Monika Thakur
V. K. Modi *Editors*

Emerging Technologies in Food Science

Focus on the Developing World

Springer

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Foreword I

The book *Emerging Technologies in Food Science: Focus on the Developing World* encompassing emerging technologies and innovations in the food sector is mainly focused on developing nations. Food security is achieved when all people have access to enough, safe and nutritious food and are thereby able to maintain healthy and active lives. According to the FAO, more than 795 million people suffer from hunger worldwide due to inadequate food security in developing nations. With food insecurity as the major challenge, there have been certain emerging technologies in the food science and technology sector. This will completely change the outlook of the food sector in the developing world. The food industry is an increasingly competitive and dynamic arena, with consumers now more aware of what they eat and, more importantly, what they want to eat. In recent years, with the aim to improve, or replace, conventional processing technologies in order to deliver better quality and consumer need-based food products, several innovative technologies, also referred to as "emerging" or "novel" technologies, have been proposed, investigated, developed, and, in some cases, implemented.

The emerging food processing technologies have been advanced by the initiatives of food researchers and academicians during the last few decades. These technologies could significantly contribute to the production of safe and high-quality food products. Moreover, the production will have shorter processing time, reduced operational cost, and be environmentally sustainable compared to the conventional food processing technologies, which will eventually benefit the food industry. However, each emerging technology has its own limitation. Therefore, further research needs to be conducted in order to apply these technologies at a commercial level. With this background, many researchers have worked toward the development and optimization of several emerging food processing technologies.

The book has four different parts comprising twenty-five chapters, which represent the rich and many-faceted knowledge. I am confident that this book will become a primer for academicians, researchers, and professional developers, helping the reader to learn, teach, and practice the art of interpretive discussion.

The work done by the contributors and editors depicts that it needs a lot of research, innovative work, and an understanding of the past, present, and future scenarios on the subject matter. This book would prove to be a reference book for all those working in the area of Emerging Technologies in Food Science and would help them in changing the scenario in this regard in developing nations. Also, for

developed nations, it would give useful guidelines to build a bridge between the developing and developed nations to achieve mutual benefits. Also for the international and national agencies, governments, politicians and scientific organizations, and other opinion makers, the contents of the book would help them generate further thoughts to address the problems in this area. I greatly appreciate the hard work done by all the contributors and my deep compliments to the editors—Dr. Monika Thakur and Dr. V. K. Modi—for doing this most valuable work.

Ritnand Balved Education Foundation (RBEF), Ashok K. Chauhan
AKC Group of Companies
Amity University
Noida, Uttar Pradesh, India

Foreword II

The book *Emerging Technologies in Food Science—Focus on the Developing World* provides a comprehensive overview of food safety, nutritional security, innovative and emerging technologies in the food sector with respect to developing nations.

This book also reviews innovations in food science to tackle the challenges of food safety, nutritional security and sustainability in the modern era. The book has four parts: Overview of Food Industry, Food Safety, Nutritional Security and Sustainability, and Emerging Technologies and Innovations. The topics have been treated in depth in the 25 chapters from different areas of food science and technology, which balances perspectives and vision for innovations in the developing world globally.

This book will be a valuable reference source for young professionals, researchers, academicians, corporate leaders and policy makers to understand various innovations, developments and researches in the field of food science and technology. Besides, it will also benefit academia and industry together to foster new initiatives and explore latest innovations and concerns. I congratulate the editors and contributors for bringing this book.

Amity University
Noida, Uttar Pradesh, India

Balvinder Shukla

Foreword III

The book *Emerging Technologies in Food Science—Focus on the Developing World* describes the emerging food technologies used in food production and processing and it impact on our daily lives. It is a complete compendium offering the latest technological innovations and includes vital information in research and development for the food processing sector. It also covers topics such as food safety, nutritional security and sustainability. The issues addressed in this book have been selected to make the consumers aware of and to provide them an overall picture of the food industry in the developing world.

People are talking about Industry 4.0 as the "Industry of the Future" in which there has been communication between machines and systems. Various emerging technologies significantly contribute to the production of safe and higher quality food products with added advantages.

The book has four parts with 25 chapters contributed by authors all over India. It covers a broad selection of topics written by specialists in the field, and the volume will be of interest to food scientists and technologists, food process engineers, researchers, faculty and students, and many others in the food industry. I congratulate the editors for their vision and tremendous efforts.

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Amarinder Singh Bawa

Preface

Innovative food processing technologies have been widely investigated in the food processing sector in recent years. These technologies offer advantages for advancing the quality of conventional and traditional foods and for combating the growing challenges posed by globalization, increased competitive pressures and diverse consumer demands. However, there is a need to explore these novel technologies for further use by the food industry.

This book presents a comprehensive overview of innovations in food science to tackle the challenges of food safety, nutritional security and sustainability and pinpoints the trends in future research and developments. It has four parts: Overview of Food Industry, Food Safety, Nutritional Security and Sustainability, and Emerging Technologies and Innovations. The topics have been distributed into 25 chapters from different areas of food science and technology, which balances perspectives and vision for innovations in the developing world globally.

The first part "Overview of Food Industry" provides an overview, role of innovation in the food industry and application of nanotechnology with many opportunities and challenges in various food sectors.

The second part concerns the development of new vibrant technologies for achieving "Food Safety". A major goal for food scientists is to produce healthy and safe foods for consumers.

The third part is devoted to "Nutritional Security and Sustainability" of the food and agricultural sector. The aim is to provide enough food, with quality, to meet the nutritional needs of a growing population and to conserve natural resources for future generations. A sustainable food system supports food security, makes optimal use of natural and human resources and provides the consumer with nutritionally adequate, safe, healthy and affordable food for the present and future generations. Changes in both food consumption and food production are important to ensure more sustainable food systems and to achieve food and nutrition security.

The fourth part deals with "Emerging Technologies and Innovations" in the food sector. In recent years, with the aim to improve, or replace, conventional processing technologies in order to deliver better quality and consumer need-based food products, several innovative technologies, also referred to as "emerging" or "novel" technologies, have been proposed, investigated, developed and, in some cases, implemented.

The editors of the book express their gratitude to all the contributors for sharing their research work. We are also thankful to Springer Nature for giving us this opportunity. We hope that the content presented in this book will be useful for the reader involved in the field of food science and technology.

Noida, India — Monika Thakur
Noida, India — V. K. Modi

Acknowledgements

Emerging Technologies in Food science provides a comprehensive overview of innovations, safety, nutritional security, sustainability and emerging technologies in the food sector. We are extremely indebted to Respected Founder President, Dr. Ashok K Chauhan, for the blessings and constant encouragement. We have great pleasure to acknowledge the whole-hearted support received from Dr. Atul Chauhan, Chancellor, Amity University Uttar Pradesh, and President RBEF; without their encouraging words, this endeavour is impossible. We are thankful to Prof. Balvinder Shukla, Vice Chancellor, Amity University Uttar Pradesh, for her constant motivation and support at all stages of the development of the book.

We are thankful to Dr. A S Bawa and Prof. T N Lakhanpal for their kind support and timely guidance in the conceptualization of the work. Our sincere gratitude to Dr. W Selvamurthy and Dr. Nutan Kaushik for their valuable guidance and never-ending support. Our special thanks to Dr. Renu Khedkar and Dr. Karuna Singh, Amity Institute of Food Technology, for their constant support and motivation. We also thank all the faculty members and staff members of Amity Institute of Food Technology, Amity University Uttar Pradesh, Noida, for their full cooperation in this endeavour.

We are extremely indebted to all the authors who have contributed chapters and happily agreed to share their work on various aspects of food science and technology. Without their painstaking efforts, it would not have been possible for us to bring this volume. Our sincere thanks to Springer Nature for their full support and cooperation during the publication of this volume. We are also thankful to the production team at Springer for all their efforts in publishing the book.

Finally, our deep and sincere gratitude to our family for their continuous and unparalleled love, help, and support.

Monika Thakur
V. K. Modi

Abbreviations

%	Percent
&	and
/	per
°C	Degree Celsius
3D	Three dimensional
APC	Aerobic plate count
APFO	Meat Food Products Order (MFPO)
AR	Augmented reality
ATP	Adenosine triphosphate
BHA	Butylated hydroxyanisole
BHT	Butylated hydroxytoluene
BIS	Bureau of Indian Standards
BMR	Basic metabolic rate
CAGR	Compounded annual growth rate
cAMP	Cyclic adenosine monophosphate
cm	centimetre
conc.	concentrated
CPSC	Consumer Product Safety Commission
D W	Dry weight
DG	Degree of gelatinization
dil.	dilute
DNA	Deoxyribonucleic acid
e.g.	for example
Ed.	edition
ed.	editor
eds.	editors
EFSA	European Food and Safety Authority
EPA	Environmental Protection Agency
et al.	et alia; and others
etc.	et cetera
EVA	Ethylene vinyl acetate
EVOH	Ethylene vinyl alcohol
FAO	Food and Agriculture Organization
FBO's	Food business operators (FBOs)

FCM	Food contact materials
FDA	Food and Drug Administration
FDI	Foreign direct investment
Fig.	Figure
FME	Food matrix engineering
FSSAI	Food Safety and Standards Authority of India
FSSAI	Food Safety and Standards of Indian
g	gram
GNP	Gross national product
GVA	Gross value added
HPP	High pressure processing
hrs.	hours
i.e.	that is
Kg	Kilogram
l	litre
LCA	Life cycle analysis
LM	Local market
m	metre
MAP	Modified atmosphere packaging
mg	milligram
min	minutes
ml	millilitre
mln tons	million tonnes
mm	millimetre
MoFPI	Ministry of Food Processing Industry
MPP	Mango peel powder
MT	Million tonnes
MUFA	Monounsaturated
NFC	Near field communication
NIOSH	National Institute for Occupational Safety and Health
NPD	New product development
OD	Osmotic dehydration at atmospheric pressure
ODF	Open defecation free
OSHA	Occupational Safety and Health Administration
OT	Osmotic treatment
OTA	Ochratoxin A
PA	Polyamides
PAC	Physiologically active compounds
PDE	Phosphodiesterase
PE	Polyethylene
PET	Polyethylene terephthalate
PG	Propyl gallate
PP	Polypropylene
PP	Precautionary principle
PS	Polystyrene

PUFA	Polyunsaturated fatty acids
PVC	Polyvinyl chloride
PVDC	Polyvinylidene chloride
PVOD	Pulsed vacuum osmotic dehydration
QCR	Quick cooking rice
RA	Risk assessment
RC	Risk communication
RDA	Recommended dietary allowance
RFID	Radio frequency identification
RM	Retail market
RSM	Response surface methodology
SBM	Swachh Bharat Mission
SFA	Saturated fatty acids
sp.	Species (singular)
spp.	Species (plural)
sq km	Square kilometre
TBHQ	tert-butyl hydroquinone
TRC	Transparent risk communication
UNDP	United Nations Development Programme
USD	United States dollar
USDA	United States Department of Agriculture
USDA	US Department of Agriculture
USPTO	US Patent and Trademark Office
var.	variety
VI	Vacuum impregnation
viz.	videlicet; namely
VOD	Omotic dehydration at vacuum pressure
vol. (s)	volume(s)
w.r.t.	with respect to
WHO	World Health Organization
YMC	Yeast and mold
µg	microgram
µl	microlitre
µm	micrometre

Contents

Editors and Contributors

About the Editors

Monika Thakur is an Assistant Professor at Amity Institute of Food Technology, Amity University, Noida. She is a Double Gold medalist and completed her PhD at Himachal Pradesh University, Shimla. Her main areas of expertise are Food Microbiology, Functional Foods & Nutraceuticals. She joined Amity Institute of Food Technology in 2009. Apart from her teaching assignments, she has been involved in various research projects, extension activities and commercial consultations. She serves on the editorial boards of various journals of national and international repute, and is a member of various prestigious societies. She has more than 70 papers in national and international journals, book chapters and abstracts to her credit, and has published three books in the area of Food Science.

V. K. Modi is the Head of Institute at Amity Institute of Food Technology, Amity University, Noida. He joined Amity Institute of Food Technology after his superannuation as Chief Scientist and Professor AcSIR from CSIR-Central Food Technological Research Institute, Mysore. He graduated from Punjab Agricultural University, Ludhiana with a degree in Food Science and Technology. He joined the CSIR-Central Food Technological Research Institute, Mysore in 1987 and spent the next 30 years working in the area of Food Science and Technology. He was awarded a Post Doctorate UNU fellowship to carry out research work on flavour at the University of Nottingham, UK, University of Reading, UK, and Queen's University of Belfast, Northern Ireland. He has received several prestigious national awards such as Fellow of AFST-2013 by the Association of Food Scientists and Technologists India (AIFT), Laljee Godhoo Smarak Nidhi Award (2011) by the AIFT, and Best Technology Award by the CSIR- CFTRI. Dr Modi has published more than 100 articles in national and international journals, holds 13 granted patents, and has developed 33 technologies, which have since been licensed to more than 130 entrepreneurs for successful commercialization.

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Part I

Overview of Food Industry

Overview of Food Industry and Role of Innovation in Food Industry

1

Harloveleen Kaur Sandhu, Rachna Sehrawat, Anit Kumar, and Prabhat K. Nema

Abstract

Food business is one of the major segments, which influences the economy of India. Economic and technical changes taking place in society and in the processing and manufacturing of the food has made a substantial impact on the whole food supply chain, right from farm to fork and made it obligatory for the food business stakeholders to divert their attention toward food products that fulfill the consumer's needs for a healthier lifestyle. As a result, innovation has been extensively inspected also within the industry.

Keywords

Food industry · Innovations · Processed foods

1.1 Introduction

Food processing is the process by which raw ingredients are transformed into edible food along with enhancing its shelf life. The processed food industry includes both the primary processes and value-added foods. Primary processed foods include products such as packed milk, tea, fruits and vegetables, milled rice, flour, unbranded

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edible oil, coffee, spices, salt, and pulses, sold in non-packed or packed forms, and value-added processed food includes products such as processed dairy products (cheese, butter, paneer, and ghee), jams, processed fruits and vegetables, juices, processed poultry, processed marine products, among others. The food industry feeds people around the globe with a wide range of food businesses. This sector imparts large employment opportunities and hence contributes to the country's overall development. Globally, the processing industry is valued at over $2 trillion and comprises of over 400,000 businesses with an expected growth rate of around 11.4% in 2019.

Food business is one of the major segments, which influences the economy of India. Ministry of Food Processing Industry (MOFPI) data shows that Indian food industry is estimated to be at USD 39.71 billion with an 11% compounded annual growth rate (CAGR). The Indian food and grocery market retails contribute 70% of the sales and are ranked the sixth largest in the entire world. The global and Indian food retails sales are valued at USD 4 trillion and USD 490 billion in 2013, respectively, as estimated by USDA (United States Department of Agriculture). Production, processing, marketing, and consumption of the food in the developing countries have been significantly changed by the food and agricultural sectors in these countries (Busch and Bain 2004; Henson and Reardon 2005; Pinstrup-Andersen 2000; Swinnen and Maertens 2006; Deshingkar et al. 2003).

The Indian food processing sector witnessed a substantial growth postindependence during the 1980s. Green revolution increased the agricultural production many folds following and increased necessity for postharvest management. Realizing the true potential of the industry, business community diversified the industry from grain trading to processing (Kachru 2006). The presence of both organized and unorganized players in the market and the different eating patterns of the consumers throughout the country differentiates the Indian market from the other well-established markets across the world. Indian consumers prefer unprocessed fruits and vegetables via homemade preparations, which is contradictory to developed nations where people prefer ready-to-eat foods. This is a major reason why Indian food processing industry is still underdeveloped despite strong agricultural production and a strong technological base. With 35% of the produce being processed, dairy products have the highest share in processed food industry, whereas fruits and vegetables have the lowest with only 2.2% of the produce going for processing. This may be due to higher inclination of consumers toward fresh fruits and vegetables over processed ones (Merchant 2008). However, in urban areas, the trend is slowly shifting to processed foods due to lack of time.

Increasing inclination of consumers in India toward processed food owing to the work culture has resulted in a substantial increase in number of industries in organized sector. In the past few years, the sector saw growth of 31%. This expansion gives a very boosting view of food processing industry. The retail segment also gets benefited by the inflow of Foreign Direct Investment (FDI). It gives farmers a platform to sell their produce to farmers at a profitable price by eliminating the middlemen.

The inflow of FDI and growing number of food processing industries underline the need of science and technology competence of our food processing industries. The incentives of the Indian food processing industry will be further enriched by a well-developed technology infrastructure. About 100% foreign direct investment in retail sector as desired by MOFPI can help to boost processed food exports since the demand from the domestic market alone cannot be sufficient. If the FDI were allowed, foreign expertise and technology brought in by retail chains would ultimately benefit the farmers. The FDI in retail can therefore increase the prospects of the processing industry (Agricultural and Processed Food Products Export Development Authority).

The CSO Reports of annual survey of industries evaluated the annual growth performance of the food processing industries. The growth performance was measured in terms of employment, the gross value added (GVA), and the number of units. It shows that in respect of investment, output growth, number of units, and employment, the high value segments, such as fish and fish products, meat and meat products, milk and milk products, starches and starch products, fruits and vegetables, and confectionery, have gained remarkably in the post-reform period. Starches and starch products have achieved maximum growth in the number of units during the post-liberalization period followed by fruits and vegetables.

1.2 Innovations in Food Industry

Economic and technical and changes taking place in society and in the processing and manufacturing of the food has made a substantial impact on the whole food supply chain, right from farm till fork and made it obligatory for the food business stakeholders to divert their attention towards food products that fulfill the consumer's needs for a healthier lifestyle. As a result, innovation has been extensively inspected also within the industry.

The food industry is usually categorized as a segment with lower research intensity, resulting in one of the lowest R&D-to-sales ratios of any industrial sector. Furthermore, this sector is less dynamic in terms of technological changes since the number of patented inventions are too less than manufacturing sectors (Martinez and Briz 2000). Beckeman and Skjöldebrand (2007) evaluated the degree of innovation in the food industry, emphasizing the fact that "very little innovation is taking place in the food industry." However, the food industry has been growing at a faster pace owing to the technological shift from the production to the information and then to the service age.

Moreover, the technological innovations have to be in sync with the social and cultural inventions for their ready acceptance and so that they satisfy the consumer's nutritional, social, and personal needs (Bigliardi and Galati 2013).