

# HOW BAKING WORKS

Exploring the Fundamentals of Baking Science

SECOND EDITION

Paula Figoni



JOHN WILEY & SONS, INC.



# HOW BAKING WORKS

Exploring the Fundamentals of Baking Science

SECOND EDITION

Paula Figoni



JOHN WILEY & SONS, INC.

# Table of Contents

Title Page

Copyright Page

PREFACE

A NOTE ABOUT TEMPERATURE AND WEIGHT CONVERSIONS

CHANGES TO THE SECOND EDITION

ABOUT THE EXPERIMENTS

EQUIPMENT AND SMALLWARES

ACKNOWLEDGMENTS

CHAPTER 1 - INTRODUCTION TO BAKING

INTRODUCTION

THE IMPORTANCE OF ACCURACY IN THE BAKESHOP

BALANCES AND SCALES

UNITS OF MEASURE

WEIGHT AND VOLUME MEASUREMENTS

THE DIFFERENCE BETWEEN DENSITY AND THICKNESS

THE DIFFERENCE BETWEEN WEIGHT OUNCES AND FLUID OUNCES

BAKER'S PERCENTAGES

THE IMPORTANCE OF CONTROLLING INGREDIENT TEMPERATURES

THE IMPORTANCE OF CONTROLLING OVEN TEMPERATURES

QUESTIONS FOR REVIEW

QUESTIONS FOR DISCUSSION

EXERCISES AND EXPERIMENTS

CHAPTER 2 - HEAT TRANSFER

INTRODUCTION

METHODS OF HEAT TRANSFER

QUESTIONS FOR REVIEW

QUESTIONS FOR DISCUSSION

EXERCISES AND EXPERIMENTS

CHAPTER 3 - OVERVIEW OF THE BAKING PROCESS

INTRODUCTION

SETTING THE STAGE FOR SUCCESS  
STAGE I: MIXING  
STAGE II: BAKING  
STAGE III: COOLING  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

#### CHAPTER 4 - SENSORY PROPERTIES OF FOOD

INTRODUCTION  
APPEARANCE  
FLAVOR  
TEXTURE  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

#### CHAPTER 5 - WHEAT FLOUR

INTRODUCTION  
WHEAT KERNEL  
MAKEUP OF FLOUR  
CLASSIFYING WHEAT  
PARTICLE SIZE  
FLOUR AND DOUGH ADDITIVES AND TREATMENTS  
COMMERCIAL GRADES OF WHITE FLOURS  
TYPES OF PATENT WHEAT FLOURS  
OTHER WHEAT FLOURS  
FUNCTIONS OF FLOURS  
STORAGE OF FLOURS  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

#### CHAPTER 6 - VARIETY GRAINS AND FLOURS

INTRODUCTION  
CEREAL GRAINS  
CEREAL-FREE GRAINS AND FLOURS  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

## CHAPTER 7 - GLUTEN

INTRODUCTION

THE IMPORTANCE OF GLUTEN

THE UNIQUE NATURE OF GLUTEN

DETERMINING GLUTEN REQUIREMENTS

CONTROLLING GLUTEN DEVELOPMENT

DOUGH RELAXATION

QUESTIONS FOR REVIEW

QUESTIONS FOR DISCUSSION

EXERCISES AND EXPERIMENTS

## CHAPTER 8 - SUGAR AND OTHER SWEETENERS

INTRODUCTION

SWEETENERS

DRY CRYSTALLINE SUGARS

SYRUPS

SPECIALTY SWEETENERS

FUNCTIONS OF SWEETENERS

STORAGE AND HANDLING

QUESTIONS FOR REVIEW

QUESTIONS FOR DISCUSSION

EXERCISES AND EXPERIMENTS

## CHAPTER 9 - THICKENING AND GELLING AGENTS

INTRODUCTION

THE PROCESS OF THICKENING AND GELLING

GELATIN

VEGETABLE GUMS

STARCHES

FUNCTIONS OF THICKENING AND GELLING AGENTS

STORAGE AND HANDLING

QUESTIONS FOR REVIEW

QUESTIONS FOR DISCUSSION

EXERCISES AND EXPERIMENTS

## CHAPTER 10 - FATS, OILS, AND EMULSIFIERS

INTRODUCTION

CHEMISTRY OF FATS, OILS, AND EMULSIFIERS  
HYDROGENATION  
FATS AND OILS  
FUNCTIONS OF FATS, OILS, AND EMULSIFIERS  
STORAGE AND HANDLING  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

CHAPTER 11 - EGGS AND EGG PRODUCTS

INTRODUCTION  
THE MAKEUP OF AN EGG  
COMMERCIAL CLASSIFICATION OF SHELL EGGS  
EGG PRODUCTS  
FUNCTIONS OF EGGS  
MORE ON COAGULATION—BASIC EGG CUSTARD  
MORE ON AERATION—MERINGUE  
STORAGE AND HANDLING  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

CHAPTER 12 - MILK AND MILK PRODUCTS

INTRODUCTION  
COMMON COMMERCIAL PROCESSES TO MILK AND MILK PRODUCTS  
MAKEUP OF MILK  
MILK PRODUCTS  
FUNCTIONS OF MILK AND MILK PRODUCTS  
STORAGE AND HANDLING  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

CHAPTER 13 - LEAVENING AGENTS

INTRODUCTION  
THE PROCESS OF LEAVENING  
LEAVENING GASES  
YEAST FERMENTATION  
CHEMICAL LEAVENERS  
STORAGE AND HANDLING

QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

## CHAPTER 14 - NATURAL AND ARTIFICIAL FLAVORINGS

INTRODUCTION  
A BRIEF REVIEW OF FLAVOR  
FLAVOR PROFILES  
TYPES OF FLAVORINGS  
EVALUATING NEW FLAVORINGS  
STORAGE AND HANDLING  
QUESTIONS FOR REVIEW  
EXERCISES AND EXPERIMENTS

## CHAPTER 15 - FRUIT AND FRUIT PRODUCTS

INTRODUCTION  
HOW FRUIT IS PURCHASED  
COMMON FRUITS  
FRUIT RIPENING  
STORAGE AND HANDLING  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

## CHAPTER 16 - NUTS AND SEEDS

INTRODUCTION  
COMPOSITION OF NUTS, KERNELS, AND SEEDS  
COST  
COMMON NUTS, KERNELS, AND SEEDS  
TOASTING NUTS  
STORAGE AND HANDLING  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

## CHAPTER 17 - COCOA AND CHOCOLATE PRODUCTS

INTRODUCTION  
MAKEUP OF COCOA BEANS

COMMON COCOA AND CHOCOLATE PRODUCTS  
HANDLING CHOCOLATE PRODUCTS  
FUNCTIONS OF COCOA AND CHOCOLATE PRODUCTS  
STORAGE  
QUESTIONS FOR REVIEW  
QUESTIONS FOR DISCUSSION  
EXERCISES AND EXPERIMENTS

BIBLIOGRAPHY

INDEX



# HOW BAKING WORKS

Exploring the Fundamentals of Baking Science

SECOND EDITION

Paula Figoni



JOHN WILEY & SONS, INC.

This book is printed on acid-free paper.



Copyright © 2008 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.

Published simultaneously in Canada.

Wiley Bicentennial Logo: Richard J. Pacifico

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, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400, fax 978-646-8600, or on the web at [www.copyright.com](http://www.copyright.com). Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, 201-748-6011, fax 201-748-6008, or online at <http://www.wiley.com/go/permissions>.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services, or technical support, please contact our Customer Care Department within the United States at 800-762-2974, outside the United States at 317-572-3993 or fax 317-572-4002. Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

For more information about Wiley products, visit our Web site at <http://www.wiley.com>.

*Library of Congress Cataloging-in-Publication Data:*

eISBN : 978-0-470-31406-7

1. Baking. I. Title.

TX763.F54 2008

641.7—dc22

2006103521

## PREFACE

Years ago, there was only one way to become a baker or pastry chef, and that was to apprentice with a master craftsman. The apprentice learned by doing, repeating the necessary skills, year after year, until the skills were mastered. If bakers and pastry chefs understood their ingredients or why they did what they did, it was only after years of experience. Mostly they knew what to do because they did what they had been shown, and it worked.

Today, bakers and pastry chefs have more challenges. They must master more skills. They must adapt to faster-changing trends. They must learn to use a wider array of ingredients from different cultures. They must learn to use still more ingredients devised in the chemist's lab. They must learn all this in a shorter length of time.

Baking and pastry programs in colleges and universities are laying the foundation to meet these new challenges. Part of this foundation includes applying the knowledge of science to the bakeshop. The purpose of *How Baking Works, Second Edition* is to help lay this foundation. Yet, I'm sure some might wonder if this knowledge is necessary, even helpful. After all, isn't it enough to learn the skills of the bakeshop?

After years of working with experienced bakers and pastry chefs and after years of training students, I am convinced that, today, skills are not enough. I have faith that the knowledge of the food scientist can help in facing the challenges in the bakeshop. Finally, I have conviction that this knowledge is useful for the beginner as well as the master.

The food scientist uncovers how different ingredients are processed, views ingredients as made of individual components, and views processes and procedures in the bakeshop in terms of interactions between these components. If ingredients can be viewed in this way, their behavior in the bakeshop begins to make more sense. How they will react under new conditions and new situations can better be predicted, and failures in the bakeshop can be averted. The goal of this book is to share the views of the food scientist with bakers and pastry chefs. Yet, I have tried to keep this book focused on the interests and needs of beginning and practicing bakers and pastry chefs. The only theories presented are those necessary to better understand that which will be immediately useful in the bakeshop.

Beyond the practical usefulness of science, there is a beauty to it, a beauty best appreciated when science is applied to the everyday world. I hope that this book allows those who might not yet see this beauty to at least see the possibility of it.



## A NOTE ABOUT TEMPERATURE AND WEIGHT CONVERSIONS

Numbers can sound deceptively precise. For instance, the temperature at which yeast cells die is often cited as 140°F (60°C). But was the heat moist or dry? Was the temperature brought up quickly or slowly? What strain of yeast was used, and how much acid, salt, and sugar were present?

The actual temperature at which yeast cells die depends on these and other factors, and that temperature is not necessarily 140°F (60°C). For this reason, many temperatures provided in this text are converted from Fahrenheit to Celsius in ranges of five degrees. While this may appear inexact, it best reflects the reality of the situation.

Other times, however, temperatures are meant to be precise. For example, it matters when proofing yeast dough whether the temperature is 81°F (27°C) or 85°F (29°C). In this case, temperatures are converted from Fahrenheit to Celsius to the nearest whole degree.

Likewise, weight and volume conversions are not necessarily given to the precise gram or milliliter. In most cases, U.S./imperial units are provided in increments of .25 ounce, while metric units are converted in increments of 5 grams or 5 milliliters. This reflects the reality of the bakeshop, where most equipment reads down to these increments.



## CHANGES TO THE SECOND EDITION

While the core format and theme of the text remains the same, several important changes have been made to the *Second Edition* of *How Baking Works*. Material was added to reflect the increasing use of newer ingredients. In particular, stevia, agave syrup, and other sweeteners were added. Along with this, information was added on the source and processing of sweeteners, to increase the depth of understanding of how they differ as well as how they are similar to each other. This is reflected in an expansion of Chapter 8.

At the same time that newer ingredients have been developed, there has been an increased interest in more traditional ingredients, such as stone-ground flours and ancient grains. Chapters 5 and 6 have added information to reflect these interests. The text also reflects new changes to federal law and growing consumer awareness of nutrition and health. This includes information on the labeling of food allergens in the

United States, more information on dietary fiber, and additional and updated information on trans fats and trans-free fats in Chapter 10.

An amazing amount of research has been completed in the past few years on gluten structure, in particular, but also on other flour components and their interactions. This comes at a time when scientists are selectively breeding new varieties of wheat with specific properties to meet the changing needs of farmers, processors, and consumers across the globe. Based on this new knowledge, updated information on gluten structure and its interactions is provided in Chapter 7.

Various enzymes and reducing agents have always been important to large-scale commercial bakers, who typically add them as dough conditioners or improvers. However, they are also naturally present in flours and in other common ingredients used in bread baking. Since their special properties are exploited by artisan bakers as they adjust fermentation and mixing conditions, it seemed important to discuss them in more detail. Chapters 5 and 7 include increased coverage of enzymes and reducing agents. Finally, Chapter 9 reflects an improved discussion of starch structure and a more accurate representation of the process of starch gelatinization.

Questions at the end of each chapter have been divided into *Questions for Review* and *Questions for Discussion*. *Questions for Review* are straightforward; they reflect the material as it is presented in the text. *Questions for Discussion* are questions that in general require a higher level of thinking, that require integration of information from several areas of the chapter, or that apply information in a slightly different manner than is presented in the text.

The main change to the **Second Edition** is the development of exercises and experiments at the end of each chapter. These exercises and experiments are designed to reinforce material from the text in a way that shows rather than tells. Some of the exercises are exclusively paper exercises, with a few involving math. Many more involve the sensory evaluation of ingredients. There are several reasons for including these sensory exercises in the text. First is the narrow objective of learning to identify characterizing traits of ingredients, to better understand the effects that they will have on finished products. Second is the even narrower but very practical objective of learning to identify ingredients that may be unlabeled or accidentally mislabeled. Third is the broad objective of increasing awareness of all the tastes, textures, and sights in the bakeshop, no matter how small or mundane. There is much to be learned in a bakeshop, even when the same items are prepped and baked day after day. The first step to learning is learning to be aware.

An Instructor's Manual (ISBN 978-0470-04512-1) accompanies this book. It can be obtained by contacting your Wiley sales representative. An electronic version of the Instructor's Manual is available to qualified instructors on the companion Web site, at [www.wiley.com/college/figoni](http://www.wiley.com/college/figoni).



## ABOUT THE EXPERIMENTS

While the exercises at the end of each chapter are self-explanatory, the experiments do need some explanation. The experiments allow students to further develop basic bakeshop skills, but that is not the main objective of the experiments. Instead, the emphasis of the experiments is on comparing and evaluating products that vary in some systematic way. The real “products” of these experiments are students’ findings, which they summarize in the Results Tables provided at the end of each experiment. There are also specific questions at the end of each experiment, with space provided for students to summarize their conclusions.

The experiments are designed so that one or more can be conducted within a four-hour session by a class divided into five or more groups. Each group in the classroom completes one or more of the products in the experiment. When all products are made and cooled, students evaluate the products, either as a class or individually. Room-temperature water (bottled water, if tap water has a strong taste) should be provided, to cleanse the palate between tastings, and students should constantly return to the control product to make side-by-side comparisons of it with each test product. Whenever possible, two separate groups should prepare the control product for each experiment, in case one turns out unacceptable.

The key to well-conducted experiments is for the products to be prepared and baked under carefully-controlled conditions. This is emphasized by the detail provided in the formulas within each experiment. However, understand that the specific mixing and bake times could change, to adjust to the different equipment and conditions in your classroom bakeshop. What is more important than following the provided methods of preparation exactly as written is that each product made within an experiment by a class be completed exactly as all the others.

Above all else, however, common sense rules when completing experiments. There are times when rigid rules must be forsaken, and chefs and scientists must know when to “work with their ingredients.” What this means is that if it is necessary to make adjustments to products because of the nature of the ingredient, those adjustments should be made. An example of when adjustments must be made to products is in the experiment on preparing rolls with different flours, included in different forms in Chapters 5 and 6. If the same amount of water were used for each type of flour, the gluten in the flour would not be properly hydrated. These adjustments are not made lightly, however, and they must be recorded in a Results Table. Notice that a *Comments* column is included in each table, for this very purpose.

While any classroom bakeshop can be used, there are certain modifications that might need to be made to efficiently run the experiments. For instance, the bakeshop should be supplied with multiple versions of smaller-scale equipment and smallwares. As an example, multiple five-quart mixers, one per group, are needed in place of one large mixer. A list of equipment and smallwares for outfitting a bakeshop for these experiments follows.



## EQUIPMENT AND SMALLWARES

1. Baker's or electronic scales
2. Measuring cups and measuring spoons, assorted sizes
3. Sieves or strainers
4. Mixers with 5-quart bowls, three-speed Hobart N50, ten-speed Commercial Kitchenaid, or equivalent
5. Flat beaters, dough hooks, and wire whips for mixers
6. Bowl scrapers
7. Bench scrapers
8. Dough cutters, 2' or 2½' or equivalent
9. Oven thermometers
10. Parchment paper
11. Ovens (conventional, reel, deck, etc.)
12. Stovetop burners
13. Half sheet pans
14. Muffin tins and liners (2½ or 3½' size)
15. Half hotel pans
16. Silicone (Silpat) pads, to fit half sheet pans
17. Portion scoops, including #16 (2¾ oz.) and #30
18. Timers
19. Rulers
20. Proof box
21. Stainless steel bowls, especially 2- and 4-quart sizes
22. Mixing spoons, wooden and stainless
23. Spatulas, heat-resistant silicone
24. Stainless steel saucepans, heavy 1½ quart
25. Rolling pins
26. Knives, assorted serrated, paring, etc.
27. Plastic wrap
28. Pastry bags
29. Pastry tubes, plain
30. Vegetable peelers
31. Cake pans, 9-inch round
32. Cutting boards
33. Plastic teaspoons for tasting
34. Cups for water
35. Tape and markers for labeling



## ACKNOWLEDGMENTS

I would like to thank the administration of the College of Culinary Arts at Johnson & Wales University (J&W), who first suggested that I write this text. Without their prodding and support, I would not have known that I could really do it.

The faculty in the International Baking and Pastry Institute at J&W deserve a special thanks. They let me into their bakeshops, answered my questions, presented me with practical problems, and made me feel like I was one of them. They demonstrated firsthand to the students through their own knowledge and understanding of science that science does indeed belong in the bakeshop. They have made my years at J&W immensely rewarding, challenging, and fun, and that has made all the difference to me.

In particular, I would like to thank my friend Chef Martha Crawford, whose presence is felt in the classrooms and halls at J&W, even as she has moved on. Chef Crawford taught me many things, including how to begin to think like a pastry chef. She has a knack for getting to the core of any problem and laying out a path to its solution. Whenever I strayed, she firmly and wisely placed me back on track. For this, and for much more, I am grateful.

I would also like to pay a debt of gratitude to Chef Joseph Amendola, who pioneered the education of bakers and pastry chefs in this country. Chef Amendola had the vision to see where education should head, and he placed us on that path.

I would like to thank the reviewers of the manuscript. Their helpful comments and suggestions strengthened the manuscript. They are Dr. Bill Atwell of Cargill, Inc.; Gloria M. Cabral of Bristol Community College; Kelli Dever of Boise State University; Kathryn Gordon of The Art Institute of New York City; Catherine M. Hallman of Walker State Community College; Monica J. Lanczak of Pennsylvania College of Technology; Simon Stevenson of Connecticut Culinary Institute; and Scott Weiss of Carteret Community College.

Finally, I would like to thank my family. My mother, who taught me how to bake, my father, who taught me to love food, and both my parents, as well as my sisters, who years ago encouraged me to continue even as they ate my first experiments in baking. They helped shape me, and in doing so, they helped to shape this book. Bob deserves a special thanks, because he was on the front line, tolerating my late nights at the computer and steadying my mood as it changed with each day. This book is yours as well as mine.

*Paula Figoni*

*Providence, Rhode Island*

# CHAPTER 1

## INTRODUCTION TO BAKING

### CHAPTER OBJECTIVES

1. Discuss the importance of accuracy in the bakeshop and how it is achieved.
2. Differentiate between volumetric and weight measurements and specify when each should be used.
3. Differentiate between metric and U.S. common units.
4. Introduce the concept of baker's percentages.
5. Discuss the importance of controlling ingredient temperatures.



## INTRODUCTION

Those who enter the fields of baking and pastry arts do so for a variety of reasons. For some, it is the joy of working with their hands, of creating edible works of art from a few basic ingredients. For others, it is the rush they get from the fast pace of the bakeshop, or from its satisfying sights and smells. Still others like the challenge of pleasing and surprising customers. No matter the reason, the decision to work in the field is usually grounded in a love of food, and maybe past experience in a bakeshop or a home kitchen.

Working in a professional bakeshop is different from baking at home, however. Production in a bakeshop is on a larger scale. It takes place day in and day out, sometimes under severe time pressures, in uncomfortably hot and humid conditions, and over long hours. Despite the discomforts and pressures, product quality must remain consistently high, because that is what the customer expects.

It takes specialized knowledge and practiced skills to accomplish these goals successfully. It helps to be attentive to the sights, sounds, and smells of the bakeshop. Experienced bakers and pastry chefs, for example, listen to the sound of cake batter being beaten in a bowl, knowing that changes in sound accompany changes to the batter itself. They push and pummel bread dough to feel how it responds. They use smells from the oven to judge when baking is nearly complete, and they sample their finished products before presenting them to the customer.

Experienced bakers and pastry chefs rely, too, on tools like timers and thermometers, because they know how time and temperature affect product quality. They also rely heavily on accurate scales.