

Fifth Edition

BAILEY'S INDUSTRIAL OIL & FAT PRODUCTS



Volume 3

Edible Oil &
Fat Products:
Products and
Application
Technology

Edited by

Y.H. Hui

BAILEY'S INDUSTRIAL OIL AND FAT PRODUCTS

Fifth Edition

Volume 3

*Edible Oil and Fat Products:
Products and Application Technology*

Edited by

Y. H. HUI

Technology and Commerce, International



A Wiley-Interscience Publication

JOHN WILEY & SONS, INC.

New York • Chichester • Brisbane • Toronto • Singapore

Cover drawing courtesy of De Smet Process & Technology, Inc. The De Smet Multistock deodorizer incorporates a commercially proven single-vessel design to deodorize different feedstocks at capacities of over 720 TPD.

This text is printed on acid-free paper.

Copyright © 1996 by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012.

Library of Congress Cataloging in Publication Data

Bailey, Alton Edward, 1907–1953.

[Industrial oil and fat products]

Bailey's industrial oil and fat products. —5th ed./edited by

Y. H. Hui.

p. cm.

ISBN 0-471-59427-X (alk. paper)

1. Oils and fats. I. Hui, Y. H. (Yiu H.) II. Title.

TP670.B28 1996

665—dc20

95-9528

Printed in the United States of America

10 9 8 7 6 5 4 3 2

*Bailey's Industrial
Oil and Fat Products*

EDITORIAL ADVISORY BOARD

Company or Association

Archer Daniels Midland Company
Decatur, Illinois

Bunge Foods Corporation
Bradley, Illinois

Cargill, Inc.
Minneapolis, Minnesota

Central Soya Company
Fort Wayne, Indiana

General Foods
White Plains, New York

Kraft
Glenview, Illinois
Land O'Lakes, Inc.
Minneapolis, Minnesota

Lockwood Greene Engineers, Inc.
Spartanburg, South Carolina

National Renderers Association
Alexandria, Virginia

POS Pilot Plant Corporation
Saskatchewan, Canada

Wurster & Sanger, Inc.
Minneapolis, Minnesota

Individual

Dr. Chi Tang Ho
Department of Food Science
Cook College
Rutgers University
New Brunswick, New Jersey

Represented by

Dr. Thomas H. Smouse
Manager, Oil Processing Research

Mr. Tom Crosby
Director, Research and
Development

Mr. Stephan C. Anderson
Vice President, Oil Seeds
Processing

Dr. Bernard F. Szuhaj
Director, Research and
Development

Dr. Charles J. Cante
Vice President, Research and
Development, Engineering, Test
Kitchens

Dr. Ronald D. Harris
Vice President

Dr. David Hettinga
Vice President, Research
Technology Engineering

Mr. Bob Hart
Director of Design

Dr. Don A. Franco
Director, Technical Services

Mr. R.A. Carr
President

Mr. Barry Smith
General Manager

Contributors

MICHAEL M. BLUMENTHAL: Libra Technologies, Inc., Metuchen, New Jersey, Frying technology.

MICHAEL M. CHRYSAM: Nabisco Foods, Inc., East Hanover, New Jersey, Margarines and spreads.

BOB GEBHARDT: Kraft Food Ingredients, Memphis, Tennessee, Oils and fats in snack foods.

DAVID HETTINGA: Land O'Lakes, Inc., Minneapolis, Minnesota, Butter.

R.G. KRISHNAMURTHY: Kraft Foods, Inc., Glenview, Illinois, Cooking oils, salad oils, and oil-based dressings.

EDMUND W. LUSAS: Texas A&M University, College Station, Fats in feedstuffs and pet foods.

DOUGLAS J. METZROTH: Cherry-Burrell Process Equipment, Louisville, Kentucky, Shortening: Science and technology.

RICHARD D. O'BRIEN: Consultant, Plano, Texas, Shortening: types of formulations.

GEORGE M. PIGOTT: University of Washington, Seattle, Marine oils.

DANIEL E. PRATT: Purdue University, West Lafayette, Indiana, Antioxidants: technical and regulatory considerations.

MIAN N. RIAZ: Texas A&M University, College Station, Fats in feedstuffs and pet foods.

CLYDE E. STAUFFER: Consultant, Cincinnati, Ohio, Oils and fats in bakery products; Emulsifiers for the food industry.

ROBERT E. WAINWRIGHT: ABITEC Corporation, Columbus, Ohio, Oils and fats in confections.

VERNON C. WITTE: Kraft Foods, Inc., Glenview, Illinois, Cooking oils, salad oils, and oil-based dressings.

Reviewers

To assure accuracy of the information, each Chapter in this five-volume text has been reviewed by experts in industry, government, and academia. Although most Chapters have one or two reviewers, some have as many as five or six. A list of the reviewers is presented. However, in studying this list, please note:

1. The authors of the Chapters have also served as reviewers for Chapters other than their own. They are not included in this list.
2. This list is incomplete for a variety of reasons. The review was spread over three years and some names are misplaced, some reviewers wish to remain anonymous, and so on. A note of appreciation and/or apology is extended to those reviewers not included in the list.

INDIVIDUALS

VERLIN ALLBRITTON: Pure Flo Product Group, Chicago, Illinois

ROBERT ALLEN: Consultant, Scroggins, Texas

DAVID J. ANNEKEN: Henkel Corporation/Emery Group, Cincinnati, Ohio

RAHAMAN ANSARI: Quest International Fragrances, Mount Olins, New Jersey

RALPH ASTARITA: Consultant, Chester, New York

ANTHONY ATHANASSIADIS: Consultant, Belgium

IMRE BALAZS: Central Soya Company, Fort Wayne, Indiana

THOMAS J. BARTUS: Van Leer Chocolate Corporation, Jersey City, New Jersey

CHRISTOPHER BEHARRY: Procter & Gamble, Cincinnati, Ohio

ELLIOT BERLIN: U.S. Department of Agriculture, Beltsville, Maryland

KAREN BETT: U.S. Department of Agriculture, New Orleans, Louisiana

BRUCE H. BOOTH: Zapata Protein USA, Reedville, Virginia

CHARLES BRAH: Patrick Cudahy Company, Cudahy, Wisconsin

- THOMAS L. CAIN: Van Der Bergh Foods, Joliet, Illinois —
GEORGE CAVANAGH: Consultant, Fresno, California
MAROLYN R. CHAMBERS: Riceland Foods Inc., Little Rock, Arkansas
CHUCK CHITTICK: Geka Thermal Systems Inc., Atlanta, Georgia
WILLIAM E. COCHRAN: Liberty Vegetable Oil Company, Santa Fe Spring, California
RICHARD COPELAND: Central Soya Company, Fort Wayne, Indiana
IAN COTTRELL: Rhône-Poulenc Food Ingredients, Cranbury, New Jersey
C. DAYTON: Central Soya Company, Fort Wayne, Indiana
ETIENNE DEFFENSE: Tirtiaux, Belgium
ROBERT DELASHUNT: Consultant, Pickwick Dam, Tennessee
GIORGIO DELL'ACQUA: Fratelli Gianazza, Italy
JOSEPH F. DEMPSEY: Karlshamns USA Inc., Harrison, New Jersey
ALBERT J. DIJKSTRA: n.v. Vandemoortele, Belgium
MARK DREHER: Nabisco Foods, Parsippany, New Jersey
WALTER FARR: Owensboro Grain Company, Owensboro, Kentucky
FIELDEN FRALEY: Pure Flo Product Group, Chicago, Illinois
HERBERT GEHRING: Koerting Hannover AG, Germany
JAMES GEYER: Wisconsin Dairies, Baraboo, Wisconsin
LEWRENE GLASER: U.S. Department of Agriculture, Washington, D.C.
PAUL HALBERSTADT: Swift Eckrich Inc., Downers Grove, Illinois
GEORGE W. HALEK: Rutgers University, New Brunswick, New Jersey
EARL G. HAMMOND: Iowa State University, Ames, Iowa
ANTHONY J. HARPER: De Smet Process & Technology, Belgium
RICHARD HEINZE: Griffith Laboratories, Alsip, Illinois
VIRGINIA H. HOLSINGER: U.S. Department of Agriculture, Philadelphia, Pennsylvania
ARTHUR HOUSE: Lou Ana Foods, Opelousas, Louisiana
TOM HURLEY: Lou Ana Foods, Opelousas, Louisiana
LEWIS G. JACOBS: Distillation Product Industry, Rochester, New York
LAWRENCE JOHNSON: Iowa State University, Ames, Iowa
DONALD V. KINSMAN: Henkel Corporation/Emery Group, Cincinnati, Ohio
LINDA KITSON: Archer Daniels Midland Company, Decatur, Illinois
D. LAMPERT: Cargill Inc., Minneapolis, Minnesota
DAVID LAWRENCE: Safeway, Deninson, Texas
ZALMAN LEIBOVITZ: H.L.S., Israel
STACEY LEVINE: Bunge Foods, Bradley, Illinois
MARY LOCNISKAR: University of Texas, Austin, Texas
ROBERT LOEWE: Keebler Inc., Elmhurst, Illinois
EARNIE LOUIS: Perdue Farms Inc., Salisbury, Maryland

TED MAG: Consultant, Canada
 EUGENE MATERN: Ed Miniati Inc., Chicago, Illinois
 WILLIAM MCPHERSON: EMI Corporation, Des Plaines, Illinois
 KEN MCVAY: Henkel-Emery Group, Cincinnati, Ohio
 JEANNE COCHRANE MILEWSKI: RTM Winners, Atlanta, Georgia
 RON MOELLER: Cargill Inc., Minneapolis, Minnesota
 DON MORTON: Premier Edible Oils Corporation, Portland, Oregon
 JERRY MURPHY: Rangen Inc., Buhl, Idaho
 BRIAN F. OSBORNE: Hutrel Engineering, Vancouver Canada
 BOB PIERCE: Fats and Oils Consultant, Tucson, Arizona
 ANTHONY SACCONI: Karlshamns, USA, Harrison, New Jersey
 FOUAD Z. SALEEB: General Foods, White Plains, New York
 TIMOTHY SAUNDERS: North Carolina State University, Raleigh, North Carolina
 MARY SCHMIDT: Sandoz Nutrition, Minneapolis, Minnesota
 RICHARD W. SCHOENFELD: SVO Enterprises, Eastlake, Ohio
 JAMES SCHWARTZ: Procter & Gamble, Cincinnati, Ohio
 JACQUES SEGERS: OPAU (Unilever), Holland
 PETER SJOBERG: Deodorization, Tetra-Laval, Sweden
 MARTIN SILGE: Mariani Packing Inc., San Jose, California
 PETER SLEGGS: Campro Agra Ltd., Canada
 BARRY SMITH: Crown Iron Works, Minneapolis, Minnesota
 FRANK E. SULLIVAN: Consultant, San Diego, California
 BEVERLY TEPPER: Rutgers University, New Brunswick, New Jersey
 DAVID TRECKER: Pfizer Food Science Group, Groton, Connecticut
 STEPHEN W. TURNER: Henkel Corporation, Cincinnati, Ohio
 PHILLIPPE VAN DOOSSELEARE: De Smet Process & Technology, Belgium
 PETER WAN: U.S. Department of Agriculture, New Orleans, Louisiana
 KLAUS WEBER: Krupp Machinentechnik, Germany
 ANTHONY E. WINSTON: Church & Dwight Company, Inc., Princeton, New Jersey
 VERNON C. WITTE: Kraft General Foods, Glenview, Illinois
 JOHN S. WYATT: Grindsted Products Inc., Industrial Airport, Kansas
 JIM YEATES: Ag Processing Inc., Omaha, Nebraska

COMPANIES

De Smet Process & Technology, Belgium
 Hixson, Cincinnati, Ohio

A Tribute to Alton E. Bailey



ALTON E. BAILEY

Alton Edward Bailey was born in Midland, Texas, in 1907 and died 46 years later in Memphis, Tennessee. During his relatively short professional career, A.E. Bailey made an imprint on the science and technology of fats and oils unequalled by any other person either before or since. Of his accomplishments, it is agreed that the most important was the legacy of his book, *Bailey's Industrial Oil and Fat Products*, first published in 1945. It immediately became

the Bible of the fats and oils industry and continues to be so regarded, even today. While updated and expanded several times since his death in order to include more recent scientific findings and engineering developments, the 1945 first edition can still be perused with the reader hardly being aware that A.E. Bailey wrote the words 50 years previously.

In our present age, when having a Ph.D. from a prestigious university is almost mandatory in order to be taken seriously as a research investigator or authoritative author, it is interesting to note that “Ed” Bailey’s university education ended upon receiving a B.S. in Chemical Engineering from the University of New Mexico in 1927.

Following graduation, A.E. Bailey was employed in the laboratories of the Cudahy Packing Company, first in Omaha, Nebraska, and later in Memphis, Tennessee. He left Cudahy in 1941 to accept a position as head of the oil processing research section of the United States Department of Agriculture at their Southern Regional Research Laboratory in New Orleans. It was in the pilot plant there that Ed Bailey tested out and quantified many of his ideas. His published laboratory work relied heavily on the use of the then new tool of dilatometry to explain and understand the functional characteristics of fats.

Five years later, Alton Bailey resigned from the USDA to join the Votator Division of the Girdler Corporation in Louisville, Kentucky, as Chief Process Engineer of their Oil and Fat Section. In that position, he was instrumental in the development of the semicontinuous deodorizer which, in addition to producing products of very high quality, permitted rapid changeover from one product to another. In 1950, Mr. Bailey returned to Memphis as Vice President and Director of Research for The Humko Company, a position he occupied until his death.

Alton E. Bailey joined the American Oil Chemists’ Society in 1935 and subsequently made many contributions to the technical publications, education programs, and organization management of AOCS. He was elected to the Governing Board in 1949 and served the Society as its president in 1951–1952.

According to his contemporaries, Ed Bailey possessed an exceptional intellect, intense curiosity, and extremely high motivation. Those attributes were coupled with an almost photographic memory, along with significant ability to organize material and put it into writing in a straightforward and understandable manner.

When Fred Astaire died, Mikhail Baryshnikov commented, “Mr. Astaire was an *artiste*, the rest of us are dancers.” We, who are authors of individual Chapters of this fifth edition, feel the same relationship with Mr. Alton E. Bailey. We hope you will find our efforts worthy of being published in a book bearing his name.

ROBERT C. HASTERT

October 1995

BAILEY'S LEGACY IS DECADES OF FATS AND OILS RESEARCH

Following in the innovative footsteps of Alton E. Bailey, agricultural research scientists continue to have a significant impact on the fats and oils industry of today and tomorrow. Working in the scientific environment that cultured Bailey's creative genius, researchers at the regional research centers of the USDA's Agricultural Research Service (ARS) have contributed to decades of advancements in the processes and applications of fats and oils, both for food and industrial uses.

An extended program of research enabled scientists to help transform the soybean into the major source of high-protein feeds and food oil products of today. In the early 1940s the flavor of soybean oil was variously described by consumers as "grassy" or "beany" or "fishy," and it tasted even worse after it had been stored for awhile. In consultation with colleagues in the fats and oils industry, scientists decided that establishment of some uniformity of judgment about how various soybean oils tasted was an essential first step in the research. The technique of flavor evaluation, which they developed involving selected, trained taste panels and numerical rating of the flavors, was the first significant milestone in improving soybean oil.

Guided by judgments of taste panels, researchers identified the source of many of the off-flavors in soybean oil as trace metals, particularly iron and copper. Even extremely small amounts of these contaminants sped oxidation of the oil, shortening its storage life and promoting undesirable flavors. Responding to these findings, industry removed brass valves in refineries and substituted stainless steel for the cold, rolled steel in equipment that came in contact with soybean oil. These actions alone improved the flavor of the oil. It was further discovered that the addition of citric acid to the deodorized oil would deactivate the trace metals in soybean oil. Today, practically all soybean oil is protected by adding citric acid during processing.

But many questions remained unanswered. Metal contaminants could speed the development of off-flavors, but chemists wondered what caused the flavors to develop in the first place. One of the principal causes turned out to be linolenic acid, a fatty acid that makes up from 7 to 9% of soybean oil. Of all the major edible vegetable oils on the market only soybean and rapeseed oils contained linolenic acid at these levels. It is this constituent of soybean oil that was a major contributor to deterioration on the shelf or when the oil was heated repeatedly in deep fryers. The industry turned to the nickel-catalyzed, partial hydrogenation process to lower the linolenic acid content of soybean oil to about 3.0%. In the 1960s, it was this lightly hydrogenated product that enabled soybean oil to displace cottonseed oil as the major edible oil in the world.

At the same time, the discovery that linolenic acid was a major reason soybean oil went bad spurred plant breeders in research to find soybean and

rapeseed lines with lower linolenic acid content, research that continues to this day.

Today, while hydrogenation of soybean oil is still required for use as a high temperature cooking oil, in shortenings and margarines, and for long-term storage, evaluations by taste panels have made it clear that the industry's implementation of improved processing techniques and protection of the oil during processing produces an oil that is stable at ambient temperatures and has good shelf-life stability.

Other researchers modified cottonseed oil, giving it properties similar to that of cocoa butter. The confectionery fats derived from cottonseed and soybean oil are now being used for many applications in the industry. Further, the fatty acids from vegetable oils were combined with sucrose or table sugar to form sucrose esters, used today as emulsifiers, stabilizers, and texturizers in baked goods, baking mixes, biscuit mixes, frozen dairy desserts, and whipped milk products.

Over the years, ARS has devoted much of its resources to discovering new industrial uses for fats and oils. A new market for fats and oils was created by the discovery of a process called epoxidation, in which hydrogen peroxide was used to insert an atom of oxygen into the hydrocarbon chain of fatty acids. Epoxidized oils, when used as plasticizers, blend well with commonly used resins. They also eliminate the need for poisonous salts of lead, barium, or cadmium in vinyl plastics, which turn the plastics cloudy or opaque. Seventy-five percent of the 50,000 tons of epoxidized oils now used are based on soybean oil. The discovery also helped to create a billion-dollar plastics industry. Today, about 75% of the plasticizers for flexible vinyl plastics are made from soybean oil.

Modification of vegetable oil fatty acids has been a significant alternative to petrochemicals for chemical feedstocks. Oleic acid is converted to emulsifiers, cosmetic ingredients, and other specialty chemicals and is used in textile mills in lubricants and antistatic agents. Acetoglycerides, derived from fatty acids, can be formed into thin, stretchable films for a variety of uses in the food and cosmetics industries. Another development was a group of multipurpose chemicals called isopropenyl esters from fatty acids. These can be used to make paper and cotton repel water, to coat glass to reduce breakage in bottling lines, and in other applications where they have proven superiority to chemicals now in use.

A significant market for soybean oil was created in 1988 when scientists formulated a 100% soybean-oil-based printing ink that not only has a lower cost than petroleum-based inks, but also gives superior penetration of pigment into newsprint. These inks are adjustable to a wide range of viscosity and tackiness for news offset printing and have rub-off characteristics equal to those formulated and marketed as low-rub inks.

In 1959, the North Central Section, American Oil Chemists' Society, established the Alton E. Bailey award to annually recognize research and/or service

in the field of oils, fats, and related disciplines. The list of 35 scientist recipients from academia, industry, and government is testament to the lasting impact of Bailey's legacy of research in the fats and oils field.

TIMOTHY L. MOUNTS

October 1995

Preface

This fifth edition of *Bailey's Industrial Oil and Fat Products* differs from the fourth edition in many ways:

1. There are five volumes instead of three.
2. All five volumes are published at one time instead of over several years.
3. In the fourth edition, Chapters on edible and nonedible products were distributed over the three volumes. However, the fifth edition is clearly divided into the two groups: edible (Volumes 1–4) and nonedible (Volume 5).
4. Volume 1 serves as an introduction covering several subjects, some of which are basic to the discipline while others, because of their unique themes, cannot be placed in other volumes. As a result, Volume 1 covers such topics as chemistry, nutrition, toxicology, vegetable oil, animal fats, flavors, analysis, and sensory evaluations. Each of Volumes 2 to 4 covers one specific topic on edible oils or fats. Volume 2 covers individual oil seeds; Volume 3 discusses the application of oils and fats; and Volume 4 concentrates on the technology and engineering of processing vegetable oils.
5. Volume 5 covers the application of oils and fats in nonedible products including consumer goods such as soap, paints, leather, textiles, pharmaceuticals, and cosmetics. Other topics include rendering, fatty acids, and glycerine.

As observed, this new edition does not exactly update the fourth edition. Rather, it is more comprehensive and covers more applied information. Many professionals have expressed to me the following:

1. Much of the information in the older editions will always be useful.
2. Each new edition does not always update information in the last edition.

3. Each new edition always covers more information than the last edition.
4. Each new edition provides more applied information than the last edition.

Volume 3 contains the following information: Six Chapters on commercial products (butter, margarine, shortening, edible oils, and marine oils), each of which concentrates on chemistry, biology, and production technology and engineering. Four Chapters concentrate, respectively, on the application of fats and oils in pet foods, bakery products, confections, and snack foods; each provides insight into the role of fats and oils in product manufacturing and applications. Two Chapters focus on important processing chemicals (emulsifiers and antioxidants) for the fats and oils industry. One Chapter is devoted entirely to the latest research, development, and applications in frying oil technology.

In any book with multiple authors, the editor faces the same difficulties: length, content, format, delay, and updates. In spite of the difficulties encountered in an undertaking of this magnitude, I feel that through the excellent work of the authors I have achieved the major goal of this edition. This five-volume text will provide professionals in the oil and fat industry an excellent reference source on the subject matter with a special emphasis on edible products. Most of the authors are from industry, with a limited number from academia and government. They have worked hard to make this edition a success and I will forever be grateful for their participation. But, of course, you are the final judge of the usefulness of this work.

Y. H. HUI

Acknowledgment

Most of us are aware that to prepare and publish a professional book of this magnitude is invariably the result of teamwork.

To overcome the technical difficulties, I have been advised by two groups of experts: members of the editorial advisory board and my professional colleagues. It is not an exaggeration to state that this work could not have been completed without their counsel during the last four years. Additionally, through the years of professional consultation for this project, several individuals have actually become my indispensable advisors. They have helped me above and beyond the normal call of professional courtesy. They are well-known individuals in the oils and fats industry. As a matter of fact, two of them were past presidents of the American Oil Chemists' Society. I will always be grateful to Ken Carlson, Bob Hastert, Tom Smouse, and Peter Wan; I value their friendship.

Every time we read a book we evaluate two things in our minds: the information and the quality of the book. I have worked with the production staff at Wiley in 1978, 1986, 1987, and 1991. They have consistently produced books of excellent quality. This one is no exception.

Let me express my most sincere appreciation to everyone who has participated in the completion of this work. And, lastly, I am grateful to the support of my family.