
Brewing Science: A Multidisciplinary Approach

Michael Mosher · Kenneth Trantham

Brewing Science: A Multidisciplinary Approach

Michael Mosher
Department of Chemistry and Biochemistry
University of Northern Colorado
Greeley, CO
USA

Kenneth Trantham
Department of Physics and Physical Science
University of Nebraska at Kearney
Kearney, NE
USA

ISBN 978-3-319-46393-3 ISBN 978-3-319-46394-0 (eBook)
DOI 10.1007/978-3-319-46394-0

Library of Congress Control Number: 2016952006

© Springer International Publishing Switzerland 2017

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

To the Student

What do your professors do at the end of a day at college? Many, the authors included, will enjoy a craft brew and discuss the day's successes and opportunities for improvement. Thus began the discussion for the beginnings of this book. "Wouldn't it be awesome," we thought, "if we could highlight the science that goes into brewing? The students would just love a brewing science class!" We spent the next weeks and months designing and planning a course that would illustrate the interdisciplinary nature of brewing science.

The result is what you will find here. This text represents the topics that are taught in our courses on an Introduction to Brewing. These courses are very popular at our institutions and attended by students from almost every major. We have tried to write from your perspective and provide not only the processes that you will encounter in the brewery, but also provide the reasons why those processes are completed and the science behind them. And we have written the text with no assumptions as to what courses you have previously taken. As topics are introduced, we also introduce the science behind them starting from the basics. As we have found, teaching "just in time" provides useful examples for you to use to help you understand the background and the topic in question.

Every few pages, you will find CHECKPOINT boxes. These are designed to provide you with a chance to take a break and confirm that you have gathered the key topics of the discussion to that point. This is also how we have constructed the images that accompany the discussion. When images and tables appear in the text, it is important to take a break from reading and examine them in detail. Understand why each is included in the chapter, and why each is presented in the way it is. (Some professors, the authors included, find great quiz and test questions by looking at the figures.)

We sincerely hope that you enjoy your studies of this exciting topic. One thing you will note from the start, brewing science requires an understanding of a nearly endless range of topics from biology to chemistry to physics to history to almost every subject taught on campus. The purpose of the book is not to make you, the student, a physical chemist or a fluids engineer, but it will give you a sense of what is possible in the brewery. And, it will provide you with an understanding behind

why things are done the way that they are in the brewery. Brewing science can be very technical, but our hope is that you find the subject just as fascinating as we do.

To the Instructor

The first incarnation of the course described by the topics in this text was directed at the general studies level. The science discussed in that type of course is descriptive and general in nature. We found that the class attracted a wide range of majors with varying interest levels. This class is still taught at the University of Nebraska Kearney. However, we have found that the class also attracted those with more than a passing interest in brewing and wanted to dive deeper into the rich science that surrounds the craft brewing industry. So, we have included the detail that is appropriate for those courses that do this, such as the course taught at the University of Northern Colorado.

This text is written from a process-centric approach to uncovering the principles behind brewing science. Instead of a discussion of brewing from the perspective of the four main ingredients (water, malt, hops, and yeast), this text is formatted and written from the viewpoint of the steps taken to manufacture beer (malting, milling, mashing, boiling, etc.). The topics are focused more on the technical aspects and design principles of brewing. As the students uncover the process of mashing, they explore the background chemistry needed to fully develop their understanding. As we explore wort chilling, we dive into the background in thermodynamics that explains this process. Thus students learn what they need to know as they need to know it. We have found this process of “just in time” teaching to be very effective. It produces opportunities to introduce examples, increase motivation, and set high bars for achievement.

We hope, as well, that this text will provide you, the instructor, with the greater detail needed behind each of the processes in the brewery and the insight into the interrelationships between topics in brewing science. We realize that there are parts of the book that may be mathematically challenging to a general audience. But, the language of science is mathematics—and with practice and motivation to be successful, the general audience can succeed.

Within each chapter are CHECKPOINT questions that provide key questions that students should be able to accomplish by studying the material preceding them. At the end of each chapter are questions that expand upon these in-chapter questions. The summary section at the end of the chapter is also helpful in directing students as they move through the text.

Finally, each chapter contains at least one laboratory experiment that can help explain the material in the chapter. Both of the author’s courses in this subject have related laboratories that we have noted are extremely useful in developing student interest and motivation and providing confirmation of topics in the course. Additional “laboratory experiments” can be obtained by modifying the laboratory tests found in the American Society of Brewing Chemists Methods of Analysis resource.

It is our sincere hope that you, the instructor, find the information in this text to be helpful to you and your students irrespective of the level of your introductory course in brewing science. As a standalone text, or used in conjunction with handouts and additional readings, the material inside should be helpful to your students. Whether they are beginning their studies for a Diploma in Brewing from the Institute of Brewing and Distilling, satisfying a general studies requirement, or reading for interest, the student is sure to find interest in this topic.

Greeley, USA
Kearney, USA

Michael Mosher
Kenneth Trantham

Contents

1	Introduction to Brewing Science	1
1.1	Science and the Brewer	1
1.1.1	The Scientific Method	1
1.2	What Is Beer?	3
1.3	Some Common Conventions	6
1.3.1	Volume	6
1.3.2	Temperature	9
1.3.3	Weight	11
1.4	Yes Virginia, Beer Contains Alcohol	12
1.5	A Short History of Beer in the World	15
1.6	History of Beer in the USA	21
1.7	The Current Market for Beer	26
2	Beer Styles	35
2.1	Judging Beer	35
2.1.1	Beer Styles	36
2.1.2	Conforming to a Style	36
2.2	Parameters that Classify a Beer Style	38
2.2.1	Physical Parameters	38
2.3	Common Beer Styles	44
2.3.1	Lagers	44
2.3.2	Ales	47
2.4	Historical Beer Styles	51
2.5	How to Sample and Taste Beer	52
2.5.1	Beer Glasses	53
2.5.2	Serving Temperature	55
2.5.3	Sampling and Tasting	56
3	Molecules and Other Matters	63
3.1	The Atom	63
3.1.1	Compounds	66
3.2	Laws that Govern Atoms, Molecules, and Ionic Compounds	70

3.3	The World of Carbon-Containing Molecules	74
3.3.1	Basic Functional Groups in Brewing	75
3.3.2	Amino Acid Polymers	81
3.3.3	Drawing Organic Molecules	82
3.3.4	Naming Organic Molecules	84
3.4	Reactions of Organic Molecules	86
3.4.1	Oxidation and Reduction	87
3.4.2	Condensation Reactions	87
3.4.3	Isomerization Reactions	88
3.4.4	Radical Reactions	88
3.4.5	Maillard Reactions	90
4	Overview of the Brewing Process	95
4.1	Overview of the Process	95
4.1.1	Agricultural	96
4.1.2	Malting	98
4.1.3	Mashing	100
4.1.4	Lautering and Sparging	102
4.1.5	Boiling	105
4.1.6	Fermentation	107
4.1.7	Conditioning and Bottling	108
4.2	Cleaning and Sterilizing	109
4.3	Inputs and Outputs	111
4.3.1	Water	111
4.3.2	Grains and Malts	112
4.3.3	Hops	116
4.3.4	Yeast	118
4.3.5	Finished Product	119
5	The “Food” for the Brew	125
5.1	Biology of Barley	125
5.1.1	The Barley Corn	126
5.1.2	Barley and the Farmer	127
5.1.3	Barley Diseases and Pests	129
5.1.4	Sorting and Grading	130
5.2	Malting Barley	132
5.2.1	Germination of Barley	132
5.2.2	Equipment Used in Malting	135
5.2.3	Problems Arising from Malting	140
5.3	Maillard Reactions	141
5.4	Water—The Most Important Ingredient	144
5.4.1	Types of Water	145
5.4.2	What Makes up Water?	149

6	Mashing	157
6.1	Purpose of Mashing	157
6.2	Equipment Used in Mashing	158
6.2.1	Cereal Cookers	159
6.2.2	Mash Mixer and Mash Kettles	161
6.2.3	Mash Tun	164
6.2.4	Processes in Mashing	165
6.3	Enzymes and What They Are	165
6.4	Chemistry While Resting	167
6.4.1	Starch	167
6.4.2	Phytase	173
6.4.3	Proteases and Peptidases	174
6.4.4	Glucanase	175
6.4.5	Alpha-Amylase	175
6.4.6	Beta-Amylase	177
6.4.7	Mashout	178
7	Sparging	183
7.1	Introduction	183
7.2	Fluid Physics: Static Case	184
7.2.1	Pressure	184
7.2.2	Pascal's Law	185
7.3	Fluid Physics: Dynamic Case	190
7.3.1	Conservation of Mass: The Continuity Equation	190
7.3.2	Bernoulli's Principle and Laminar Flow	192
7.3.3	Pressure and Hydraulic Head	195
7.3.4	Head and Pump Dynamics	197
7.3.5	Darcy's Law and Laminar Flow in Porous Media	205
7.4	Equipment Used in Sparging and Lautering	215
7.4.1	Batch Sparging	215
7.4.2	Fly Sparging	216
7.4.3	Mash Filter	218
7.5	When Do We Stop Sparging?	219
8	Wort Boiling	227
8.1	Why Boil the Wort?	227
8.2	The Equipment of the Boil	230
8.2.1	Metals and Heating	231
8.2.2	Corrosion	234
8.2.3	Methods for Heating	235
8.2.4	Direct-Fire Vessels	237
8.2.5	Calandria	239
8.2.6	Other Heating Systems	241
8.3	Heat and Temperature	243
8.3.1	Types of Energy	243

8.4	Heat Capacity and Heat Transfer	246
8.4.1	Phase Transition: Boiling	247
8.4.2	Power	248
8.5	Hops in the Boil	250
8.5.1	The Hop Flower Revisited.	250
8.5.2	Hop Oil Constituents.	251
8.5.3	Modified Hop Oils	254
9	Cooling and Fermenting	263
9.1	Setting the Stage.	263
9.2	Wort Chilling	264
9.2.1	Heat Exchangers	265
9.3	Equipment Used in Fermentation	272
9.3.1	Refrigeration	273
9.3.2	Fermenters, CCV, and Round Squares	294
9.4	Yeast	299
9.4.1	Yeast Morphology	300
9.4.2	Yeast Metabolism	302
9.4.3	Products of Yeast	307
10	Conditioning	313
10.1	Why Condition?	313
10.1.1	Secondary Fermentation	314
10.1.2	Warm Conditioning.	315
10.1.3	Other Adjustments.	318
10.2	Equipment Used in Conditioning	322
10.2.1	The Conditioning Tank	322
10.2.2	Cask Conditioning	323
11	Packaging	331
11.1	Introduction	331
11.2	Carbonation and Other Gases	331
11.2.1	Pressure Loss in Transferring Liquids	332
11.2.2	Other Gases Used in “Carbonation”	335
11.3	Packaging	338
11.3.1	Small Pack	338
11.3.2	Large Pack	346
11.4	Pasteurization	349
11.4.1	Tunnel Pasteurization	352
11.4.2	Flash Pasteurization.	353
11.4.3	Other Methods of Pasteurization	355
12	Quality Assurance and Quality Control.	359
12.1	What Is Quality?.	359
12.2	Quality Control.	360
12.2.1	Safety in the Brewery	361

12.3	Quality Assurance	367
12.4	HACCP Analysis	369
12.5	Sensory Analyses	371
Appendix A: Math for the Brewer		379
Appendix B: R134a Refrigerant Data		391
Index		405