

This edition first published 2017 © 2017 John Wiley & Sons Ltd

All rights reserved. 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 or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of C. Anandharamakrishnan to be identified as the author of the editorial material in this work has been asserted in accordance with law.

*Registered Offices*

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

*Editorial Office*

9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at [www.wiley.com](http://www.wiley.com).

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

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

Names: Anandharamakrishnan, C., editor.

Title: Handbook of drying for dairy products / edited by

Dr. C. Anandharamakrishnan.

Description: Chichester, UK ; Hoboken, NJ : John Wiley & Sons, 2017. |

Includes bibliographical references and index.

Identifiers: LCCN 2016047616 | ISBN 9781118930496 (cloth) | ISBN 9781118930502 (epub)

Subjects: LCSH: Dairy products—Drying.

Classification: LCC SF250.5 .H36 2017 | DDC 637—dc23 LC record available at <https://lcn.loc.gov/2016047616>

Cover image: Atropat/Gettyimages

Cover design: Wiley

Set in 10/12pt Warnock by SPi Global, Chennai, India

[8.1 Introduction](#)

[8.2 Experimental design tools for process optimization](#)

[8.3 Drying process variables and their influence on process and product quality](#)

[8.4 Conclusion](#)

[References](#)

[Chapter 9: Computational Fluid Dynamics Modelling of the Dairy Drying Processes](#)

[9.1 Introduction](#)

[9.2 Spray drying](#)

[9.3 Freeze drying](#)

[9.4 Spray freeze drying](#)

[9.5 Conclusions and future scope](#)

[References](#)

[Chapter 10: Physicochemical and Sensory Properties of Dried Dairy Products](#)

[10.1 Introduction](#)

9

## Computational Fluid Dynamics Modelling of the Dairy Drying Processes

*J. Gimbut<sup>1</sup>, W.P. Law<sup>1</sup> and C. Anandharamkrishnan<sup>2</sup>*

<sup>1</sup>Centre of Excellence for Advanced Research in Fluid Flow, *Universiti Malaysia Pahang* 26300, Gambang, *Pahang, Malaysia*

<sup>2</sup>Indian Institute of Crop Processing Technology, Ministry of Food Processing Industries, Government of India, Thanjavur 613 005, Tamil Nadu

### 9.1 Introduction

Computer simulations of the drying of dairy products are now widely used in food engineering research. They enable the underlying mechanism and performance of the drying process to be predicted, which is useful for design retrofits to improve performance or to optimize the operation of existing equipment. Mathematical equations describing momentum, heat and mass transfer coupled with equilibrium and kinetic equations, which usually form a model for a drying operation, are often solved together. In this