

The understanding of industrial processes is based primarily on two factors: (i) each process can be studied in a series of steps, called operations, and (ii) the individual operations have their own mechanisms based on physical and chemical principles. The systematic study of each unit operation leads to a simplified and unified treatment of all processes. The variety and complexity of modern industrial processes represent an exciting challenge for professionals working in the process industry as well as for professionals working in the academic world. This book addresses extensively some of these unit operations, emphasizing also the importance and relevance of those newer operations that have been emerging and are becoming more relevant from the industrial point of view. In order to meet these challenges, this book is organized into two parts: the conventional thermal processes and emerging technologies, that bring together individual chapters dedicated to each major unit operation.



Raquel P. F. Guiné

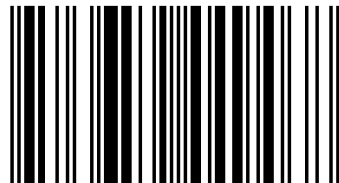
Unit Operations For The Food Industry

Volume I: Thermal Processing & Nonconventional Technologies



Raquel P. F. Guiné

Raquel P. F. Guiné, Lic. Chemical Eng., Msc. Eng. Science - Industrial Eng., PhD Chemical Eng. - Unit Operations and Transfer Phenomena, all at Coimbra University. Coordinator Prof., Food Eng. Department, Polytechnic Institute of Viseu, Portugal. Member Direction Board CI&DETS Research Centre. President Scientific Board Agrarian School of Viseu.



978-3-659-44946-8

Raquel P. F. Guiné

Unit Operations For The Food Industry

Raquel P. F. Guiné

Unit Operations For The Food Industry

**Volume I: Thermal Processing & Nonconventional
Technologies**

LAP LAMBERT Academic Publishing

Impressum / Imprint

Bibliografische Information der Deutschen Nationalbibliothek: Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.d-nb.de> abrufbar.

Alle in diesem Buch genannten Marken und Produktnamen unterliegen warenzeichen-, marken- oder patentrechtlichem Schutz bzw. sind Warenzeichen oder eingetragene Warenzeichen der jeweiligen Inhaber. Die Wiedergabe von Marken, Produktnamen, Gebrauchsnamen, Handelsnamen, Warenbezeichnungen u.s.w. in diesem Werk berechtigt auch ohne besondere Kennzeichnung nicht zu der Annahme, dass solche Namen im Sinne der Warenzeichen- und Markenschutzgesetzgebung als frei zu betrachten wären und daher von jedermann benutzt werden dürften.

Bibliographic information published by the Deutsche Nationalbibliothek: The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Any brand names and product names mentioned in this book are subject to trademark, brand or patent protection and are trademarks or registered trademarks of their respective holders. The use of brand names, product names, common names, trade names, product descriptions etc. even without a particular marking in this works is in no way to be construed to mean that such names may be regarded as unrestricted in respect of trademark and brand protection legislation and could thus be used by anyone.

Coverbild / Cover image: www.ingimage.com

Verlag / Publisher:

LAP LAMBERT Academic Publishing

ist ein Imprint der / is a trademark of

OmniScriptum GmbH & Co. KG

Heinrich-Böcking-Str. 6-8, 66121 Saarbrücken, Deutschland / Germany

Email: info@lap-publishing.com

Herstellung: siehe letzte Seite /

Printed at: see last page

ISBN: 978-3-659-44946-8

Copyright © 2013 OmniScriptum GmbH & Co. KG

Alle Rechte vorbehalten. / All rights reserved. Saarbrücken 2013

**UNIT OPERATIONS
FOR THE FOOD INDUSTRY**

Volume I

**Thermal Processing
&
Nonconventional Technologies**

Raquel de Pinho Ferreira Guiné

2013

ACKNOWLEDGMENT

Thanks to Professor Maria João Barroca Dias for the technical and scientific revision of the present work

TABLE OF CONTENTS

<i>I – Thermal processing</i>	<i>I</i>
1 – Heat transfer principles	3
1.1 – Heat transfer by conduction.....	4
1.1.1 – Thermal conductivity.....	5
1.1.2 – Conduction through a layer of material	5
1.1.3 – Thermal conductances in series	6
1.1.4 – Thermal conductances in parallel	8
1.2 – Heat transfer in a surface.....	9
1.3 – Heat transfer in transient state	10
1.4 – Heat transfer by radiation	13
1.5 – Heat transfer by convection.....	16
1.5.1 – Natural convection.....	17
1.5.2 – Forced convection.....	19
1.6 – Overall heat transfer coefficients.....	22
1.7 – Heat transfer with condensing vapors.....	23
1.8 – Heat transfer with vaporizing liquids	24
2 – Heat exchangers	25
2.1 – Overall heat transfer coefficient	25
2.2 – Medium temperature difference	27
2.3 – Influence on the direction of movement on the efficiency	28
2.4 – Heat recovery.....	30
2.5 – Equipment	32
3 – The thermal processing of foods	35
3.1 – Water activity	36
3.2 – Effect of water activity on foods	39
3.3 – Thermal death time.....	42
3.4 – Lethal equivalent power	43
4 – Blanching	47
4.1 – Objectives of blanching	48
4.2 – Blanching methods	48
4.3 – Effect of blanching on foods	50
5 – Pasteurization	53
5.1 – Theoretical considerations	55
5.2 – Pasteurization methods.....	55
5.3 – Effects on foods.....	57

- 6 – Heat sterilization 59**
 - 6.1 – Development of microorganisms in food..... 59
 - 6.2 – Sterilization in the package..... 60
 - 6.3 – Sterilization processes at ultra-high temperatures..... 73
 - 6.4 – Effect on foods..... 75
- 7 – Evaporation 81**
 - 7.1 – Heat transfer in evaporators 81
 - 7.2 – Vacuum evaporation 82
 - 7.3 – Condensers..... 82
 - 7.4 – Single effect evaporator 83
 - 7.5 – Multiple effect evaporation..... 84
 - 7.5.1 – Feeding of multiple effect evaporators 85
 - 7.5.2 – Advantages of multiple effect evaporators 86
 - 7.6 – Vapor recompression 88
 - 7.7 – Boiling point elevation..... 88
 - 7.8 – Evaporation of heat-sensitive substances..... 90
- 8 – Drying 91**
 - 8.1 – Physical stated of the water..... 92
 - 8.2 – Energy necessary to vaporization 93
 - 8.3 – Heat transfer in drying 94
 - 8.4 – Mass transfer in drying 96
 - 8.5 – Air drying..... 96
 - 8.5.1 – Ppsychometrics 96
 - 8.5.2 – Moisture content in equilibrium..... 100
 - 8.5.3 – Mechanism of water loss in the food 101
 - 8.5.4 – Drying rate 105
 - 8.6 – Drying by conduction 108
 - 8.7 – Driers 108
 - 8.7.1 – Yield of the dryer 111
 - 8.8 – Effects on food..... 111
 - 8.9 – Rehydration..... 117
- 9 – Freezing..... 119**
 - 9.1 – Theoretical considerations 119
 - 9.2 – Freezing facilities 125
 - 9.3 – Defrosting facilities..... 127
 - 9.4 – Effect on foods..... 128
- 10 – Lyophilization..... 133**
 - 10.1 – Theoretical aspects..... 133
 - 10.2 – Facilities..... 137
 - 10.3 – Effects on food..... 138

11 – Extrusion	141
11.1 – Theoretical aspects	142
11.2 – Methods	143
11.3 – Applications.....	144
11.4 – Effect on foods	147
12 – Oven cooking.....	149
12.1 – Theoretical aspects	149
12.2 – Methods	150
12.3 – Effect on foods	150
13 – Frying.....	155
13.1 – Theoretical aspects	155
13.2 – Methods	156
13.3 – Effect on foods	157
<i>II – Nonconventional technologies.....</i>	161
14 – Introduction to emerging and unconventional technologies.....	163
15 – Forms of heating by radiant energy.....	165
16 – Microwave heating	167
16.1 – Theoretical considerations	167
16.2 – Facilities	168
16.3 – Advantages of microwave	169
16.4 – Applications.....	169
16.5 – Effects on microorganisms and enzymes.....	172
16.6 – Effects on food	173
17 – Infrared radiation.....	175
17.1 – Theoretical aspects	175
17.2 – Facilities	177
17.3 – Applications.....	178
17.4 – Effect on foods	178
18 – Radiofrequency heating	179
18.1 – Theoretical concepts	179
18.2 – Facilities	180
18.3 – Applications.....	181
19 – Ohmic heating	185
19.1 – Basic concepts	185
19.2 – Equipments	186
19.3 – Applications.....	188
19.4 – Effect on foods	190

20 – High pressure processing	193
20.1 – Introduction.....	193
20.2 – Preservation capacity	193
20.3 – Facilities.....	196
20.4 – Applications	198
20.5 – Effect on foods.....	199
21 – Pulsed electric fields.....	203
21.1 – Introduction.....	203
21.2 – Facilities.....	203
21.3 – Applications	206
22 – High intensity pulsed light.....	209
22.1 – Principles	209
22.2 – Facilities.....	210
22.3 – Effects on microorganisms	210
22.4 – Applications	211
22.5 – Effects on food.....	211
23 – Ultrasounds.....	213
23.1 – Introduction.....	213
23.2 – Facilities.....	214
23.3 – Preservation capacity	215
23.4 – Ultrasound processing.....	215
23.5 – Effect on foods.....	217
24 – Irradiation	219
24.1 – Theoretical aspects.....	221
24.2 – Facilities.....	223
24.3 – Effect of irradiation on organisms	223
24.4 – Effect of irradiation on the packaging.....	225
24.5 – Effect of irradiation on food	226
<i>References</i>	229

