

Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources*. AP42 is located on the EPA web site at [www.epa.gov/ttn/chief/ap42/](http://www.epa.gov/ttn/chief/ap42/)

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02\_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

**AP-42 Section Number:** 9.9.2

**Reference Number:** 3

**Title:** Manufacturing Technology Of Ready-to-Eat Cereals, Breakfast Cereals And How They are Made

Fast, R. B.

American Association of Cereal Chemists, Inc.

1990



# **Breakfast Cereals**

## **And How They Are Made**

Edited by  
Robert B. Fast and Elwood F. Caldwell

Published by the  
**American Association of Cereal Chemists, Inc.**  
St. Paul, Minnesota, USA

Cover photographs: Front, Malt-O-Meal Co., Northfield, MN  
Back, Rainbow Foods, Inc., Minneapolis, MN

Library of Congress Catalog Card Number: 89-082452  
International Standard Book Number: 0-913250-70-8

©1990 by the American Association of Cereal Chemists, Inc.

All rights reserved.

No part of this book may be reproduced in any form, including photocopy, microfilm, information storage and retrieval system, computer database or software, or by any means, including electronic or mechanical, without written permission from the publisher.

Printed in the United States of America

American Association of Cereal Chemists  
3340 Pilot Knob Road  
St. Paul, Minnesota, 55121 USA

Be  
Ro  
El  
My  
Ro  
Su  
Ho  
Le  
Th  
Ch  
Ge  
Ha  
Bri  
Ro  
Ed  
Ro  
Sc  
Fre  
Joh  
Do  
Wi

## Author-Contributors and Their Affiliations

**Benjamin Borenstein**, Hoffmann-LaRoche (*retired*), Teaneck, NJ  
07666

**Robert E. Burns**, Spray Dynamics Division, Par-Way Manufacturing  
Co., Costa Mesa, CA 92627

**Elwood F. Caldwell**, American Association of Cereal Chemists,  
St. Paul, MN 55121

**Myrland J. Dahl**, Malt-O-Meal Co., Northfield, MN 55057

**Robert B. Fast**, Robert B. Fast Associates, Inc., Poultney, VT 05764

**Susan J. Getgood**, Wolverine Corp., Merrimac, MA 01860

**Howard T. Gordon**, Hoffmann-LaRoche, Inc., Nutley, NJ 07110

**Leonard E. Johnson**, Hoffmann-LaRoche, Inc., Nutley, NJ 07110

**Theodore P. Labuza**, Dept. of Food Science and Nutrition, University  
of Minnesota, St. Paul, MN 55108

**Charles Lauhoff**, Lauhoff Corp., Detroit, MI 48207-4493

**George H. Lauhoff**, Lauhoff Corp., Detroit, MI 48207-4493

**Haines B. Lockhart**, The Quaker Oats Co. (*retired*), Crystal Lake,  
IL 60014

**Britton D. F. Miller**, Food Engineering Corp., Minneapolis, MN 55441

**Robert C. Miller**, Consulting Engineer, Auburn, NY 13021

**Edward J. Monahan**, General Mills, Inc. (*retired*), Golden Valley,  
MN 55422

**Robert O. Nesheim**, Advanced Health Care, Monterey, CA 93940

**Scott E. Seibert**, National Oats Co., Cedar Rapids, IA 52402

**Fred J. Shouldice**, Shouldice Bros., Inc., Battle Creek, MI 49015

**John E. Stauffer**, Stauffer Technology, Greenwich, CT 06830

**Donald D. Taylor**, Wolverine Corp., Merrimac, MA 01860

**William J. Thomson**, Spooner Inc., Williamsville, NY 14221

Northfield, MN  
nc., Minneapolis, MN

89-082452  
250-70-8

al Chemists, Inc.

any form, including  
ind retrieval system,  
eans, including  
ermission from the

background in the field and  
sons—product development  
alespersons, nutritionists,  
and others—by providing  
applied to the development,  
reals.

narily to the ready-to-eat  
l market around the world,  
gins by introducing readers  
gives an overview of the  
attractive edible products.  
al details, covered in five  
g. Formulation is discussed  
book. In order to keep it  
any detail with the myriad  
edients that we might have,  
uthors who might wish to

and packaging information  
n conclude with one chapter  
rtification and preservation  
rance in cereal plants. Two  
one listing some of the  
al processing and packaging  
nal references beyond those

our cooperating author-  
viewed sections and chapters  
ere themselves contributors  
we thank Jeff Culbertson,  
d Labuza, Leon Levine, Bob  
Seibert, Frank Wilgen, Bill  
sed parts of the manuscript  
ry, secretary, for her patient  
embers of the AACC editorial  
echnical assistance.

Robert B. Fast  
Elwood F. Caldwell

## Contents

### CHAPTER ONE

#### **1 The Cereal Grains**

*Elwood F. Caldwell and Robert B. Fast*

Corn • Wheat • Oats, Rice, and Barley Compared with Corn and Wheat •  
Oats • Rice • Barley • Other Cereal Grains • Other Traditional Ingredients  
of Breakfast Cereals

### CHAPTER TWO

#### **15 Manufacturing Technology of Ready-to-Eat Cereals**

*Robert B. Fast*

Flaked Cereals • Gun-Puffed Whole Grains • Extruded Gun-Puffed Cereals •  
Shredded Whole Grains • Extruded and Other Shredded Cereals • Oven-  
Puffed Cereals • Granola Cereals • Extruded Expanded Cereals

### CHAPTER THREE

#### **43 Unit Operations and Equipment. I. Blending and Cooking**

*Elwood F. Caldwell, Robert B. Fast, Charles Lauhoff, and Robert C. Miller*

Blending • Cooking • Lump Breaking and Sizing

### CHAPTER FOUR

#### **87 Unit Operations and Equipment. II. Drying and Dryers**

*Britton D. F. Miller*

Basic Principles of Drying • Selecting a Dryer

### CHAPTER FIVE

#### **109 Unit Operations and Equipment. III. Tempering, Flaking, and Toasting**

*Elwood F. Caldwell, Robert B. Fast, Susan J. Getgood, George H. Lauhoff,  
Fred J. Shouldice, Donald D. Taylor, and William J. Thomson*

Tempering • Flaking and Flaking Mills • Toasting and Toasting Ovens

	CHAPTER SIX	
<b>135</b>	<b>Unit Operations and Equipment. IV. Extrusion and Extruders</b>	<b>301</b>
	<i>Robert C. Miller</i>	
	Extruder Components • Principles of Die Flow • Principles of Screw Flow • Extrusion-Forming of Cereal Products • Direct Expansion of Cereal Products by Extrusion	
	CHAPTER SEVEN	
<b>195</b>	<b>Application of Nutritional and Flavoring/ Sweetening Coatings</b>	<b>319</b>
	<i>Robert E. Burns and Robert B. Fast</i>	
	The Process • Phase I • Phase II • Dry Flavor Bit Application • Formulation • Conclusion	
	CHAPTER EIGHT	
<b>221</b>	<b>Package Materials and Packaging of Ready-to- Eat Breakfast Cereals</b>	<b>349</b>
	<i>Edward J. Monahan and Elwood F. Caldwell</i>	
	Multiple Functions of Packaging • Package Components • Packaging Equipment • The Cereal Packaging Line • Advances in Cereal Packaging	<b>355</b>
	CHAPTER NINE	
<b>243</b>	<b>Hot Cereals</b>	<b>363</b>
	<i>Elwood F. Caldwell, Myrland Dahl, Robert B. Fast, and Scott E. Seibert</i>	
	Size of Markets and Trends • Rolled Oats and Related Products • Packaging of Hot Cereals • Farina-Based Cereals • Other Hot Cereals from Wheat, Rice, and Corn	
	CHAPTER TEN	
<b>273</b>	<b>Fortification and Preservation of Cereals</b>	
	<i>Benjamin Borenstein, Elwood F. Caldwell, Howard T. Gordon, Leonard Johnson, and Theodore P. Labuza</i>	
	Fortification • Preservation	

ent. IV.

• Principles of Screw Flow •  
Expansion of Cereal Products

d Flavoring/

3it Application • Formulation •

aging of Ready-to-

omponents • Packaging  
ances in Cereal Packaging

Fast, and Scott E. Seibert  
Related Products • Packaging  
Hot Cereals from Wheat, Rice,

on of Cereals

Howard T. Gordon,

CHAPTER ELEVEN

301 **Cereal Nutrition**

*Robert O. Nesheim and Haines B. Lockhart*

Breakfast Cereals as a Source of Protein • Breakfast Cereals as a Source of  
Fats and Fatty Acids • Breakfast Cereals as a Source of Carbohydrate •  
Breakfast Cereals as a Source of Vitamins and Minerals • Conclusion

CHAPTER TWELVE

319 **Quality Assurance in Breakfast Cereal Plants**

*John E. Stauffer and Elwood F. Caldwell*

Quality Assurance Versus Quality Control • Key Elements of Quality  
Assurance • Hazard Analysis and Critical Control Points • Statistical  
Quality Control • Good Manufacturing Practice • Distribution • Consumer  
Affairs • Product Recall

APPENDIX A

349 **Partial List of Manufacturers of Equipment for  
Processing and Packaging of Breakfast Cereals**

APPENDIX B

355 **Additional References**

363 **Index**