

SpringerBriefs in Food, Health, and Nutrition

Springer Briefs in Food, Health, and Nutrition present concise summaries of cutting edge research and practical applications across a wide range of topics related to the field of food science, including its impact and relationship to health and nutrition. Subjects include: Food Chemistry, including analytical methods; ingredient functionality; physic-chemical aspects; thermodynamics Food Microbiology, including food safety; fermentation; foodborne pathogens; detection methods Food Process Engineering, including unit operations; mass transfer; heating, chilling and freezing; thermal and non-thermal processing, new technologies Food Physics, including material science; rheology, chewing/mastication Food Policy And applications to: Sensory Science Packaging Food Quality Product Development We are especially interested in how these areas impact or are related to health and nutrition. Featuring compact volumes of 50 to 125 pages, the series covers a range of content from professional to academic. Typical topics might include:

- A timely report of state-of-the art analytical techniques
- A bridge between new research results, as published in journal articles, and a contextual literature review
- A snapshot of a hot or emerging topic
- An in-depth case study
- A presentation of core concepts that students must understand in order to make independent contributions

More information about this series at <http://www.springer.com/series/10203>

Anthony Keith Thompson • Suriyan Supapvanich
Jiraporn Sirison

Banana Ripening

Science and Technology

 Springer

Anthony Keith Thompson
King Mongkut's Institute
of Technology Ladkrabang
Bangkok, Thailand

Suriyan Supapvanich
King Mongkut's Institute
of Technology Ladkrabang
Bangkok, Thailand

Jiraporn Sirison
King Mongkut's Institute
of Technology Ladkrabang
Bangkok, Thailand

ISSN 2197-571X ISSN 2197-5728 (electronic)
SpringerBriefs in Food, Health, and Nutrition
ISBN 978-3-030-27738-3 ISBN 978-3-030-27739-0 (eBook)
<https://doi.org/10.1007/978-3-030-27739-0>

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

There have been many textbooks published dealing exclusively with *Musa* (bananas and plantains) perhaps starting with the one written by my former boss and mentor Professor C.W. Wardlaw (*Banana Diseases: Including Plantains and Abaca* 24 editions published between 1961 and 1974) to several more excellent books. Also, several chapters in various books have also dealt with bananas.

The objective of this book was therefore to deal exclusively with how bananas are ripened. However, the technology used is based on, and has implications with, a whole range of factors. These include the cultivar, growing conditions and how and at what maturity the fruit are harvested and handled. Also, various postharvest treatments can be applied to fruit and how these impact with the ripening process can have effects on the fruit quality.

The ripening process and the changes that occur are therefore considered in detail. There is a well-established successful technology that has evolved and is applied, particularly in more developed temperate countries where bananas are imported, but this technology essentially applies to a single genotype. However, most bananas are marketed locally in the country where they are grown, and often, different technologies are used in the ripening process, which have technical, economic and health implication. All these factors are discussed, and interacting implications are considered. Also, there is often insufficient and even contradictory information on how different ripening methods affect fruit quality including carbohydrates, proteins, phenolic, vitamins, acidity and other phytochemicals as well as texture, colour and flavour.

Banana sea trade began a little more than 100 years ago, but it has helped create great economic empires and sustained the livelihoods of millions of people in producer countries as well as in importing countries. The international banana trade has been very fast in employing new advancements in refrigerated transport and ripening technologies, since they can reduce transport costs and losses and increase the distance they can be successfully transported.

Anthony Keith Thompson
Suriyan Supapvanich
Jiraporn Sirison

Abbreviations

1-MCP	1-methylcyclopropene
AA	ascorbic acid
ABA	abscisic acid
ACC	1-aminocyclopropane-1-carboxylic acid
ACC oxidase	an enzyme involved in biosynthesis of ethylene
ACC synthase	an enzyme involved in biosynthesis of ethylene
ACC synthesis	the reaction catalysed by ACC synthase
ACPd	activated carbon impregnated with palladium
ATP	adenosine triphosphate
AVG	aminoethoxyvinylglycine
CA	controlled atmosphere
CMC	carboxymethyl cellulose
DFE	dietary folate equivalent
DPPH	1,1-diphenyl-2-picrylhydrazyl
Ethrel	ethephon (2-chloroethylphosphonic acid)
GA	gibberellins
GA ₃	gibberellic acid
IAA	indole-3-acetic acid
IC	inclusion complex powder for slow ethylene release, ethylene-alpha-cyclodextrin
Imazalil	1-[allyloxy-2,4-dichlorophenethyl]imidazole, a fungicide
LDPE	low-density polyethylene film
LPE	lysophosphatidylethanolamine
MA	modified atmosphere
mRNA	messenger ribonucleic acid
PAL	phenylalanine ammonia-lyase
PE	polyethylene film
PG	polygalacturonase
PME	pectin methylesterase
POD	pyrogallol peroxidase
PPO	polyphenol oxidase

pVACs	provitamin A carotenoids
RAE	retinol activity equivalent
RH	relative humidity
RNA	ribonucleic acid
SAM	s-adenosyl-methionine
TA	total acidity; titratable acidity
TBZ	thiabendazole (2-thiazol-4-yl benzimidazole), a fungicide
ton	2240 pounds (lbs) = 1016 kg
tonne	1000 kg
TPC	total phenolic compounds
TFC	total flavonoid compounds
TSS	total soluble solids
ULO	ultralow oxygen

Contents

1	Introduction	1
	<i>Musa</i> Taxonomy	2
	<i>Musa</i> Breeding Programmes	4
	Genotypes in International Trade	5
	Some Common Genotypes	6
2	Preharvest Effects	13
	Fertilizers	13
	Organic Production	14
	Light and Day Length	14
	Disease	15
	Water Stress	18
	Damage	18
	Bunch Covers	19
	Harvest Maturity	20
3	Fruit Ripening	25
	Pre-Climacteric Phase	26
	Ripening Phase	28
	Internal Ethylene	28
	Effects of Ethylene Post Ripening Initiation	31
	Genetic Effects on Ripening	32
	Maturity of Fruit and Response to Ethylene	34
	Factors Affecting Fruit and Response to Ethylene	37
	Changes that Occur During Ripening	37
	Peel Colour	37
	Peel Spotting	40
	Peel Chemicals	40
	Finger Drop	41
	Weight Loss	41
	Moisture	43
	Texture	44

Flavour and Aroma	46
Minerals	47
Carbohydrates	48
Protein	49
Phenolics	49
Acidity	50
Ascorbic Acid	51
Carotenoids and Vitamin A	52
Folates	54
Other Phytochemicals	54
4 Postharvest Treatments to Control Ripening	57
Controlled Atmosphere Storage	57
CA on Pre-Climacteric Bananas	57
CA Effects After Ripening Initiation	58
Hypobaric Storage	59
Modified Atmosphere Packing	60
Ethylene Absorbents	62
Chemicals	64
Metal Ions	64
1-Methylcyclopropene	64
Salicylic Acid	67
Gibberellic Acid	67
Diazocyclopentadiene	68
Indole-3-Acetic Acid	68
Abscisic Acid	68
Lysophosphatidylethanolamine	69
Aminoethoxy-Vinylglycine	69
Nitrous Oxide	70
Maleic Acid	70
Coatings	71
Irradiation	72
Temperature	74
Humidity	76
5 Initiation of Ripening	79
Ethylene	80
Cylinders	82
Catalytic Generators	84
Ethrel	84
Encapsulation	87
Acetylene	88
Calcium Carbide	89
Sensory Analysis	91
Toxicity of Calcium Carbide	92
Propylene	93

Esters	93
Alcohol	93
Carbon Monoxide	94
Smoking	95
Kerosene	95
Incense	96
Heat	96
Damage and Stress	97
Fruit Generation	99
Leaves	100
6 Ripening Technology	101
Ripening Rooms	101
Modelling	105
Transport	106
Reducing Ripening Initiation in Transit	107
Ripening in Transit	108
7 Conclusions	111
References	113
Index	137

About the Authors



Jiraporn Sirison is Associate Dean and Assistant Professor in the Faculty of Agro-Industry, King Mongkut's Institute of Technology, Ladkrabang, Thailand. She studied at Maejo University and Mahidol University both in Thailand and Kyoto University in Japan. She is a Nutrition Chemist whose teaching and research are mainly in the area of the effects of processing on nutrients in food and the application of food colloids in food nutrition. She teaches nutrition to undergraduates and has published many research papers on these subjects. Also, she was brought up on her parents' banana farm in Thailand.



Suriyan Supapvanich is Assistant Professor in Postharvest Technology in the Faculty of Industrial Education and Technology, King Mongkut's Institute of Technology, Ladkrabang, Thailand. His field of specialization is postharvest biology and biochemistry of tropical fruit and vegetables. He studied at Kasetsart University and King Mongkut's University Thonburi, both in Thailand, and the University of Nottingham, UK, where he was awarded a PhD degree. He subsequently worked at the University of Natural Resources and Life Sciences in Austria and lectured in the Faculty Natural Resources and Agro-Industry at Kasetsart University. He has 19 years teaching experience in courses on postharvest technology of agricultural products and introduction of food science and technology to undergraduate students and advanced postharvest technology to MSc students. He has also published more than 40 papers in international journals and 2 book

chapters. He is currently coordinating postharvest research projects with KMITL Prince of Chumphon Campus, KMUTT, Thammasat University and Anhui Agricultural University in China.



Anthony Keith Thompson is Visiting Professor at King Mongkut's Institute of Technology Ladkrabang in Thailand and was formerly Professor of Plant Science, University of Asmara, Eritrea; Professor of Postharvest Technology and Head of Department, Cranfield University, UK; Team Leader on an EU project on restructuring the banana industry in the Windward Islands; Principal Scientific Officer, Tropical Products Institute, London; Postharvest Expert for the UN in Sudan, Yemen and Korea for the Food and Agriculture Organization, Ghana and Sri Lanka for the International Trade Centre and Gambia for the World Bank; Advisor to the British, Jamaican and Colombian Governments in postharvest technology of fruit and vegetables; Research Fellow in Crop Science, University of the West Indies, Trinidad; Demonstrator in Biometrics, University of Leeds; as well as Consultant for various commercial and government organizations in many countries throughout the world. He has published over 100 scientific papers and many scientific textbooks.