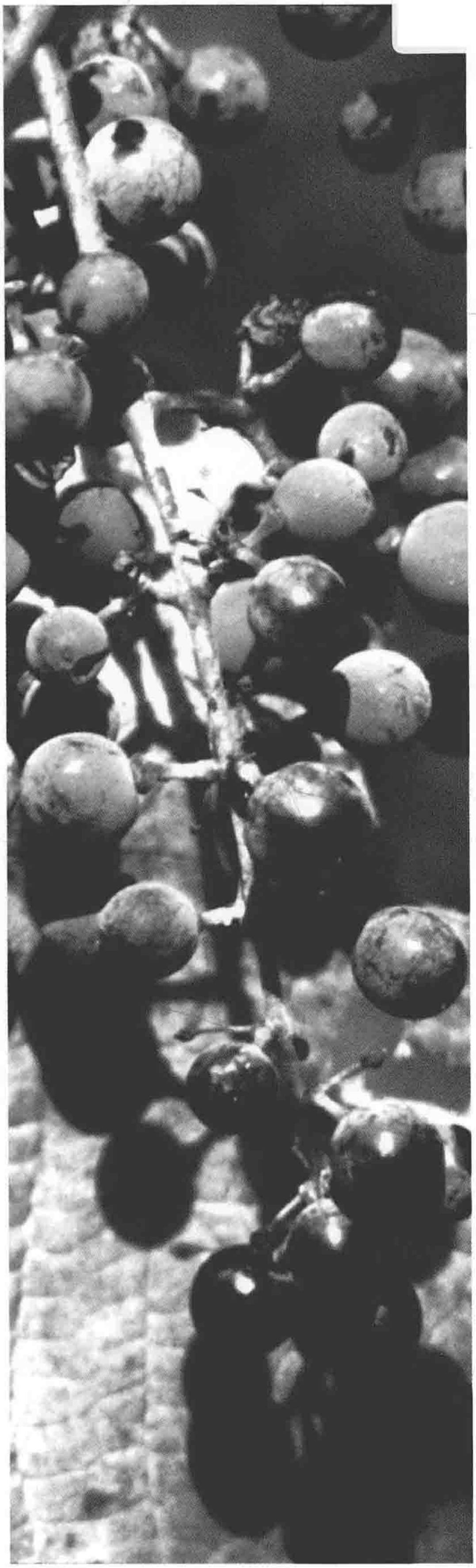
THIRD EDITION

Wine Science

PRINCIPLES AND APPLICATIONS

Ronald S. Jackson



Third Edition

Wine Science

Principles

and

Applications

Ronald S. Jackson, PhD

ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG
LONDON • NEW YORK • OXFORD • PARIS
SAN DIEGO • SAN FRANCISCO
SYDNEY • TOKYO
Academic Press is an imprint of Elsevier

Academic Press is an imprint of Elsevier
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
84 Theobald's Road, London WC1X 8RR, UK
525 B Street, Suite 1900, San Diego, California 92101-4495, USA

First edition 1994
Second edition 2000
Third edition 2008

Library of Congress Cataloging in Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-12-373646-8

Typeset by Charontec Ltd (A Macmillan Company), Chennai, India
www.charontec.com
Printed and bound in Canada

08 09 10 11 12 10 9 8 7 6 5 4 3 2 1

Third Edition

Wine Science

Principles

and

Applications

The book is dedicated to the
miraculous microbes that can turn a
marvelous fruit into a seraphic beverage,
to God who has given us the ability to
savor its finest qualities and pleasures,
and to my mother and father, to whom
I will eternally owe a debt of gratitude
for their unwavering support.

About the Author

The author received his bachelor's and maser's degrees from Queen's University and doctorate from the University of Toronto. His time in Vineland, Ontario, and subsequently on a sabbatical at Cornell University, redirected his interest in plant disease toward viticulture and ecology. As part of his regular teaching duties, he developed the first wine techonology course in Canada at Brandon University. For Many years he was a technical advisor to the Manitoba Liquor Control Commission, developed sensory tests to assess candidates of its Sensory Panel, and was a member of its External Tasting Panel. In addition he is author of *Wine Tasting: A Professional Handbook, Conserve Water Drink Wine*, numerous technical reviews, and an annual section in Tom Stevenson's Wine Report. Dr Jackson is retired from university activity and now concentrates his on writing. To contact the author send correspondence to his attention at Elsevier, 525 B Street, Suite 1900, San Diego, CA 92101–4495 USA.

Preface

There are three pillars of wine science – grape culture, wine production, and sensory analysis. Although it is traditional to cover these topics separately, a joint discussion is valuable and reinforces their natural interrelationships.

Consistent with present biological thought, much of wine science is expressed in terms of chemistry. Because of the botanical nature of the raw materials and its microbial transformation into wine, the physiology and genetics of the vine, yeasts, and bacteria are crucial to an understanding of the origins of wine quality. Similarly, microclimatology and soil physicochemistry are revealing the vineyard origins of grape quality. Finally, a knowledge of human sensory psychophysiology is essential for interpreting wine quality data. For those more interested in applications, much of the scientific discussion has been placed so that the practical aspects can be accessed without necessarily reading and understanding the scientific explanations.

Much of the data used in the book is derived from a few cultivars that originated in the cooler central regions of Western Europe. Thus, caution must be taken in extrapolating much of the information to warmer climates. The value of challenging established wisdom is evident from the success of Australian wine produced from cultivars grown in regions quite different from their European birthplace. In addition, the oft-quoted value of cooler mesoclimates must be qualified because it is derived from cultivars that arose in moderate climates. Cultivars that originated in cold climates generally are considered to develop best in the warmest sites of the ancestral region. Thus, for varieties derived in hot regions, the most favorable conditions for flavor accumulation are likely to be considerably different from those commonly quoted for moderate and cool climates.

Specific recommendations are avoided because of the international scope of the work. Even books with a regional focus find it difficult to give precise directions due to the variability in regional and site specific conditions. Science can suggest guidelines and reasons for good practice, and enunciate the potential advantages and disadvantages of particular options. However, it is the grape grower and winemaker who knows the subtleties of his or her sites, cultivars, and fermentation conditions. Individual experimentation and data recording are the only certain way for them to maximize grape potential.

One of the negative side-effects of our rapidly advancing (changing) state of knowledge is the confusion created as to what is the "truth." Too often non-scientists get annoyed with the inconstant recommendation from "experts." There is the misconception that scientists *know*, rather than are *searchers* for the truth. For some, this has resulted in their discarding technological advances for ancient techniques. This certainly facilitates many viniviticultural decisions, and can be used profitably in the "back to nature" philosophy of winemaking. While I cannot deny the commercial success some producers have with this approach, it is not the route by which quality wine will fill the supermarket shelf.

It is hoped that this book will help place our present knowledge in perspective and illustrate where further study is needed. It is not possible in a book to provide a detailed treatment of all diverging views. I have chosen those views that in my opinion have the greatest support, practical importance, or potential for significance. In addition, several topics are quite contentious among grape growers and winemakers. For some issues, further study will clarify the topic; for others, personal preference will always be the deciding factor. I extend my apologies to those who may feel that their views have been inadequately represented.

The effects of global warming on viticulture is increasingly coming under investigation. However, its true influence is only speculation at the moment. Thus, these have not been included. If some of the scenarios suggested come to fruition, the effect will be horrific. Although some famous vineyards may be under water, and grape adaptation to site be seriously dislocated, the more devastating effects are likely to result from the extreme and destructive disruption of world agriculture, trade, and economy, and the political and social strife that will follow.

Where no common chemical name is available or preferred, I.U.P.A.C. terminology has been used. In conformity with the International Code of Botanical Nomenclature, grape cultivar names are noted by single quotes (i.e. 'Pinot noir'), in lieu of the other accepted practice, placing *cv.* before the name. Except in tables, the present-day practice of naming rootstock cultivars with a number and the originator's name is used, *in lieu* of the number and a contraction of the originator's name (i.e. 3309 Couderc vs. 3309 C).

A list of Suggested Readings is given at the end of each chapter to guide further study. Although several are in languages other than English, they are excellent sources of precise information. To have omitted them would have done a disservice to those wishing to pursue the topics concerned. In addition, References are given in the book if the information is very specific or not readily available in the Suggested Readings. Further details can be obtained from sources given for the figures and tables.

Samuel Johnson made a cogent observation about the subject of this book:

> *This is one of the disadvantages of wine; it makes man mistake words for thoughts.*

Ronald S. Jackson

Acknowledgments

Without the astute observations of generations of winemakers and grape growers, and the dedicated research of countless enologists and viticulturalists, this work would have been impossible. Thus, acknowledgment is given to those whose work has not been specifically cited. Appreciation also is given to those who read and provided constructive criticism of various chapters of the manuscript. Credit must also go to the various editors who have helped over the years in the preparation of various editions of the text. However, special thanks goes to Nancy Maragioglio. She has facilitated every aspect of the preparation of the third edition. Her constant encouragement and creativity has not only provided considerable improvements, but made its preparation a joy.

Gratitude is also expressed to the many researchers, companies, institutes, and publishers who freely donated the photographs, data, diagrams or figures reproduced in the book.

Finally, but not least, I must express my deepest appreciation to my wife, Suzanne Ouellet, for her unshakable support in the preparation of the various editions of this work.

Contents

3

Grapevine Structure and Function

4

Vineyard Practice

5

Site Selection and Climate

6

Chemical Constituents of Grapes and Wine

7

Fermentation

8

Postfermentation Treatments and Related Topics

9

Specific and Distinctive Wine Styles

10

Wine Laws, Authentication, and Geography

11

Sensory Perception and Wine Assessment

12

Wine and Health

1

Introduction

Grapevine and Wine Origin

Wine has an archeological record dating back more than 7.5 thousand years. The earliest suspected wine residues come from the early to mid-fifth millennium B.C. – Hajji Firuz Tepe, in the northern Zagros Mountains of Iran (McGovern *et al.*, 1996). Evidence from Neolithic pottery from Georgia suggests that contemporaneous wine production was dispersed throughout the region (McGovern, in preparation). Older examples of fermented beverages have been discovered (McGovern *et al.*, 2004), but they appear to have been produced from rice, honey, and fruit (hawthorn and/or grape). Such beverages were being produced in China as early as 7000 B.C. The presence of wine residues is usually identified by the presence of tartaric acid residues, although additional procedures for identifying grape tannin residues are in development (Garnier *et al.*, 2003).

Other than the technical problems associated with identifying wine residues, there is the thorny issue of what constitutes wine – does spontaneously fermented grape juice qualify as wine, or should the term be restricted to juice fermented and stored in a manner to retain its wine-like properties?

The first unequivocal evidence of intentional winemaking appears in the representations of wine presses from the reign of Udimu (Egypt), some 5000 years ago (Petrie, 1923). Wine residues also have been found in clearly identified wine amphoras in many ancient Egyptian tombs, beginning at least with King Semerkhet – 1st Dynasty, 2920–2770 B.C. (Guasch-Jané *et al.*, 2004). They have also discovered evidence for both white and red wine in amphorae found in King Tutankhamun's tomb (1325 B.C.). Identification of red wine was made by the presence of syringic acid, an alkaline breakdown product of malvidin-3-glycoside. The same technique was used to establish the red grape origin of the ancient Egyptian drink – *Shedeh* (Guasch-Jané *et al.*, 2006).

Most researchers believe that winemaking was discovered, or at least evolved, in southern Caucasia. This area includes parts of present-day northwestern Turkey, northern Iraq, Azerbaijan, and Georgia. It is also generally thought that the domestication of the wine grape (*Vitis vinifera*) ensued in the same area. Remains of what appear to be domesticated grapes have been found in a Neolithic village in the Transcaucasian region of Georgia (Ramishvili, 1983). It is in this region that the natural distribution of *V. vinifera* most closely approaches the probable origins of Western agriculture – along the Tigris and Euphrates Rivers (Zohary and Hopf, 2000). Grapevine domestication also may have occurred independently in Spain (Núñez and Walker, 1989).

Although grapes readily ferment, due to the prevalence of fermentable sugars, the wine yeast (*Saccharomyces cerevisiae*) is not a major, indigenous member of the grape flora. The natural habitat of the ancestral strains of *S. cerevisiae* appears to be the bark and sap exudate of oak trees (Phaff, 1986). If so, the habit of grapevines climbing trees, such as oak, and the joint harvesting of grapes and acorns, may have encouraged the inoculation of grapes and grape juice with *S. cerevisiae*. The fortuitous overlap in the distribution of the progenitors of both *S. cerevisiae* and *V. vinifera* with the northern spread of agriculture into Anatolia may have fostered the discovery of winemaking, as well as its subsequent development and spread. It may not be pure coincidence that most major yeast-fermented beverages and foods (wine, beer, mead, and bread) have their origins in the Near East.

The earliest evidence of the connection between wine and *Saccharomyces cerevisiae* comes from an amphora found in the tomb of Narmer, the Scorpion King (ca. 3150 B.C.). *S. cerevisiae* was confirmed by the extraction of DNA from one of the amphoras. The DNA showed more similarity with modern strains of *S. cerevisiae* than closely related species, *S. bayanus* and *S. paradoxus* (Cavalieri *et al.*, 2003). The latter is considered to be the progenitor of *S. cerevisiae*. Specific words referring to yeast action (ferment) begin to appear about 2000 B.C. (Forbes, 1965).

Other yeasts indigenous to grapes, such as *Kloeckera apiculata* and various *Candida* spp., can readily initiate fermentation. However, they seldom complete fermentation. Their sensitivity to the accumulating alcohol content and limited fermentative metabolism curtails their activity. In contrast, beer with its lower alcohol content may have initially been fermented by yeasts other than *S. cerevisiae*.

The Near Eastern origin and spread of winemaking are supported by the remarkable similarity between the words meaning wine in most Indo-European languages (Table 2.1). The spread of agriculture into Europe appears to be associated with the dispersion of Proto-Indo-European-speaking Caucasians (or their language and culture) (Renfrew, 1989). In addition, most eastern Mediterranean myths locate the origin of winemaking in northeastern Asia Minor (Stanislawski, 1975).

Unlike the major cereal crops of the Near East (wheat and barley), cultivated grapes develop an extensive yeast population by maturity, although rarely including the wine yeast (*Saccharomyces cerevisiae*). Piled unattended for several days, grape cells begin to self-ferment as oxygen becomes limiting. When the berries rupture, juice from the fruit is rapidly colonized by the yeast flora. These continue the conversion of fruit sugars into alcohol (ethanol). Unless *S. cerevisiae* is present to continue the fermentation, fermentation usually ceases before all the sugars are converted to alcohol. Unlike the native yeast population, *S. cerevisiae* can completely metabolize fermentable sugars.

The fermentation of grape juice into wine is greatly facilitated if the fruit is first crushed. Crushing releases and mixes the juice with yeasts on the grape skins (and associated equipment). Although yeast fermentation is more rapid in contact with slight amounts of oxygen, continued exposure to air favors the growth of a wide range of yeasts and bacteria. The latter can quickly turn the nascent wine into vinegar. Although unacceptable as a beverage, the vinegar so produced was probably valuable in its own right. As a source of acetic acid, vinegar expedited pottery production and the preservation (pickling) of perishable foods.

Of the many fruits gathered by ancient man, only grapes store carbohydrates predominantly in the form of soluble sugars. Thus, the major caloric source in grapes is in a form readily metabolized by wine yeasts. Most other fleshy fruits store carbohydrates as starch and pectins, nutrients not fermentable by wine yeasts. The rapid and extensive production of ethanol by *S. cerevisiae* quickly limits the growth of most bacteria and other yeasts in grape juice. Consequently, wine yeasts generate conditions that rapidly give them almost exclusive access to grape nutrients. Subsequent yeast growth is possible after the sugars are metabolized, if oxygen becomes available. An example is the respiration of ethanol by *flor* yeasts (see Chapter 9).

Another unique property of grapes concerns the acids they contain. The major acid found in mature grapes is tartaric acid. This acid occurs in small quantities in the vegetative parts of some other plants (Stafford, 1959), but rarely in fruit. Because tartaric acid is metabolized by few microbes, wine remains sufficiently acidic to limit the growth of most bacteria and fungi. In addition, the acidity gives wine much of its fresh taste. The combined action of grape acidity and the accumulation of ethanol suppresses the growth and metabolism of most potential wine-spoilage organisms. This property is enhanced in the absence of air (oxygen). For ancient man, the result of grape fermentation was the transformation of a perishable, periodically available fruit, into a relatively stable beverage with novel and potentially intoxicating properties.

Unlike many crop plants, the grapevine has required little genetic modification to adapt it to cultivation. Its mineral and water requirements are low, permitting it to flourish on soils and hillsides unsuitable for other food crops. Its ability to grow up trees and other supports meant it could be grown with little tending in association with other crops. In addition, its immense regenerative potential has allowed it to permit intense pruning. Intense pruning turned a trailing climber into a short shrub-like plant suitable for monoculture. The short stature of the shrubby vine minimized the need for supports and may have decreased water stress in semiarid environments by shading the soil. The regenerative powers and woody structure of the vine also have permitted it to withstand considerable winterkill and still possess the potential to produce commercially acceptable yields in cool climates. This favored the spread of viticulture into central Europe and the subsequent selection of, or hybridization with, indigenous grapevines.

The major change that converted "wild" vines into a "domesticated" crop was the selection of bisexual mutants. The vast majority of wild vines are functionally unisexual, despite usually possessing both male and female parts. In several cultivars, conversion to functional bisexuality has involved the inactivation of a single gene. However, the complexity of sexual differentiation in some cultivars (Carbonneau, 1983) suggests the involvement of mutations in several genes.

How ancient peoples domesticated the grapevine will probably never be known. However, two scenarios seem likely. Several Neolithic sites show significant collections of grape seeds in refuse piles, indicating the importance of grapes to the local inhabitants. Although most of these seed remains indicate charring, seed escaping the heating process could have found conditions ideal for growth among the ashes. Were any of these progeny rare bisexual (self-fertile) vines, they could have produced a crop, despite being isolated from feral vines. More likely, functional bisexual vines were unintentionally selected when feral vines were planted adjacent to settlements, and away from wild populations. Self-fertile vines would have become conspicuous by their fruitfulness, especially if unfruitful (male) vines were rogued. Cuttings from such vines could have provided plants appropriate for the initiation of nascent viticulture.

Although other modifications may characterize domesticated strains, changes in seed and leaf shape are not of viticultural value. The lower acidity and higher sugar content that characterize cultivated varieties are not the exclusive attributes of domesticated vines. These properties may reflect more cultural conditions than genetic modifications.

Because canes lying on the ground root easily when covered by soil, layering probably developed as the first method of vegetative propagation. Success with layering would have ultimately led to propagation by cuttings. Early viticulturalists, if they did not already know from other perennial crops, would have come to realize that to retain desirable traits, vegetative propagation was preferable to sowing seed. Vegetative propagation retains desirable combinations of genetic traits unmodified.

In drier regions, the limited growth of vines could be left to trail on the ground. However, in moister regions, it would have been better to plant vines next to trees for support. This technique is still used in some parts of Portugal, and was, until comparatively recently, fairly common in parts of Italy. It had the advantage of leaving arable land free for annual food crops. One of the major problems with training up trees is that most of the fruit is soon located out of easy reach. Some inventive cultivator probably found that staking and trimming restricted growth to a convenient height, facilitating fruit gathering. In addition, pruning off excess growth at the end of the season would have been discovered to benefit fruit maturation. The combination of easier harvesting and improved ripening probably spurred further experimentation with pruning and training systems. Combined with advances in wine production and storage, the stage would have been set for the development of wine trade.

The evolution of winemaking from a periodic, haphazard event to a common cultural occurrence presupposes the development of a settled lifestyle. A nomadic habit is incompatible with harvesting a sufficient quantity of grapes to produce steady supply of wine. In addition,