, Free, and Molecular Sulfur Dioxide	222
6.2.4.3	Additions of Sulfur Dioxide to Prevent Enzymatic Oxidation	222
6.2.4.4	The Use of Sulfur Dioxide to Prevent Chemical and Microbial Oxidation	222
6.3	Excessive Sulfur Dioxide	222
6.3.1	High Levels of SO ₂ : Flaw or Fault?	222
6.3.2	Sensory Detection of Excess Sulfur Dioxide	223
6.3.3	Possible Reasons for High SO ₂ Levels	223
6.3.4	Removal of Excessive Sulfur Dioxide from Wine	223
6.4	Oxygen Management in Winemaking	224
6.4.1	The Role and Management of Oxygen During Fermentation	224
6.4.2	Oxygenating During Fermentation	224
6.4.3	Micro-oxygenation During Fermentation	225
6.4.4	Micro-oxygenation Post-fermentation	226
6.4.5	Barrel Maturation	227
6.4.6	Lees Ageing	227
6.5	Reduction in Wine: Positive and Negative	227
6.5.1	Reducing Agents	227
6.5.2	Positive Reduction	227
6.5.2.1	Reduced Notes as a Hallmark?	227
6.5.2.2	Desirable Aromas of Some VSCs	228
6.5.2.3	Minerality	228
6.5.3	Negative Reduction	229
6.6	Hydrogen Sulfide	229
6.6.1	Hydrogen Sulfide: A Serious Fault When Present Above Sensory Threshold	229
6.6.2	Sensory Characteristics and Detection of Hydrogen Sulfide in Wine	230
6.6.3	The Formation of Hydrogen Sulfide in Wine	230
6.6.3.1	Formation by the Actions of Yeasts During the Alcoholic Fermentation	230
6.6.3.2	Production by Reduction of Elemental Sulfur or Inorganic Sulfur	231
6.7	Prevention of Hydrogen Sulfide Formation	232
6.8	Treatment for Hydrogen Sulfide in Wine	233
6.8.1	Physical Treatments	234

- 6.8.1.1 Splash Racking 234
- 6.8.1.2 Aeration or Inert Gas Bubbling 234
- 6.8.2 Chemical Additions as Treatments 234
 - 6.8.2.1 Sulfiting 234
 - 6.8.2.2 Use of an Oxidising Agent 235
- 6.9 Mercaptans, Sulfides, Disulfides, Trisulfides, and Thioesters 237
 - 6.9.1 Low- and High-Boiling-Point VSCs 237
 - 6.9.2 Mercaptans 237
 - 6.9.2.1 Methanethiol, Also Known as Methyl Mercaptan (MeSH) 238
 - 6.9.2.2 Ethanethiol, Also Known as Ethyl Mercaptans (EtSH) 238
 - 6.9.3 Sulfides Other than H₂S 239
 - 6.9.3.1 Dimethyl Sulfide (DMS) 239
 - 6.9.3.2 Ethyl Sulfide 239
 - 6.9.3.3 Diethyl Sulfide 239
 - 6.9.4 Disulfides 239
 - 6.9.4.1 Carbon Disulfide 240
 - 6.9.4.2 Diethyl Disulfide 240
 - 6.9.4.3 Dimethyl Disulfide (DMDS) 240
 - 6.9.5 Trisulfides: Dimethyl Trisulfide (DMTS) 240
 - 6.9.6 Thioesters 240
 - 6.9.6.1 Methyl Thioacetate 241
 - 6.9.6.2 Ethyl Thioacetate 241
- 6.10 Post-bottling Reduction 241
 - 6.10.1 A New Wine Fault 241
 - 6.10.2 The Causes of Post-bottling Reduction 242
 - 6.10.3 The Oxygen Transmission Rates (OTRs) of Closures 243
- 6.11 Lightstrike 243
 - 6.11.1 Wines Likely to Be Affected by Lightstrike 243
 - 6.11.2 Sensory Detection 244
 - 6.11.3 Causes and Incidences of the Fault 244
 - 6.11.3.1 The Transmission of UV Light Through Clear Glass Bottles 244
 - 6.11.3.2 The Role of Riboflavin, Sulfur-Containing Amino Acids, and Iron Tartrate 245
 - 6.11.4 Prevention of Lightstrike 246
 - 6.11.4.1 Vinification Measures 246
 - 6.11.4.2 Packaging Measures 246
 - 6.11.4.3 Storage Measures 246
 - 6.11.5 Treatment 246
- 6.12 Laboratory Analysis for Sulfur Dioxide, Hydrogen Sulfide, and Volatile Sulfur Compounds 247
 - 6.12.1 Sulfur Dioxide 247
 - 6.12.2 Hydrogen Sulfide and Volatile Sulfur Compounds 247
 - 6.12.2.1 A Quick and Easy Test for H₂S Using Copper Sulfate 247
 - 6.12.2.2 The Copper/Cadmium Test for H₂S, Mercaptans (–SH Group), Disulfides, and Dimethyl Sulfide 247

6.12.2.3	Gas Chromatography	248
6.13	Final Reflections	249
	References	249
7	Excessive Volatile Acidity and Ethyl Acetate	257
7.1	Introduction	257
7.2	Volatile Acidity and Ethyl Acetate	258
7.3	The Controversy of High Levels of Volatile Acidity	258
7.3.1	Are Elevated Levels of Volatile Acidity Sometimes Acceptable?	258
7.3.2	1947 Château Cheval Blanc – The Greatest Faulty Wine Ever Made	259
7.4	Fixed Acids and Volatile Acids	260
7.4.1	Total Acidity	260
7.4.2	Fixed Acids	260
7.4.2.1	Tartaric Acid	260
7.4.2.2	Citric Acid	260
7.4.2.3	Malic Acid	261
7.4.2.4	Lactic Acid	261
7.4.2.5	Succinic Acid	261
7.4.3	Volatile Acids	261
7.4.3.1	Acetic Acid	261
7.4.3.2	Butyric Acid	261
7.4.3.3	Isobutyric Acid	262
7.4.3.4	Propionic Acid	262
7.4.3.5	Hexanoic Acid	262
7.4.3.6	Sorbic Acid	262
7.4.3.7	Sulfurous Acid	262
7.5	Sensory Characteristics and Detection of Volatile Acidity	262
7.6	Legal Limits	263
7.7	Acetic Acid Bacteria	263
7.8	Production of Acetic Acid in Wine	265
7.8.1	Microbiological Production	265
7.8.1.1	Production by Yeasts	265
7.8.1.2	Production by Bacteria, Including Acetic Acid Bacteria	266
7.8.2	Physiochemical Production	267
7.9	Ethyl Acetate	268
7.9.1	Production of Ethyl Acetate in Wine	268
7.9.2	Microbiological Production	269
7.9.2.1	Production by Yeasts	269
7.9.2.2	Production by Acetic Acid Bacteria	270
7.9.3	Chemical Production	270
7.9.4	New Barrels Do Not Contain Ethyl Acetate	270
7.9.5	Sensory Characteristics and Detection of Ethyl Acetate	271
7.10	Prevention of Excessive Volatile Acidity and Ethyl Acetate	271
7.10.1	Fruit Selection and Processing	272

- 7.10.2 Exclusion of Vectors 272
- 7.10.3 Cleaning 272
- 7.10.4 Avoiding Cross-Contamination 272
- 7.10.5 Must Adjustment Including Nutrient Additions 272
- 7.10.6 Addition of Lysozyme 273
- 7.10.7 Cold Soaking (Red Wines) 273
- 7.10.8 Inoculation with Desired Strains of *Saccharomyces cerevisiae* 274
- 7.10.9 Alcoholic Fermentation 274
- 7.10.10 Malolactic Fermentation 274
- 7.10.11 Addition of Sulfur Dioxide and Maintaining Appropriate Molecular SO₂ 275
- 7.10.12 Avoiding Ullage in Vats and Barrels 275
- 7.10.13 Micro-oxygenation 276
- 7.10.14 Cleaning and Sanitising Barrels that Show Signs of Acetic Acid 276
- 7.10.15 Cautious Use of Citric Acid 276
- 7.10.16 Avoiding the Growth of *Brettanomyces* 277
- 7.10.17 Minimising Oxygen Uptake During Cellar Operations 277
- 7.10.18 Barrel Ageing 277
- 7.10.19 Monitoring and Analysis 277
- 7.10.20 Bottling 278
- 7.11 Laboratory Analysis 278
- 7.11.1 Volatile Acidity and Acetic Acid Bacteria 278
- 7.11.2 Laboratory Analysis – Ethyl Acetate 278
- 7.12 Treatments 278
- 7.12.1 Excessive Volatile Acidity 278
- 7.12.1.1 Dealing with Rising Levels of VA 279
- 7.12.1.2 Blending 279
- 7.12.1.3 Fining 280
- 7.12.1.4 Nanofiltration Coupled with Ion Exchange 280
- 7.12.1.5 Reverse Osmosis 280
- 7.12.1.6 Future Possibilities of Bio-reduction of VA Levels 281
- 7.12.2 Ethyl Acetate 281
- 7.13 Final Reflections 281
- References 282

8 Atypical Ageing (ATA) – Sometimes Called Untypical Ageing (UTA) 286

- 8.1 Introduction 286
- 8.2 The Atypical Ageing Controversy 287
- 8.3 The Causes of Atypical Ageing and Formation Pathways 287
- 8.3.1 The Role of 2-Aminoacetophenone (2-AAP) 287
- 8.3.2 The Formation of 2-AAP 288
- 8.3.3 The Role of Other Chemical Compounds 289
- 8.3.4 Distinguishing ATA from Premature Oxidation (Premox), and Reduction 289
- 8.4 Sensory Detection 290
- 8.4.1 Sensory Characteristics 290

- 8.4.2 Sensory Perception Threshold of 2-AAP 290
- 8.5 Laboratory Detection 290
- 8.6 The Main Viticultural Causes of ATA 291
- 8.7 Prevention 291
 - 8.7.1 In the Vineyard 291
 - 8.7.2 In the Winery 292
 - 8.7.3 Ascorbic Acid Addition 293
- 8.8 Treatments 293
- 8.9 Final Reflections 293
 - References 294

- 9 Fermentation in Bottle 296**
 - 9.1 Introduction 296
 - 9.1.1 Bottle-Fermented Sparkling Wines 296
 - 9.1.2 Pétillant-Naturels 296
 - 9.1.3 Unwanted Bottle Fermentation 297
 - 9.2 Sensory Detection 298
 - 9.3 Alcoholic Fermentation in Bottle 298
 - 9.4 Malolactic Fermentation (MLF) in Bottle 299
 - 9.5 Prevention: Preparing Wine for Bottling and the Bottling Process 299
 - 9.5.1 Preparing Wine for Bottling 299
 - 9.5.1.1 Fining and Other Clarification 299
 - 9.5.1.2 Adjustment of Free and Molecular SO₂ 300
 - 9.5.1.3 Addition of a Fermentation Inhibitor 300
 - 9.5.1.4 Heat Treatments 302
 - 9.5.1.5 Membrane Filtration 302
 - 9.5.2 The Bottling Process 303
 - 9.5.2.1 The Final Production Source of Contamination 303
 - 9.5.2.2 The Bottling Line and Operation 303
 - 9.6 Treatment 304
 - 9.7 Final Reflections 305
 - References 305

- 10 Hazes 307**
 - 10.1 Introduction 307
 - 10.2 Protein Haze 308
 - 10.2.1 The Formation and Impact of Protein Hazes 308
 - 10.2.2 Prevention of Protein Haze Formation 309
 - 10.2.2.1 Pre-fermentation Reduction in Haze-Forming Proteins 309
 - 10.2.2.2 Post-fermentation Reduction in Haze-Forming Proteins 310
 - 10.2.2.3 Testing for Protein Stability 310
 - 10.2.2.4 Fining with Bentonite 311
 - 10.2.2.5 Alternatives to Bentonite 313
 - 10.2.2.6 Possible Future Alternatives to Bentonite 313
 - 10.3 Microbial Hazes 313

- 10.4 Metal Hazes 313
 - 10.4.1 Copper Haze 313
 - 10.4.1.1 Formation of Copper Haze 313
 - 10.4.1.2 Prevention/Removal of Copper Haze 314
 - 10.4.2 Iron Haze 314
 - 10.4.2.1 Formation of Iron Haze 314
 - 10.4.2.2 Prevention/Removal of Iron Haze 315
- 10.5 Final Reflections 315
- References 315

- 11 Lactic Acid Bacteria-Related Faults 318**
 - 11.1 Introduction to Lactic Acid Bacteria 318
 - 11.2 Lactic Acid Bacteria and Their Natural Sources 319
 - 11.3 Malolactic Fermentation (MLF) 320
 - 11.3.1 History of the Understanding MLF 320
 - 11.3.2 The MLF Process 320
 - 11.3.2.1 Temperature 322
 - 11.3.2.2 Sulfur Dioxide (SO₂) 322
 - 11.3.2.3 pH 322
 - 11.3.2.4 Alcohol 323
 - 11.3.2.5 Nutrients 323
 - 11.4 Undesirable Aromas, Off-Flavours, and Wine Spoilage Caused by Lactic Acid Bacteria 323
 - 11.4.1 Off-Odours Associated with Lactic Acid Bacteria 323
 - 11.4.2 Acrolein 323
 - 11.4.3 Excess Diacetyl 324
 - 11.4.4 Mannitol 325
 - 11.4.5 Ropiness 325
 - 11.4.6 Mousiness 326
 - 11.4.7 Tourne 327
 - 11.4.8 Indole 327
 - 11.4.9 Geranium Taste 327
 - 11.5 Prevention of Lactic Acid Bacteria-Related Faults 327
 - 11.6 Analysis 328
 - 11.7 Final Reflections 328
 - References 329

- 12 Smoke Taint and Other Airborne Contaminations 331**
 - 12.1 Introduction 331
 - 12.2 Smoke Taint Compounds in the Atmosphere 332
 - 12.3 Critical Times in the Growing Season and Duration of Exposure for Smoke Taint to Impact 333
 - 12.4 The Volatile Phenols Responsible for Smoke Taint; Their Odours and Flavours and Sensory Detection Thresholds 333
 - 12.5 Smoke Taint in Wines 334

- 12.6 Other Sources of Guaiacol and 4-Methyl-guaiacol in Wines 334
- 12.7 Laboratory Testing 334
- 12.8 Prevention of Development of Smoke-Related Volatile Phenols from Affected Grapes 334
- 12.9 Treatments 336
 - 12.9.1 Activated Carbon 336
 - 12.9.2 Other Fining Treatments 336
 - 12.9.3 Reverse Osmosis (RO) and Solid Phase Adsorption 336
 - 12.9.4 The Addition of Oak Products to Affected Wines 336
 - 12.9.5 Blending 336
 - 12.9.6 Limiting Time in Bottle Pre-sale 337
- 12.10 Other Airborne Contaminations 337
 - 12.10.1 Spray Drift 337
 - 12.10.2 Eucalyptol – 1,8-Cineole 337
 - 12.10.2.1 Prevention 338
- 12.11 Final Reflections 338
 - References 338

- 13 Ladybeetle and Brown Marmorated Stink Bug Taints 341**
 - 13.1 Introduction 341
 - 13.2 Methoxypyrazines 341
 - 13.3 Ladybeetles (Also Known as Ladybirds and Ladybugs) 342
 - 13.3.1 Background 342
 - 13.3.2 Infested Grapes 343
 - 13.3.3 Sensory Characteristics, Detection, and Consumer Rejection Thresholds 343
 - 13.3.3.1 Sensory Characteristics 343
 - 13.3.3.2 Sensory Detection Thresholds and Consumer Rejection Thresholds 344
 - 13.3.4 Prevention 345
 - 13.3.5 Treatments 345
 - 13.4 Brown Marmorated Stink Bug (*Halyomorpha halys*) Taint 345
 - 13.4.1 Background 345
 - 13.4.2 Infested Grapes 347
 - 13.4.3 Sensory Characteristics, Detection, and Consumer Rejection Thresholds 347
 - 13.4.3.1 Sensory Characteristics 347
 - 13.4.3.2 Sensory Detection Thresholds and Consumer Rejection Thresholds (CRT) 347
 - 13.4.4 Prevention 348
 - 13.4.5 Treatments 348
 - 13.5 Final Reflections 348
 - References 349

- 14 Sundry Faults, Contaminants, Including Undesirable Compounds from a Health Perspective and Flaws Due to Poor Balance 352**
 - 14.1 Mycotoxins, Particularly Ochratoxin A 352
 - 14.1.1 The Presence of Ochratoxin A 352
 - 14.1.2 The Origins of Ochratoxin A in Wines 353

- 14.1.3 Prevention of, or Minimising, Contamination with OTA 353
- 14.1.4 Analysis 354
- 14.1.5 Treatment of Affected Wines 354
- 14.2 Dibutyl Phthalate and Other Phthalates 355
- 14.3 Ethyl Carbamate 355
 - 14.3.1 Production of Ethyl Carbamate in Wines 355
 - 14.3.2 Prevention of Ethyl Carbamate in Wines 356
 - 14.3.3 Analysis 356
- 14.4 Biogenic Amines 356
- 14.5 Ethyl Sorbate and Sorbyl Alcohol (Geraniol) Off-Odours 357
 - 14.5.1 The Use of Potassium Sorbate and Conversion to Compounds Giving Off-Odours 357
 - 14.5.2 Prevention 357
- 14.6 Paper-Taste 358
- 14.7 Plastic Taints – Styrene 358
- 14.8 Indole 358
 - 14.8.1 The Presence of Indole in Wine 358
 - 14.8.2 Sensory Perception 359
- 14.9 Geosmin 359
 - 14.9.1 Sources of Geosmin in Wine 359
 - 14.9.2 Organoleptic Detection and Sensory Perception Thresholds 359
 - 14.9.3 Treatment 360
- 14.10 2-Bromo-4-methylphenol – Iodine, Oyster Taste 360
- 14.11 Heat Damage 360
 - 14.11.1 Transport and Storage 360
 - 14.11.2 Sensory Detection 361
 - 14.11.3 Pathways to Heat Damage 361
- 14.12 Matters of Balance 361
 - 14.12.1 Unbalanced Wines May Be Regarded as Flawed 361
 - 14.12.2 Alcohol 362
 - 14.12.3 Acidity 362
 - 14.12.4 Body and Structure 363
 - 14.12.5 Tannins 363
 - 14.12.6 Fruit and Flavour Concentration 364
 - 14.12.7 Residual Sugar (If Any) 364
- 14.13 Final Reflections 364
 - References 364
- 15 TDN and Tartrate Crystals: Faults or Not? 369**
 - 15.1 TDN 369
 - 15.1.1 What Is TDN? 369
 - 15.1.2 The Formation of TDN 369
 - 15.1.3 Sensory Characteristics and Sensory Detection Thresholds 370
 - 15.1.3.1 Sensory Characteristics 370
 - 15.1.3.2 Sensory Detection Thresholds 370

15.1.3.3	Prevalence of TDN in Riesling Wines	370
15.1.4	Minimising TDN in Wine Production	370
15.1.5	TDN in Bottled Wine	371
15.1.6	The TDN Controversy	371
15.2	Tartrate Deposits	372
15.2.1	The Formation of Tartrate Deposits	372
15.2.2	Sources of Calcium in Wines	373
15.2.3	Calcium Tartrate Instability	374
15.2.4	Sources of Potassium in Wines	375
15.2.5	Potassium Bitartrate Instability	375
15.2.6	Prevention of Tartrate Formation	375
15.2.7	Prevention of Precipitation of Potassium Bitartrate Crystals in Packaged Wine	376
15.2.7.1	Methods Used for KHT Stabilisation	376
15.2.7.2	Cold Stabilisation	376
15.2.7.3	Ion Exchange	377
15.2.7.4	Electrodialysis	377
15.2.7.5	Metatartaric Acid Addition	377
15.2.7.6	Carboxymethylcellulose (CMC)	378
15.2.7.7	Mannoproteins	378
15.2.7.8	Potassium Polyaspartate (KPA)	378
15.2.7.9	Considerations as to the Choice of Methods of Prevention of KHT Crystallisation	379
15.2.7.10	Gum Arabic and Co-blends of Additives	379
15.2.8	Prevention of Precipitation of Calcium Tartrate Crystals in Packaged Wine	380
15.2.8.1	Methods Permitted by the OIV	380
15.2.8.2	The Addition of Calcium Tartrate	380
15.2.8.3	The Addition of Racemic (DL) Tartaric Acid	380
15.2.9	Predictive Tests	380
15.2.9.1	Potassium Bitartrate	380
15.2.9.2	Calcium Tartrate	381
15.3	Final Reflections	381
	References	382
16	Must Correction, Wine Correction, and Alcohol Reduction Using Membrane Technologies	385
16.1	Introduction	385
16.1.1	The Use of Membranes in Stabilising Wines for Export Markets	385
16.1.2	Wine as a 'Natural' Product	386
16.2	Membrane Processes Used in the Wine Industry	386
16.3	Clarification	387
16.3.1	'Traditional' Clarification and Filtration Methods in Common Use	387
16.3.2	Membrane Filtration of Must and Wine	388
16.3.2.1	Clarification of Must	388
16.3.2.2	Clarification of Wine	389

16.3.3	Cross-Flow Micro Filtration	389
16.4	Membrane Fouling	391
16.5	Must Correction, Wine Correction, and Alcohol Reduction	391
16.5.1	Reverse Osmosis	391
16.5.1.1	Must Correction by RO – Increasing Sugar Concentration	392
16.5.1.2	Must Correction by RO, Ultrafiltration/Nanofiltration – Reducing Sugar Concentration	393
16.5.2	Ultrafiltration	393
16.5.3	Wine Correction – Reducing Alcohol Content	393
16.6	Fault Correction	395
16.6.1	Removing Acetic Acid	395
16.6.2	Removal of <i>Brettanomyces</i> Yeasts, and the Treatment of Volatile Phenols	395
16.6.3	Removal of Smoke Taint	396
16.7	Wine Stabilisation and pH Adjustment by Electrodialysis	396
16.7.1	Tartrate Stabilisation	397
16.7.2	pH and Acidity Adjustment	398
16.8	Final Reflections	398
	References	400
17	The Impact of Container and Closure Upon Wine Faults	404
17.1	Introduction	404
17.2	Glass Bottles	405
17.2.1	Overview	405
17.2.2	A Brief History of Glass Bottles for Wine	405
17.2.3	The Impact of Bottle Size Upon Wine Development and Quality	406
17.2.4	The Impacts of Bottle Colour and Glass Thickness/Weight	406
17.3	Bottle Closures	407
17.3.1	Types of Closure	407
17.3.2	Dissolved Oxygen in Wine	407
17.3.2.1	Sources of Dissolved Oxygen and Total Package Oxygen in Wine	407
17.3.2.2	Consequences of Oxygen Uptake During the Bottling Operation	408
17.3.2.3	Oxygen Transmission Rates (OTRs), Permeation, Migration, and Scalping	408
17.4	The Maintenance of Adequate Free and Molecular SO ₂ in Bottled Wine	410
17.4.1	The Adjustment of Free and Molecular SO ₂ at Bottling	410
17.4.2	Retention of Adequate Free Sulfur Dioxide in Bottle	410
17.4.3	The Influence of Closure Type Upon Reductive Characters	410
17.4.4	The Market for the Various Types of Closures	411
17.5	Cork Closures	411
17.5.1	A Brief History of Cork Closures	411
17.5.2	The Origin of Cork and Production of Cork Stoppers	412
17.5.3	The Cork Production Process	414
17.5.4	Natural Corks and Colmated Corks	417
17.5.4.1	Grades of Natural Cork	417
17.5.4.2	Colmated Corks	417
17.6	Technical Corks and Agglomerated Corks	417

- 17.6.1 Micro-agglomerated Corks 417
- 17.6.2 Twin Top, 1 + 1 and Sparkling Wine Other Technical Corks 418
- 17.6.3 Helix 418
- 17.6.4 ProCork 418
- 17.7 Diam Cork Closure 418
 - 17.7.1 History: From the Altec Disaster to Diam Success 418
 - 17.7.2 The Technology of the Diam Closure 419
 - 17.7.3 The Range of Diam Closures and OTRs 419
- 17.8 Synthetic Closures 420
 - 17.8.1 Co-extruded Closures 420
 - 17.8.1.1 Nomacorc 420
 - 17.8.2 Injection-Moulded Closures 420
 - 17.8.3 Flavour Scalping 421
 - 17.9 Screw Caps 421
 - 17.9.1 History 421
 - 17.9.2 Screw Cap Liners 421
 - 17.9.3 Post-Bottling Reduction 422
 - 17.9.4 Damage to Screw Caps 422
 - 17.10 Vinolok 423
 - 17.11 Some Advantages and Disadvantages of Various Closure Types 423
 - 17.12 The Bottling Operation 424
 - 17.13 PET Bottles 424
 - 17.14 Cans 425
 - 17.15 Bag-in-Box 426
 - 17.15.1 History of Bag-in-Box 426
 - 17.15.2 The Manufacture of the Bag 427
 - 17.15.3 Filling Bag-in-Box Wines 427
 - 17.16 Final Reflections 427
 - References 428
- 18 Best Practice for Fault and Flaw Prevention 432**
 - 18.1 The Wine Industry 432
 - 18.2 HACCP 432
 - 18.3 Standard Operating Procedures (SOPs) 433
 - 18.4 Traceability 433
 - 18.5 Winery Design 433
 - 18.6 Cleaning and Sanitation 434
 - 18.6.1 Winery Water 434
 - 18.6.2 Cleaning Agents 435
 - 18.6.3 Cleaning of Equipment 435
 - 18.6.4 Suggested Sequence for Cleaning Equipment 436
 - 18.6.5 Barrel Cleaning 437
 - 18.7 Good Practice Winemaking Procedures to Avoid Spoilage, Faults, and Flaws 437
 - 18.7.1 Harvesting 438

18.7.2	Transportation of Harvested Fruit	438
18.7.3	Sorting	439
18.7.4	De-stemming, Crushing	439
18.7.5	Pressing (for White or Rosé Wines)	439
18.7.6	Yeast Nutrients	439
18.7.7	Oxygenating During Fermentation	439
18.7.8	Use of Inert Gasses and Topping of Containers	440
18.7.9	Bottling	440
18.8	The Use of Oenological Additions and Processing Aids	440
18.8.1	Sulfur Dioxide	440
18.8.1.1	Properties of Sulfur Dioxide	440
18.8.1.2	Total, Bound, Free, and Molecular Sulfur Dioxide	441
18.8.1.3	Health and Legal Considerations	442
18.8.1.4	The Use of Sulfur Dioxide in Winemaking	443
18.8.2	Dimethyl Dicarbonate (Velcorin)	444
18.8.3	Lysozyme	444
18.8.4	Chitosan	444
18.9	Routine Wine Analysis	445
18.10	Final, Final Reflections	446
	References	449

Appendix A Levels of Free SO₂ Required to Give 0.5, 0.625, and 0.8 mg/l of Molecular SO₂ for Differing Wine pH Values 451

Further Reading	452
Glossary	454
Useful Websites	461
Index	465