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).

1.3 Basic Need for Innovations

1.3.1 Supply of High-Quality Raw Materials in a Circular Economy

The current world population is 7.6 billion and is increasing at a rate of 1.09% per year with 83 million more people to feed every year. In order to feed a growing population, we need to produce "more with less" and ensure equal distribution of resources to all. Moreover, a strong emphasis to maximize the yield and quality per unit also needs to be looked into. The initial raw material quality is crucial to produce high-value products. Sustainable production is expected to be a major future competitive advantage—both nationally and on the export markets. According to FAO estimates, around 33% of food is wasted globally. In the developing countries, this wastage is at the beginning of the food value chain; however, in case of rich countries, this wastage usually occurs at the end of the food value chain at the consumer or the retailer level. According to the United Nations Development Programme (UNDP), up to 40% of the food produced in India is wasted, and US citizens waste around 150,000 tons of food each day (Conrad et al. 2018). There is a burning need for research and innovation in this field to address the growing issue of food waste and to help various stakeholders linked with food business from production until consumption to reduce effectively the food waste produced.

1.3.2 Products for the Global Consumer

Markets are consumer centric and multiple, and constantly changing food preferences along with lack of proper understanding of the consumer preferences by the stakeholders lead to unsuccessful and costly consumer entries. Capturing the knowledge and adaptation to new market and ever-changing consumer trends and ability to foresee the demands of consumers of tomorrow is very crucial for a food business to be successful. Establishing strong interactions with consumers is key to reduce failing risks when new products are introduced, or the existing products are launched into new markets.

Majority of consumers are conscious about the food production trends and do not prefer large-scale industrialized food production. They prefer "clean labels" and prefer avoiding foods with additives. They are more concerned about food quality, and it is not always possible to mitigate these concerns by merely providing more information about the product. Export of the products to consumers around the globe poses many technological challenges including retention of freshness, quality, and shelf life of the products during the entire transportation time. The fluctuations and high temperatures and humidity also challenge the product quality during transportation and at the distribution end. This can be overcome by faster or more energy-intensive transportation of products or by using chilled/cold storage techniques. Finally, developing packaging technology as a stabilization technique may help to keep the quality intact.

1.3.3 Food Safety

Consumers develop an irreversible disbelief in food producers when foodborne disease outbreaks occur. Consumer awareness and concerns have increased great a deal in this modern age. Globalization increased transportation of animals, humans, and consumer goods, which in turn increases the risk of rapid spreading of communicable diseases. Export of food product is hampered by the spread of epidemics and pandemics such as the bird flu and swine fever. Moreover, it is very challenging to prevent the outbreaks of foodborne diseases; hence, it becomes very critical to keep a stringent key on the safety of food being produced.

The use of energy-efficient cooling systems and reduction in usage of water for cleaning procedures should never compromise the safety of food produced. Food safety challenge is also posed by the long distribution times and changes brought about in composition of the products to make them healthier or to match the changing consumer needs. Lastly, stringent guidelines for export and the customer need demand for clear traceability and documentation of product composition, safety, and its shelf life. In this perspective, it is important to maintain and independently document traceability from farm to fork for export products as a mark of consent. Moreover, the introduction of personal analytical technology enables consumers and customers to test the products, providing results that may be shared worldwide in an instant. This could possibly result in companies going out of business.

1.3.4 Foods for a Healthier Life

Healthy nutrition, along with physical activity, is one of the foundations of a healthy lifestyle and directly linked to the health costs of society. Cardiovascular diseases, worldwide obesity, depression, and several such ailments have shifted the food concern toward healthier diets, which help to reduce the occurrence of such diseases. Subsequently, the onus shifts to food industry, as it must play a significant role in manufacturing foods for a healthier life and in helping the consumers make informed choices about their food intake. Food contributes to consumer health at all stages of life. Research-based insights can be used to help the consumer make informed and personalized choices in supporting a healthy lifestyle and preventing diet-related chronic diseases. Foods for a healthier life include not only the foods linked to major lifestyle-related diseases but also products directed toward a broader therapeutic area (e.g., early life nutrition and performance foods). There is, however, a great consumer demand for use of natural ingredients due to supposed beneficial health effects. Concerns about “E numbers” and an overall drive toward increased transparency of the food system have created a demand for new, less refined ingredients.

1.4 Recent Innovations

1.4.1 Insects as a Source of Food

Increasing world population highlights the major issue of food security in developing countries, but the food produced should ensure safety and the ecological stability. Insects satisfy both these requirements. In northeastern India, the nutty flavored "pollute fry" (made from silkworm pupae) and fried silkworms are regular dishes of the Assamese tribes with 255 species of insects being used as food in these areas (Chakravorty 2014). The consumption of coleopteran species was the highest among these edible species of insects constituting about 34% of all the insects consumed followed by Orthoptera (24%), Hemiptera (17%), Hymenoptera (10%), Odonata (8%), Lepidoptera (4%), Isoptera (2%), and the least was Ephemeroptera (1%). Ethnic people of Northeast India practice entomophagy particularly the tribes of Assam, Manipur, Nagaland, and Arunachal Pradesh, but it is not very common among the tribes of Meghalaya and Mizoram (Chakravorty 2014).

Insects are a rich source of proteins, amino acids, and vitamins, and most of them contain more of these nutrients than present in equal amounts of beef or fish. It is also reported that of all the insects analyzed, 95% of them had a caloric value higher than wheat, rye, or teosinte. About 87% of them had higher than that of corn; 70% had higher than that of fish, lentils, and beans; 63% had higher than that of beef; and 50% of them had a caloric value higher than that of soybeans (Fig. 1.1).

1.4.2 Use of Minor Crop

In order to achieve food security and zero hunger, it is important to focus on the utilization of neglected and underutilized crops and other sources of food. Utilization of indigenous/underutilized/minor crops will help the poor farmer in raising the

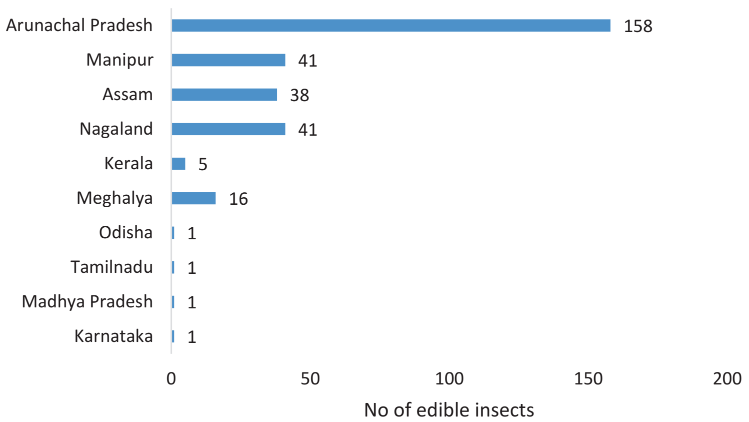

Fig. 1.1 Graphical representation of insect species consumed in different states of India

income in developing and under developed countries, lowering down over reliance on staple crop and diversification from staple crops, enhancing the product quality, and helping in the preservation of indigenous crops and cultural diversity. Some of the underutilized crops are cereals (Buckwheat, Amaranth, Foxtail millet, Finger millet, Proso millet, Grain amaranth, Sorghum, Quinoa, Tartary buckwheat, Specialty rice), horticultural species (drumstick, chayote, Indian gooseberry, fenugreek, pumpkin, jackfruit, snake gourd, roselle, wood apple), seeds, nuts, spices (Nepali butter tree, linseed, perilla walnut, Nepali pepper), pulses (cow pea, black gram, grass pea, horse gram, faba bean, mung bean, lentil, soybean, rice bean), roots, and tubers (fancy yam, elephant foot yam, swamp taro, purple yam, sweet potato, taro) (Li and Siddique 2018). Several studies have undergone to utilize the underutilized crops in extruded products such as pasta, noodles, bakery products, confectionary, and beverages. These sources are potential future smart foods as they will lead to production diversity and dietary diversity.

1.4.3 Optimization and Commercialization of Traditional Products

There is increasing trend among the consumer to consume traditional food products, but to prepare traditional product is a time-consuming process at home. Due to hectic life schedule and increase in number of working women, it is difficult to prepare traditional food product at home, and the trend is there to consume ready-to-cook products. Moreover, the same traditional product has variation from region to region. This augments the researchers and manufacturers to optimize the traditional products for their commercialization. Some of the traditional products over which work has been carried out are khoa, peda, basundi, kheer, milk cake, idli, dosa, puranpoli, and khaza (Jha et al. 2012; Aggarwal et al. 2018). Puranpoli (stuffed chapati/bread) a dish popular in western India was optimized for its ingredients such as chickpea dhal and jaggery, and sensory parameters were analyzed using fuzzy logic (Kardile et al. 2018). Changes in the physicochemical and sensory properties during storage of la-peda was studied by Jha et al. (2012). Apart from optimization, research over the fortification of these traditional products with fiber and replacement of sugar and fat content in order increase the nutritive value of traditional products has been carried out. Defatted soy flour was supplemented in gulab jamun, to increase the protein content of sweet dish (Singh et al. 2009). Chhana kheer (dessert popular in Indian subcontinent) was prepared, where artificial sweeteners (aspartame (0.015%), acesulfame-K (0.015%), and sucralose (0.05%)) were used to replace the conventional sugar and prepared dessert can be utilized for diabetics patients (Gautam et al. 2012).

1.4.4 Innovation in Technology

Different innovative technologies that are gaining worldwide attention not only of academician but also of industrialist are 3D printing of food, drying (low pressure superheated steam), and refractance window drying technology, nonthermal technologies, and high-pressure homogenization.

Three-dimensional (3D) printing is digital fabrication by layer-by-layer deposition of food material in 3D space which is custom-designed food with the choices of altering the nutritional profile, without involving human intervention (Lipton 2017). Custom or personalized designed products are specially designed by specially trained artisans in limited numbers. Fabrication of personalized designed food products with the help of 3D printers leads to increase in production efficiency and reduction in manufacturing cost. Several 3D printers are available in the market (i.e., Choc Edge Choc Creator V2.0 Plus U.K.; Micromake Food 3D printer, China; Natural Machines Foodini Spain), and these techniques has shrunk down the mini food plants to the size of an oven. The "ink" for an extrusion-type 3D food printer has been made from starch-based materials, bioactive compounds, and healthy additives. Kouzani et al. (2017) utilized the mixture of restructured tuna fish, pumpkin, and beetroot and developed product especially for people suffering from dysphagia. Orange leather constructs were developed (Azam et al. 2018) using orange concentrate, wheat starch, which is difficult to make through traditional method of processing due to viscous properties of material and high moisture.

Several innovations in drying technology (i.e., low pressure superheated steam drying and refractance window drying) have gained lot of attention due to retention of bioactive components, better color, and texture as compared with traditional method of drying (Sehrawat et al. 2017, 2018a, b; Sehrawat and Nema 2018). Nonthermal techniques are also used for commercial manufacturing of products but at a slower rate due to high cost involved either in manufacturing process or due to equipment cost (Kumar et al. 2018). High-pressure micro-fluidization is gaining attention for reducing the size of particles and providing better emulsion and particle dispersion in beverages. The reduction of particle size in dairy products improves digestibility and better color, and viscosity is achieved (Chavan et al. 2014, 2015).

1.4.5 Biodegradable and Edible Packaging Innovations

Global consumption of plastics is growing at the rate of 5% with the present consumption at more than 400 million tons. The nonbiodegradability of the plastics has led to a great deal of pollution both land and marine. India generates 25,940 tons of plastic waste on a daily basis which accounts for 80% of total plastic consumed, and of all the waste discarded, around 40% is not collected for recycling. The Indian plastic industry is among the fastest growing ones with a compounded annual growth rate (CAGR) of around 10% between 2010 and 2015, as reported by FICCI.

To curb this menace, the use of biodegradable and edible packaging is being encouraged. Many Indian firms have started making edible cutlery to avoid the problem of dumping into landfills. Edible films and coatings on one hand can reduce the cost and bulk of traditional packaging and at the same time help in the preservation of food. Edible films and coatings are prepared from hydrocolloid-based biopolymers, such as polysaccharides like gums, cellulose, alginates, starch, chitosan, pectin, and proteins, from animal or vegetable origin. Edible coatings act as a gas and moisture barrier for the product and nowadays with the advent of newer technology have been used to regulate the release of food additives and nutrients (Campos et al. 2011). Water-soluble edible films and edible baked cutlery (made from a mixture of sorghum, rice and wheat flours) is gaining importance in the country these days, as they take just a few days to weeks to disintegrate and are not harmful even if stray animals consume them against the conventional plastic bags which have taken away the life of a number of stray and marine animals.

1.4.6 Innovation in Waste Utilization

According to FAO report 2013, about 1.3 billion tons of food is being wasted annually around the globe while around 842 million people in poor countries experience chronic hunger conditions. Food wastage is highest in the developed countries (Buzby and Hyman 2012). Additionally, food wastage is a mounting but an avoidable challenge; hence, UN has made it a part of sustainable development goals "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (UN 2017). Waste management innovations can be incremental (process and technology) and radical. Incremental process innovation includes modifying one or more of the processes to reduce and recycle waste. One such example of process improvement to reduce food waste is small portioning of the food for serving.

1.4.7 Innovation in Safety

Food safety concerns the consumers every time they purchase a packaged food product. Safety of the product remains a question until the packet is opened. Food experts have come up with packaging innovations in the form of sensors to assess the product and package integrity by analytes quantification. It thus informs about the product safety status even before it is opened. It can also be in the form of indicators to give the desired qualitative information in the food environment (Gregor-Svetec 2018). Indicators give qualitative or semiqualitative information about the product quality, the extent of a reaction between two or more substances, the concentration of a specific substance or class of substances, or the presence or absence of a substance (O'Grady and Kerry 2008). These indicators can be in form of freshness indicators, gas indicators, and temperature indicators (Hogan and Kerry 2008).

Temperature indicators tell whether the product is treated below or above a critical temperature, which warns the consumers against the survival of microbes, denaturation of proteins, etc. Microbial growth or chemical changes in a product are indicated by freshness indicators which provide direct information on the product's quality (Siro 2012). This identification is based on the decomposition or reaction products formed on loss of freshness of a product. The detection of occurrence of leakages or the assessment of efficacy active packaging components (e.g., O_2 and CO_2 scavengers) is done by the use of gas indicators (Yam et al. 2005).

Sensors can be gas sensors or biosensors. Gas sensors respond quantitatively to the gas analytes that could be O_2, CO_2, etc. The sensor barcode contains a membrane attached to it which is a biosensor which carries an antibody of a specific pathogen. The ink integrated into the biosensor turns red in the presence of a contaminating bacteria, and the barcode will not transmit data when scanned (Yam et al. 2005).

1.4.8 Innovations in Fruit and Vegetable Fortification

Among other techniques used in the preparation of functional foods, vacuum impregnation is the latest technique, which involves the impregnation of porous food matrices by swapping the internal gas or liquid blocked in open pores with adequate solutions/suspensions of physiologically active compounds (PAC). It does not destroy the food matrix to obtain functional foods but instead occupies its initial porous fraction with a liquid phase (Fito et al. 2001b). This technique is generally used for fruit and vegetables which have internal pores which can be available for PAC introduction (Fito and Chiralt 2000; Fito et al. 2001a).

Vacuum impregnation is generally practiced in case of fruits and vegetables which have high porosity such as quince, apricots, peppers, apple, strawberries, mushrooms, among others. The fruits or vegetables to be impregnated are immersed in solutions containing dissolved substances to be impregnated following which the impregnated products are stored under certain void pressure (Soni and Sandhu 1989). This technology is very useful since it improves the product texture, maintains product color, and reduces the oxidation of the product, and its exudates at defrosting. This can also help improve different vegetable products with their nutrients such as vitamin E, mineral salts such as Ca and Zn, probiotics, among others. Calcium is the most widely used fortifier in the development of functional foods. In case of calcium fortification, calcium impregnating solution interacts with plant cellular matrix and modifies its mechanical and structural properties (Gras et al. 2003).

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Nanotechnology in the Food Sector

2

Gursheen Kaur and Karuna Singh

Abstract

The application of nanotechnology in the food sector is rapidly increasing due to widespread uses of nanoparticles in food. The food industry is the major benefactor of this technology since it can be used in all areas such as farming, food packaging, processing, among others, and even plays a role in the prevention of microbial contamination. Even though the application of nanoparticles is infinite, customers are hesitant to the use of such products due to uncertainty of the health effects it may possess. This becomes an area of concern for industries as health holds priority. Along with this, a uniform international regulatory framework for nanotechnology in food is necessary to ensure safety aspect.

Keywords

Food processing · Agriculture · Food packaging · Application · Safety

2.1 Introduction

Nanotechnology today has become the call of the century. Nanotechnology refers to the mechanical systems that reduce size of particles ranging from 1 to 100 nm (Moraru et al. 2003). Nanoparticle is defined as the small object that acts as a whole unit in terms of transport and properties. They are classified according to their characteristics, size, and structures (Gladis et al. 2011). The word "nano" in layman terms means small, tiny, or atomic in nature (Garcia et al. 2010). With the advent of nanotechnology in food and nutrition, scientists are designing novel foods that have better solubility and bioavailability (Semo et al. 2007). However, apprehensions

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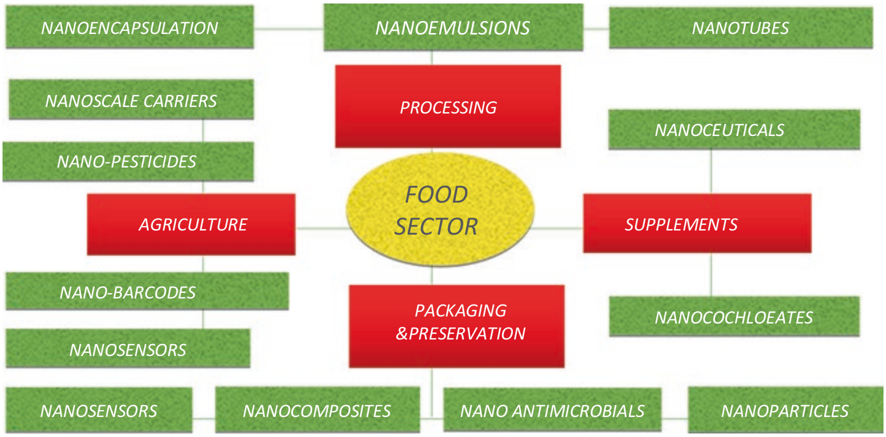

Fig. 2.1 Various nanomaterial and application in food sector

regarding nanoparticles remain. The main concern is that there are different routes of entry into humans such as digestion, inhalation, or skin absorption. Once inside the body, these nanoparticles can enter the blood stream and settle in tissues such as the brain or trigger an immune response (Scrinis 2008; Miller and Senjen 2008). Nanotechnology in agriculture and food processing can improve the quality, safety, nutritive value, and quantity of food that could meet the needs of the growing world population (Marquis et al. 2009). In this chapter, the main focus is on the applications and functions of food nanotechnology and the risks it possesses to humans. Nanoparticles have completely different consequences depending on their area of use (i.e., whether they are used as ingredients or in packaging or in processing).

2.2 Applications of Nanotechnology in Food Sector

Nanotechnology is a vast area of research and development. It can play numerous roles in the food industry. It can be used as biosensors which could scan microbes in food or may be developed into capsules that can protect food from the outside conditions. No matter what function it performs, the main purpose remains that it seeks to improve the quality of food by improving the functionality of some ingredients (Haruyama 2003).

Nanotechnology is useful almost in all sectors of the food industry, many of the techniques are very expensive or not suitable for large-scale commercial application (Nel et al. 2009). Owing to its wide area of usability, this article focuses on the nanotechnology application in areas of food processing, packaging and preservation, and dietary supplements (Fig. 2.1 and Table 2.1).

Table 2.1 Application of nanotechnology in food sectors: an overview

Agriculture	Food processing	Food packaging	Supplements
• Determine enzyme substrate interactions using single-molecule detection • Nano capsules for effective delivery of pesticides, fertilizer and other agrichemicals • Delivery of growth hormones in a controlled fashion • Nanosensors for monitoring soil conditions and crop growth • Nanochips for identity preservation and tracking • Nanosensors for detection of animal and plant pathogens • Nano capsules to deliver vaccines	• Nano capsules to improve bioavailability of nutraceuticals in standard ingredients such as cooking oils • Nanoencapsulated flavor enhancers • Nanotubes and nanoparticles as gelation and viscosifying agents • Nano capsule infusion of plant-based steroids to replace meat's cholesterol • Nanoparticles to selectively bind and remove chemicals or pathogens from food • Nano-emulsions and particles for better availability and dispersion of nutrients	• Antibodies attached to fluorescent nanoparticles to detect chemicals or foodborne pathogens • Biodegradable nanosensors for temperature, moisture, and time monitoring • Nano clays and nanofilms as barrier materials to prevent spoilage and prevent oxygen absorption • Electrochemical nanosensors to deflect ethylene • Antimicrobial and antifungal surface coatings with nanoparticles (silver, magnesium, zinc) • Lighter, stronger, and more heat-resistant films with silicate nanoparticles • Modified permeation behavior of foils	• Nanosized powders to increase absorption of nutrients • Cellulose nanocrystal composite as drug carrier • Nanoencapsulation of nutraceuticals for better absorption, better stability of targeted delivery • Nanocochleates (coiled nanoparticles) to deliver nutrients more efficiently to cells without affecting color or taste of food • Vitamin sprays dispersing active molecules into nanodroplets for better absorption

2.2.1 Agriculture

Nanotechnology is considered a novel delivery system which enhances crop productivity and decreases the use of bulk agrochemicals and provides solutions for the current problems in the field of agriculture.

Some applications of nanotechnology in agriculture are:

(a) Crop improvement
(b) Increase efficient fertilizers and pesticides
(c) Soil management
(d) Plant disease detection
(e) Water management
(f) Analysis of gene expression and regulation
(g) Postharvest technology

Various nanomaterials and their application in agriculture are discussed as follows:

2.2.1.1 Nanoscale Carriers

To improve the plant yield, there are various ways that have been developed to transport important components to plants. Nano-scale carriers or nanotubes are used for this purpose. They are effective in delivering substances such as pesticides, herbicides, fertilizers, growth regulators, among others, to theist of action (NAAS 2013). For the manufacture of these devices, polymers are used. Ionic and weak bonds are used to attach these substances to the surface of polymers. These nano-scale carriers have the potential to bind the plant roots with the soil and other organic materials in the surrounding areas. This way of transportation of substances increases their stability and decreases their deterioration by the adverse environmental conditions. This application therefore reduces the quantity of the substances that are needed by the plant and eliminates wastage.

2.2.1.2 Nano-pesticides

Nano-pesticides are substances that contain a very little amount of the active ingredient that is found in conventional pesticides. These substances enhance the dissolution and absorbance of agricultural solutions. Nano-pesticides are effective because nanomaterials that are used to formulate them have useful characteristics such as stiffness, permeability, heat stability, and solubility (Bouwmeester et al. 2009). Nano-pesticides can decrease the rate of use because the amount of chemicals that are involved is 10–15 times lesser than what is used through conventional formulas. Therefore, a smaller quantity of nano-pesticide is used to yield a satisfactory result which in turn reduces the damage to the environment (He et al. 2010). Methods that can be incorporated for transport of nano-pesticides are nano-emulsions, nanoencapsulations, and nano-containers, and pesticides encapsulated in nanoparticles were used to release pesticide in an insect's stomach and hence minimizes the contamination of plants themselves (Scrinis and Lyons 2007).

2.2.1.3 Nano-barcodes

Identification and tracking are very important parts of agro-food industry as they play a vital role in trading of agricultural products at a wholesale level. For this purpose, nano-barcodes are used, and their major specialty is that they can be made from numerous blends of materials. Materials that can be used for making nano-barcodes should have characteristics such as encode ability, readability by devices, tensile strength so that they can be used for a long time, and are nanometer in size. Nano-barcodes have two types of uses in agriculture i.e. biological and non-biological (Ditta 2012). Biological use includes the use of nano-barcodes as an ID tag. These ID tags can be used to study gene expression (El Beyrouthya and El Azzzia 2014). Nonbiological application involves the use of nano-barcodes as means of tracking of agricultural foods. This provides an easier and much user-friendly means of tracing foods which was not previously possible due to lack of practicality.

2.2.1.4 Nanosensors

Many biosensors have been designed using nanotechnology to detect pollutants in water and air. These nanosensors provide much more specificity and specialty, quick response, are user friendly, and have low cost of production. Nanosensor can be used to detect waste products such as urea or pesticide residues. They help in detection of microorganisms. They are useful because they can detect even a single pathogenic organism that could be hazardous. Nanosensors can be used to check soil disease that is caused by microorganisms such as bacteria and fungi. This is possible through the measurement of oxygen consumption by good and bad microbes during respiration. Their application also lies in their ability to measure stress to plants that is caused by uneven temperatures and atmospheric conditions (Vamvakaki and Chaniotakis 2007). Nanosensors can also be used for detection of pesticide residues as they are small, and the results are also quicker than the traditional techniques which are time consuming (Moraru et al. 2003).

2.2.2 Food Processing

Food nanotechnology is an emerging technology. Food processing and technology is one of the industry sectors where nanotechnology will play an important role. Various applications of nanotechnology in food processing sectors are discussed below:

2.2.2.1 Nano Encapsulation

Several advantages of nanoencapsulation method include improved stability, easy handling, prevention of oxidation, retention of volatile compounds, flavor enhancement, moisture control, pH control, prolonged organoleptic sensation, and increased bioavailability (Marsh and Bugusu 2007; Chaudhry et al. 2008). Nano capsules can be defined as a nano system that shows a core structure in which the drug is inside a reservoir or cavity that is surrounded by a polymer coating (Sekhon 2010). Preparation of nano capsules can be done by the following ways (Maynard et al. 2006):

- Nanoprecipitation
- Emulsion diffusion
- Double emulsion
- Emulsion coacervation
- Polymer coating
- Layer by layer

Nano capsules help to yield a desirable product and helps to trap odor and unwanted particles in food and hence results in food preservation. In the body, nano capsules transfer the food supplements through the gastrointestinal tract, and this causes an increase in bioavailability of the food (Maynard et al. 2006). Nano capsules increase the nutrient content of the food by increasing fatty acids and growth hormones (Dreher 2004). The basic principle of nanoencapsulation is to deliver the essential component at the target site by protecting it in unsuitable environments. An example of this is liposomes. These help to deliver components when the conditions are controlled and specific. They can deliver vitamins, antimicrobials, enzymes, additives, and other nutrients (Godwin et al. 2009).

Zein fiber is a new encapsulation technique which prevents lipids from degradation before it reaches the target site. These systems are very efficient because there is improved solubility. This system prevents the interaction of the component with the food so that native features of the food remain untouched and the components to be delivered remain unmodified (Klaine et al. 2008). Probiotics are also being nanoencapsulated. Novel encapsulation techniques based on cold-set gelation for delivering heat-sensitive bioactive including probiotics is an application of nanoencapsulation in food processing sector (Guhan Nath et al. 2014). It helps design vaccines that control the response of the immune system. This way probiotics are also preserved more efficiently (de Azeredo 2009). For delivery of antioxidants, archaesomes are used. They are lipids that are thermostable (Alfadul and Elneshwy 2010).

2.2.2.2 Nanoemulsions

Nano-emulsions consist of oil droplets ranged between 10 and 100 nm dispersed within an aqueous continuous phase and surrounded by surfactant molecules (Acosta 2009; McClements et al. 2007, 2009). When liquid phase is dispersed in continuous aqueous phase, nano-emulsions are formulated (Oberdörster et al. 2007). Foods that are used for the preparation of salad dressing, sweeteners, flavored oils, among others, use nano-emulsions for production. Nano-emulsions aid in release of flavors by the action of heat, pH, etc. (Ravi Kumar 2000); hence, flavors are better retained and are less susceptible to enzymatic reactions.

Nano-emulsions are superior to the conventional emulsions because the size of droplet decreases and the surface area increases. This improves digestibility and absorption. Nano-emulsions are better at penetrating the mucosal layer of the small intestine. Texture of ice cream can be improved by using nano-emulsions of protein or carbohydrates. Nano-emulsions also have antimicrobial activity. When nano-emulsions made from nonionic surfactants, microbial growth is avoided (Sanguansri and Augustin 2006). Nano-emulsions increase the bioavailability of phytochemicals such as carotenoids and polyphenols that are beneficial for reducing blood pressure, lowering risk of cancer, regulating digestive system, and strengthening the immune system (Ezhilarasi et al. 2013; Chau et al. 2007; Chen and Subirade 2005).

2.2.2.3 Nanotubes

Carbon nanotubes are novel representation of nanomaterials. They are manufactured by coiling single graphite sheets in a honeycomb structure into a thin tube that is rigid and flexible. Nanotubes are stronger than steel (Moraru et al. 2003). In the food industry, they can be used for preparation of biosensors. Carbon nanotubes are not soluble in aqueous solutions; therefore, they are difficult to use for biological purposes (Pompeo and Resascdo 2002). Nanotubes can be applied in food systems as they can become part of biosensors that can detect enzymes, proteins, DNA, and antibodies (Lee and Martin 2002). They can be modified effectively to separate molecules. The basic ideology is to develop electricity-conducting membranes that can provide heat when needed. This could reduce the energy that is lost from feedstock when it is heated. This could also be able to avoid the deteriorating effects of excessive heating on the texture and taste of feedstock. While the use of these inventions is still very expensive for application in food processing industry, they could be used in the coming years for various purposes including the separation of biomolecules from the food that can act as functional foods and be used for fortification or dietary supplementation (Moraru et al. 2003).

2.2.3 Food Packaging

Food packaging provides protection and is essential for effective storage, distribution, and preservation. It facilitates end use convenience of food products. With these important functions, packaging has become the third largest industry in the world, and it represents about 2% of the gross national product (GNP) in developed countries (Han 2005; Robertson 2005). There are numerous applications of nanotechnology in food packaging and preservation. Nanotechnology-enabled food processing is categorized as follows:

- Improved packaging
- Active packaging
- Intelligent packaging

2.2.3.1 Nanosensors

To detect any kind of change in color of the food, nanosensors are used. Nanosensors also help to notice any gas that is released from food due to spoilage. The main gases that can be detected using nanosensors are hydrogen, hydrogen sulfide, nitrogen oxide, and ammonia (Chun et al. 2010). Nanosensor is a gadget that has a data processing unit and a sensory unit, which helps to notice any alteration in light, heat, humidity, gas, and chemicals (Lizundia et al. 2016). They are efficient than conventional sensors as they are highly selective and sensitive (Scampicchio et al. 2008). In milk, gold nanoparticles are used to detect aflatoxin B_1, which is a toxic compound (Mao et al. 2006). Nanosensors also help in maintenance of soil condition for agricultural production as they can detect pesticides present on fruits and vegetables. Apart from this, carcinogens present in food can also be detected through nanosensors (Meetoo 2011). To detect microorganism infestation in food, nanosensors can directly be installed at the packaging site. Therefore, time spent on lab testing of the product is saved. Different kinds of nanosensors that can be used are array nanosensors or electronic noses. Electronic nose acts like a human nose (Vidhyalakshmi et al. 2009). To determine the presence of adulterants in food, carbon ceramic nanosensors are used (Garcia et al. 2010). Pathogens in food can also be detected using nanosensors as they reduce the incubation time (Yotova et al. 2013).

2.2.3.2 Nano Composites

They enhance the activities of polymers by combining with them (Yotova et al. 2013). Nanocomposites act as barriers as they are highly versatile in terms of their chemical properties. Food remains fresh and microorganism free for a long period of time. They prevent the release of carbon dioxide from carbonated drinks. It provides a cost-effective method of storing drinks for manufacturers as they do not have to spend much on cans or glass bottles because a simple layer of nanocomposites on the bottle can prevent this release. Gas barrier that is commonly used is called canonically which is found naturally and is cheap and environment friendly. Commercially available nano clays are Aegis, Imperm, and Urethan. These are superior to other products because they are eco-friendly, have low density, are transparent, and have better flowing properties (Davis et al. 2006). Another gas barrier is known as nanocore which is used in the production of plastic beer containers that minimize the release of carbon dioxide (He et al. 2010). Nanoparticles combined with zinc oxide or silver in nanocomposite films have antimicrobial functions (Moraru et al. 2003). Silver can destroy the bacterial cell and thereby its DNA. For use as layering material in packaging, nanocomposites made of starch and cellulose have been developed (Maynard et al. 2006).

2.2.3.3 Nanoparticles

There are various purposes that are fulfilled by nanoparticles in food processing. Some of these include improving the food's color and stability. Nanoparticles such as silicate, zinc oxide, and titanium oxide are used in the form of plastic films to minimize the passage of oxygen inside the container. This helps in keeping the food fresher for a prolonged period by decreasing moisture release. Certain nanoparticles also make possible the removal of pathogens and chemicals from food (Nam et al. 2003). The two most widely used nanoparticles are silicon dioxide and titanium dioxide that are used in food packaging. Silicon dioxide can be used as an anticaking agent (Zhao et al. 2008). It also helps in the removal of water from food. Titanium dioxide helps in whitening of food items such as milk, cheese, and many dairy products (Acosta 2009). It also acts as a UV protector. Silver nanoparticles have antimicrobial properties (Zhao et al. 2008). Silver nanoparticles can be easily dispersed as they have a large surface area which makes them chemically active. Silver is a relatively stable element, and it does not lead to any harmful effect in the body if used within prescribed amounts as are approved by the FDA standards. Silver is superior over other particles as it can combine with biofilms, and it can be easily combined with packaging materials. Silver seeps into the microbial environment and obstructs the DNA activity. By absorption and decomposition of ethylene, silver nanoparticles increase the shelf life of fruits and vegetables (Zhao et al. 2008). Apart from silver, zinc and titanium can also be used for food packaging (Acosta 2009). Titanium dioxide can only work under UV light, and thus its use is limited (Arshak et al. 2007).

2.2.3.4 Nano-antimicrobials

Microbial contamination is the major source of infection and disease that is related to weaning of foods. Therefore, combating microbial deterioration of food is of prime importance when it comes to processing, packaging, and transporting of food. Novel nano-antimicrobials are emerging, and they increase the shelf life of foods (Davis et al. 2013; Fu et al. 2014). Silver nanoparticles are being used for this purpose. They are used in a variety of forms including kitchenware. The ions of the silver nanoparticles have the potential to limit many biological activities in bacteria (Henriette and Azeredo 2009). Silver-containing nanoparticles have been approved by the US FDA for use in food for the purpose of antimicrobial activity (Schultz and Brclay 2009). Silver nano-antimicrobials are safe for food, and there is no identifiable defect with this method and no significant levels of this are released from the container which can be passed on to the food (Addo Ntim et al. 2015; Metak et al. 2015). Nanocomposites are also added as they offer stability to the food by reducing the migration of metal ions into the food. Nanocomposites commonly used are gelatin, polylactic acid, and low-density polyethylene (Becaro et al. 2015; Beigmohammadi et al. 2016). Also, the antibacterial property of zinc oxide increases with the decrease in size of the particle. Titanium dioxide can be used to control *Escherichia coli* contamination by using it as a coating in packaging material. It can be used to improve the disinfection process by combining it with silver (Momin et al. 2013).

2.2.4 Supplements

Dietary (food) supplements are products that look similar to medicines (can be sold in pharmacies) but are a special category of foods. They contain vitamins, minerals, amino acids, essential fatty acids, natural products, probiotics, etc., as active ingredients. The purpose of a supplement is to keep the human body functioning properly by delivering compounds that are needed by the human body but could not be received sufficiently from a regular diet. Nanotechnology is a rapidly growing field that ensures the development of materials with new dimensions, novel properties, and a wider range of applications.

Most commonly used human dietary nano supplements are:

- Vitamins**:** C, D, E, A, folic acid, riboflavin, provitamin:β-carotene.
- Probiotics: *Lactobacillus* and *Bifidobacterium* species.
- Antioxidants: Polyunsaturated fatty acids, curcumin, SeNPs, astaxanthin, lycopene, resveratrol, quercetin, naringin, lutein, hydroxytyrosol, polyphenols, catechins.

2.2.4.1 Nanoceuticals

Nanoceuticals are nutrients that are made into nanoparticles using nanotechnology (Schultz and Brclay 2009). Most of the nutrients and phytochemical have low solubility, and this property reduces their bioavailability. This is the reason that many vitamins and minerals are never used in their native form and a delivery system is used for such functional ingredients. The function of the delivery system is to deliver the nutrients to the target site while enhancing the flavor, texture, and shelf life of the supplement (Tanver 2006). Thus, the purpose of nanotechnology in the field of dietary supplements is to form a more effective delivery system using nanoemulsions (Wang et al. 2008). Although nanotechnology may resolve the problems of solubility and increase absorption, there is potential risk of toxicity because upper limits for phytochemical are not clearly laid out since these are not nutritional. Also, these nanoceuticals could cause barriers in the body, and their amount could increase the quantities that the body does not naturally allow for. Nanoceuticals are similar to any other dietary supplement which means that they are not controlled and can be sold to customers with minimum or no evidence of safety (Tanver 2006).

2.2.4.2 Nanocochleates

Nanocochleate is a structure that has multiple layers that include a huge, continuous, and rigid bilayer sheet of lipid that is coiled in a spiral manner with negligible aqueous space on the inside (Mozafari et al. 2006). When the outermost layer of the cochleate merges with the cell membrane, the contents are delivered because they can withstand assault from the environment, and they are prevented against deterioration because of their solid and rigid structure. The entire cochleate and nanocochleate structure is a series of solid layers, so that, even if the outer layers of cochleate and nanocochleate are exposed to harsh environmental conditions or enzymes, the encapsulated molecules will remain intact within the interior, and therefore, they are most effective when oral intake is required (Zarif 2003). To transport bioactive materials, these can be used, and this can include compounds such as protein and peptide drugs and this compounds that have poor solubility. This technique could work for effective transport of functional foods in the future (Moraru et al. 2003). However currently, their main use is in the delivery of nutraceuticals and antimicrobials (Weiss et al. 2006). Hence, basically they are involved in the effective delivery of nutrients to cells without any alteration in color or taste of food.

Various other nanocarriers for dietary supplements are:

- Nanoliposomes
- Micelles
- Nano-emulsion
- Nano capsules
- Solid liquid nanoparticles
- Core-shell nanoparticles
- Layered double hydroxides
- Mesoporous silica nanoparticles
- Cyclodextrin complexes
- Nanogels
- Nanosponges
- Nanofibers

2.3 Significance of Various Nano-Structures and Nanoparticles in Food Industry

2.3.1 Increase Bioavailability

Nanomaterials are increasingly being used to improve the bioavailability of many bioactive compounds such as coenzyme Q10, vitamins, iron, calcium, among others (Oehlke et al. 2014; Salvia-Trujillo et al. 2016). By improving the bioaccessibility and absorption, the bioavailability of bioactive compounds can be maximized. This is because when particle size is altered, solubility is improved because the surface-area-to-volume ratio increases. This increases the bioaccessibility (Kommuru et al. 2001). If suitable formulation surfactants are selected, then the gastrointestinal permeability can be enhanced (Fathi et al. 2012). This also increases both bioaccessibility and absorption (Bhushani et al. 2016). Surface-modified nanomaterials have been developed to regulate their interactions with the biological environment and thereby their biodistribution. Chemical grafting of hydrophilic molecules can be used for this modification. The most known hydrophilic molecule is polyethylene glycol (Rhim and Ng 2007).

2.3.2 Antioxidant Properties

Nanomaterials which exhibit antioxidant properties are less reactive. Polymeric nanoparticles are released into acidic environments as they are found to be suitable for encapsulation of bioactive compounds such as flavonoids (Pool et al. 2012). To control browning of cut fruits, antioxidant treatment in relation to edible coating is applied (Rojas-Grau et al. 2009). Browning of fruits also known as nonenzymatic browning is the conversion of phenolic compounds into melanin which is the brown pigment (Zawistowski et al. 1991). Packaging coated with zinc oxide nanoparticles is a reliable alternative to current technologies for enhancing the shelf life of fresh cut apples (Li et al. 2007). This is because in the presence of zinc oxide, the polyphenol oxidase activity is remarkably decreased. The original appearance of the apples also persists, and the rate of browning is much lower in nano-controlled fruits (Li et al. 2011).

2.3.3 Flavour Enhancers

Flavor is the most important component of the food system. Flavor forms perception of taste and smell which increases appetite. Techniques such as nanoencapsulation have been used widely to improve the release of flavor compounds, and retention of flavor is enhanced. This maintains the culinary balance (Nakagawa 2014). For carrying flavors in food or fragrance, silicon dioxide nanomaterials are used (Dekkers et al. 2011).

2.3.4 Color Additives

To use any kind of food color additive, it has to be first approved by the office of Cosmetics and Colors in the Center for Food Safety and Applied Nutrition and the US FDA. It has to be used in accordance with the approved uses, specifications, and restrictions. As the die of nanotechnology has emerged, a variety of nano-scale color additives are being approved as they help to psychologically appeal the consumers. Titanium dioxide has been approved by the US FDA and is being used as a color additive with the condition that the limit should not exceed 15 WW (FDA) and no certification is required any longer. There are other elements used along with titanium dioxide, namely, silicon dioxide and aluminum trioxide, as dispersing agents in color additives. However, they should be not more than 2%. Carbon black is no longer certified to be used as a color additive (FDA 2015).

2.3.5 Anticaking Agents

Anticaking agents are used to thicken pastes by maintaining flow of powdered products. For this purpose, silicon dioxide is used. It is also used as a flavor and fragrant carrier in many food products (Dekkers et al. 2011).

2.3.6 Nano Additives and Nutraceuticals

They improve nutritional value of the food. Nanoparticle-based tiny edible capsules with the aim to improve delivery of medicines, vitamins, or fragile micronutrients in the daily foods are being created to provide significant health benefits (Yan and Gilbert 2004; Koo et al. 2005). The nanocomposite, nano-emulsification, and nanostructuration are the different techniques which have been applied to encapsulate the substances in miniature forms to more effectively deliver nutrients such as protein and antioxidants for precisely targeted nutritional and health benefits. Polymeric nanoparticles are found to be suitable for the encapsulation of bioactive compounds (e.g., flavonoids and vitamins) to protect and transport bioactive compounds to target functions (Langer and Peppas 2003).

2.3.7 Enhancement of Properties of Packaging

Nanomaterials are also developed to improve the physical and mechanical nature of food by altering the strength, permeability of gas, firmness, liquid resistance, and fire resistance. The application of nanoparticles is not limited to antimicrobial food packaging, but nanocomposite and nanolaminates have been actively used in food packaging to provide a barrier from extreme thermal and mechanical shock extending food shelf life. For providing these particular properties, the latest technology developed is polymer nanocomposites that can actively be used in the food packaging industry.

These polymer nanocomposites are believed to have the ability to completely alter the food packaging industry as they are much stronger, more flame resistant, and have a role in UV protection (Lizundia et al. 2016). To avoid the use of synthetic packaging material made of plastics, alternative biodegradable nanomaterials are being developed from renewable sources and are known as biopolymers. These biopolymers can be used for disposable items (Rhim et al. 2013; Avella et al. 2005).

The edible nano-coatings on various food materials could provide a barrier to moisture and gas exchange and deliver colors, flavors, antioxidants, enzymes, and anti-browning agents and could also increase the shelf life of manufactured foods, even after the packaging is opened (Weiss et al. 2006). Encapsulating functional components within the droplets often enables a slowdown of chemical degradation processes by engineering the properties of the interfacial layer surrounding them. For example, curcumin the most active and least stable bioactive component of turmeric (*Curcuma longa*) showed reduced antioxidant activity and found to be stable to pasteurization and at different ionic strengths upon encapsulation (Sari et al. 2015).

2.4 Health Hazards Related to the Use of Nanotechnology in Food Processing

Besides a lot of advantages of nanotechnology to the food industry, safety issues associated with the nanomaterial cannot be neglected. Many researchers discussed safety concerns associated with nanomaterial use in food (Bradley et al. 2011; Jain et al. 2016). With the advent of nanotechnology, it is becoming inevitable that human beings won't be exposed to nanoparticles (Magnuson et al. 2011). There are many products that are being manufactured through the use of nanotechnology, and they may lead to dangerous health problems in consumers. Nano-emulsion is one of the areas that could lead to physical discomforts, and these effects are associated with particle size as absorption and metabolism of nano-emulsions changes as the size is minimized (Chawengkijwanich and Hayata 2008). Digestible/indigestible and organic/inorganic particles have different outcomes in the biological system (Chen and Evans 2005). If nano-emulsions are consumed at a very high level, then they might be harmful as they are made of chemical components such as surfactants and solvents. Also, diseases such as obesity and those related to heart can be a result of the high lipid content by which nano-emulsions are made (Fujishima et al. 2000).

When nanoparticles deposit themselves in the body, they can lead to cell damage in the body as they attach to the cells in the immune system and stun them (Jordan et al. 2005). Protein catabolism can occur as sometimes nanoparticles get smeared with proteins. Another category of nanoparticles that can cause harmful damage are silver nanoparticles. They disrupt the working of the lung by decreasing the ATP amounts and hindering the activity of mitochondria and DNA (Kim et al. 2007). Therefore, it is reported that silver nanoparticles along with being toxic are also carcinogenic. Carcinogenesis occurs because the small size of the nanoparticles allows them to pass through the cell barrier, and this leads to the production of free radicals which leads to oxidative changes in the tissue (Maness et al. 1999). The skin and lungs can also be damaged by toxic effects of carbon nanotubes that find their application as food packaging materials (Mills and Hazafy 2009).

Nanoparticles can also come in direct contact with organs especially if they are used as food additives (Jovanovic 2015). A study was conducted, and it was found that most of the chewing gums had 93% of titanium oxide in them that could release and get deposited in the body slowly (Tang et al. 2009). Direct contact of nanoparticles occurs when nanoencapsulation is undertaken. This happens through oral routes of food intake. Silicon oxide enters the body in this manner as it acts as carrier of flavors in food (Dekkers et al. 2011). Edible coatings that are nano in size increase the shelf life of food and prevent bacterial infestation, but these permit direct contact of humans to nanoparticles (Flores-Lopez et al. 2016; McClements 2010). Unintentional exposure of nanoparticles is also possible as the nanoparticles leak out of the nano packaging (Han et al. 2011). Aluminum can migrate into the food contents by leaching (Garcia et al. 2010). The toxicity of the nanomaterials depends upon the amount ingested and also the physical and chemical characteristics (He et al. 2010, 2015).

Major health hazards that are of supreme concern are discussed below:

- **Allergic Reaction**
- Even though nanomaterials are developed keeping in mind the allergic reactions that can be triggered, some nanoparticles can be a triggering factor which may cause pulmonary allergic reaction (Ilves and Alenius 2016). A prevalent immune response initiated by exposure to nanoparticles is increase in inflammation and ROS reduction. Silver nanoparticles can initiate nano-specific response of the immune system (Hirai et al. 2014). Other nanoparticles that may cause inflammation due to allergy are made up of carbon. It has been suggested that lung inflammation is enhanced by the use of carbon nanotubes (Nygaard et al. 2009).
- **Release of Heavy Metals**
- Nanomaterials made of heavy metals and combined with food polymers can increase barrier activity, avoid degradation of plastics through light, and are effective in prevention of microbial activity (Llorens et al. 2012). Toxicity is majorly related to the release of heavy metals from nanoparticles (He et al. 2015). Thus, accumulation of these heavy metals is a major area of concern. The most common metals that are known to discharge these metals are zinc oxide, silver, and copper oxide (Karlsson et al. 2013). The release of such metals leads to preoccupation of lipids and subsequent DNA damage in the body (Fukui et al. 2012).

2.5 Challenges to Food Nanotechnology

The main priority in the food industry is quality and safety standards related to food. Therefore, assessment of health risks in this field becomes supreme. Research related to toxicity of nanoparticles has become an important part of the food industry. Careful attention needs to be paid in this area of research, especially those related to gastrointestinal functioning and the side effects these may pose. There are serious implications of nanoparticles on health when their concentration in the body increases, which can lead to gradual cell disruption. Concerns also arise among scientists, as the use of nanomaterials in food is increasing. There is great amount of information on nanoparticle toxicity, but the consumers are not open to this issue. The reason for this is that there are insufficient facts in relation to the tests conducted (Suh et al. 2008). Hence, it becomes essential to formulate standard policies for measurement of risk. Also, there is discrepancy in results that are acquired for humans and lab animals (Maynard and Kuempel 2005).

For full knowledge of the threats that nanomaterials pose in the food industry, require improvement in three major areas.

- First, there are unique characteristics of nanomaterials that require specialized methods of research. This undermines the position of conventional techniques. Traditional techniques are not very applicable when toxicity needs to be measured in carbon nanotubes. Since nanomaterials can be cytotoxic, provisions need to be made to take care of this area (Monteiro-Riviere et al. 2009). Specific methods of analysts are needed to monitor toxic effects of nanoparticles. There is absence of systematic classification of nanomaterials. Published guidelines necessary for synthesis of nanomaterials are lacking. This creates reluctance and hesitance on the part of customers to invest in food products formulated with nanotechnology (Marquis et al. 2009).
- Another challenge that arises is that the physiochemical properties of nanoparticles change as they undergo formulation, preparation, incorporation into food, and ultimately digestion and absorption. The size of nanoparticles needs to be considered depending on the route of exposure in humans when ingested as they can initiate an immune response (Borm and Kreyling 2004). Different levels of crystallinity in the chemical composition of nanomaterials may have different cytotoxic effects (Braydich-Stolle et al. 2009).
- The routes and pathways that determine the uptake of nanoparticles must be carefully investigated (Li et al. 2007). To determine the kind and level of harm that nanoparticles can lead to in various cells and tissues, the intensity of their contact needs to be evaluated. The three major ways that nanoparticles can enter the body are through the skin, nose, and mouth (Oberdörster et al. 2007). Nanomaterials can enter the body through any path. When nanoparticles are produced in food industries, it is possible that some of the components spread into the air, and this is how nanoparticles can pass through the respiratory path (El-Badawy et al. 2010). Respiratory path also becomes a target when nanoparticles find their application in packaging. Respiratory path can also give way to the digestive tract, and these nanoparticles accumulate inside the body (Maynard and Kuempel 2005).

2.6 Regulations and Nanotechnology

Many regulations are being imposed about the use of nanomaterials in food. The institutions that are involved in suggesting such regulations are the European Food and Safety Authority (EFSA), Environmental Protection Agency (EPA), Food and Drug Administration (FDA), National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), US Department of Agriculture (USDA), Consumer Product Safety Commission (CPSC), and US Patent and Trademark Office (USPTO) (Qi et al. 2004).

Industries involved in food processing and packaging must work according to the regulations made by these bodies. The institution involved in formulation of rules and a policy regarding nano-scale materials and the harmful effects it may have on consumers is known as the European Parliament and Council Legislation (Quintanilla-Carvajal et al. 2010). If nanoparticles are to be used as a food additive, a size must be maintained. To ensure that freely engineered nanoparticles are not added to food extensively, the precautionary principle must be undertaken by the food industries (Rhim and Ng 2007).

Nanoparticles can be introduced into foods only after careful research and development. When nanoparticles are designed, they must meet the regulations that are set by the EC Food Law Regulation so that they can be used in food items. According to the set regulations, nanoparticles which are designed should be toxic and heavy metal free (Scampicchio et al. 2008). According to the regulatory bodies in Europe, additional substances that are added to food should not alter the original and organoleptic characteristics of food (Silva et al. 2012). The substance should become a part of the food and should not lead to any kind of spoilage or prove toxic to the biological system. Before nanoparticles are added to food, they should be tested for dose response and the health risks of such substances (Sondi and Salopek-Sondi 2004). Hence, any industry, institute, or individual, who has undertaken the job of designing nanomaterials that can be added to food, should follow these regulations. In India, these policies are not fully observed, and this develops a negative position for the consumers. Moreover, no official regulatory body exists that can regulate the use of nanomaterials.

2.7 Future Prospects

To find use in the food industry, there are still many nano projects that are underway and are not fully competent to be declared suitable for use in food industry. Scientists are seeking to manufacture better and more systematic nanoparticles that will be able to enhance the bioavailability without hindering on the look and flavor of the food items in which these particles are added. Smart packaging is a concept that is gradually being realized as a useful method of detecting spoilage in food by microorganisms which will be possible only when biomarkers that are antigen will be developed (Graveland-Bikker and de Kruif 2006). Food-sensitive transistors are also being researched about that can detect the slightest change in temperature, pressure, and pH. The conditions in India are completely opposite to what is practiced in developed countries as the interaction between the university and the industry is not quite established in India which is the major causative factor for backwardness of nanotechnology in commercial food products. Better devices and methods of designing are coming up in India that could harness its potential to the fullest.

2.8 Conclusion

Nanotechnology has led to revolutionary changes in the field of food processing and preservation. Nanotechnology has both pros and cons when it comes to their use in food. Nanotechnology is a million-dollar market but what holds it back is the fact that the physical and chemical properties of nanoparticles get altered when they are subjected to conditions inside the human body. Careful administration should be conducted if nanomaterials are to be introduced into food. Also, nanoparticles should be both biodegradable and nontoxic. Instead of designing nanoparticles from scratch using heavy metals and chemicals, it would be beneficial to look for naturally occurring nanoparticles in food such as casein micelles in milk. Toxicity of nanoparticles is a major cause of concern as owing to their small size, they can very easily penetrate the cells which can damage the DNA and trigger an immune response. Eco-friendly nanomaterials that are both healthy for the environment and the body need to be manufactured. As the size of the particles decreases, the health risks it poses begin to increase. Therefore, many regulatory bodies all over the world are attempting to implement safe standards and policies that can reduce the ill effects of nanomaterials. The biggest drawback that limits the use of nanomaterials is that they are still undergoing research, and therefore, the extent to which they can be harmful is not yet clear.

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Quality of Indian Sugars: Opportunities and Challenges

3

Anushka Agarwal and Narendra Mohan

Abstract

Sugar is considered as a food item which has multiple uses in the life of a common man both for direct and indirect consumption. India is considered as "Sugar Bowl" of the East producing approx. 15% of the total world sugar production. However, cyclic ups and downs of the sugar production have become the trademark of the Indian Sugar Industry and have affected the sustainability of the industry. While during surplus production the country faces problem in disposing off the plantation white sugar being produced by most of the sugar factories in international market due to quality constraints, in case of shortages, we find ourselves short of infrastructural facilities to refine the raw sugar. In India which is the world's largest sugar consumer, the total sugar use in the country grew from 17.527 million tons in 2005 to 26.001 million tons in 2014, an impressive average annual growth of 3.4%. However, interestingly, the consumption patterns in India indicate that approx. 60% of the sugar production goes to bulk consumers, that is, to beverage, confectionary, and pharmaceutical industry, where the demand has been growing at a steady pace from the last several years. The reasons behind the continuing growth in industrial consumption have been demographic changes, income growth, and growth in the share of urban populations, leading to a higher use of convenience food, sugar-rich confectionery, and soft drinks. This chapter reviews the global and Indian sugar scenario, consumption patterns, and efforts required to be made to produce superior quality sugar not only to cater to the specific need of bulk consumers but also to make Indian sugars globally competitive.

Keywords

Refined sugar · Sulfur-less sugar · Plantation white sugar

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3.1 Introduction

Cyclic ups and downs of the sugar production have become the trademark of the Indian Sugar Industry. While during surplus production the country faces problem in disposing off the plantation white sugar in international market due to quality constraints, in case of shortages, we find ourselves short of refining capacity for taking care of the imported raw sugar. At the global level, overall sugar consumption has been growing by just below 2.0% a year, but there has been a flat or slow-growing direct or tabletop consumption and rapid growth in industrial (or indirect) consumption through sugar-containing products. The reasons behind the continuing growth in industrial consumption at the expense of direct use of sugar have been demographic changes, income growth, and growth in the share of urban populations leading to a higher use of convenience food, sugar-rich confectionery, and soft drinks.

For the Indian industrial buyers or bulk consumers, there is growing awareness about the quality of the sugar, its processing under hygienic conditions, and packing for stable storage besides aspiring for special sugars or table sugars, the production of which invariably requires the refining route. An attempt has been made here to review the global and Indian sugar scenario/consumption patterns to give an idea about the necessity of producing sugar as per demand rather than producing a quality of the sugar.

3.2 Domestic and Global Sugar Consumption Patterns

There is greater need for understanding the sugar consumption patterns to decide on the quality parameters of sugar as moving from direct to indirect use of sugar; it becomes the dominating factor. It must be understood that broadly three types of sugars are produced on a larger scale (i.e., raw sugar, plantation white sugar, and refined sugar). While raw sugar produced from cane or beet juice is not used for human consumption and mostly acts as a raw material for the production of refined sugar, plantation white sugar is fit for direct consumption produced from cane or beet juice.

However, the refined sugar is of superior quality as compared with plantation white sugar and remains as the first choice for the beverage, pharmaceutical, and confectionary industry. It is pertinent to mention that one distinct advantage of refined sugar is of being sulfur-less, whereas plantation white sugar generally produced in our country contains up to 50 ppm of sulfur content due to the limitation of processing technology. Thus, there is need for production of the desired quality of sugar as per market demand rather than doing it in an arbitrary manner. A quality comparison of these types of sugars as per the BIS specifications is given in Table 3.1 (BIS Standards):

The consumption behaviors are as discussed in the following paragraphs which throw light on the importance on deciding the production of a type of sugar as per consumption and market requirement (ISO 2016).

Table 3.1 BIS specifications for raw, plantation white, and refined sugar

S. no.	Particulars	Raw sugar (IS 5975:2003)	Plantation white sugar (IS 5982:2003)	Refined sugar (IS 1151:2003)
1.	Loss on drying, percentage by mass, max	–	0.10	0.05
2.	Polarization, min	96.5	99.5	99.7
3.	Reducing sugars, percent by mass, max	1.0	0.10	0.04
4.	Color in ICUMSA units	–	150	60
5.	Conductivity ash, percentage by mass, max	0.8	0.10	0.04
6.	Sulfur dioxide, mg/kg, max	2/	70	15
7.	Crystal size material to be retained on 500 microns IS sieve percentage, min	95.0		
8.	Mean aperture	–		
9.	Coefficient of variation (%)	–		
10.	Lead, mg/kg/max	–	5.0	0.5
11.	Sediment	–	–	–
12.	Floc test	Negative	–	–
13.	Chromium µg/kg/max			20

3.3 Brazil

As far as Brazil, the biggest sugar producer, is concerned, the share of industrial use in the total consumption has suffered slow erosion, decreasing from 51.1% in 2005 to 49.9% in 2014. By contrast to industrial and direct consumption, the share of nonfood use (mainly to produce monosodium glutamate, amino acids, and pharmaceuticals) has more than doubled since 2005. In 2015, its share of the market reached nearly 12%.

Sugar use by the soft drinks industry decreased considerably within the last decade, from the average of 1.7 million tons (2005–2009) to 0.98 million tons (2010–2014) and further to just 0.89 million tons in 2015/2016 which is mainly attributed to a general trend toward a decrease in consumption of soft drinks in Brazil due to growing consumer awareness around sugar-related claims on food and beverage products (Fig. 3.1).

3.4 Thailand

As regards, Thailand, the world's fifth largest sugar producer and second largest exporter, is also a large sugar consumer with a per capita consumption considerably higher than the world average. The sugar consumption grew from 1.809 million tons in 2001 to 2.806 million tons in 2015, corresponding to an average growth rate of 3.3% a year (Fig. 3.2).

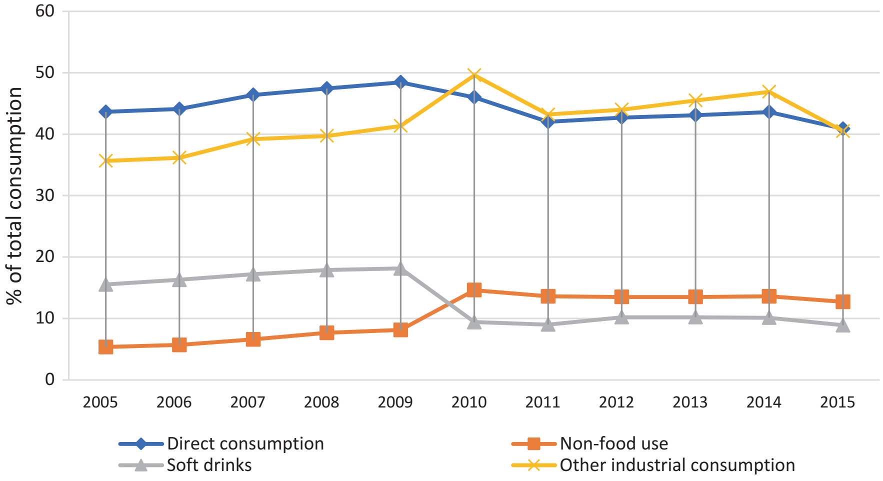

Fig. 3.1 Brazil: Sugar consumption structure

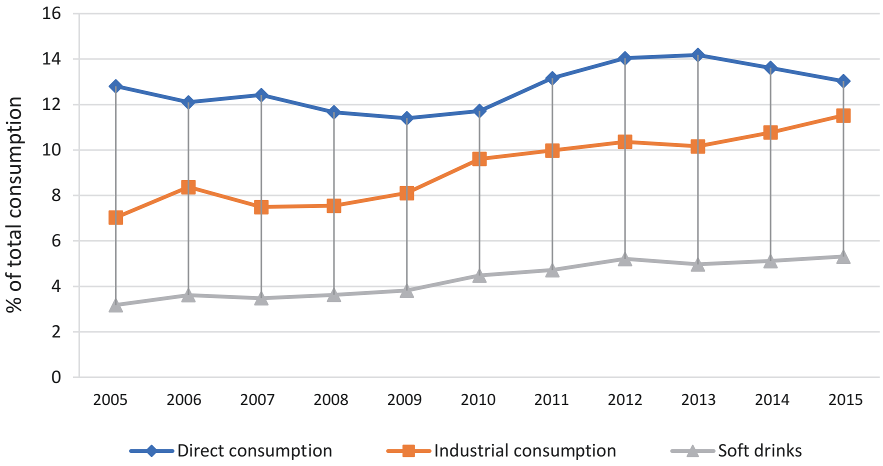

Fig. 3.2 Thailand: Sugar consumption

It may be seen from the above graphical representation that direct consumption of sugar is falling slowly but steadily, and its share in the total use of sugar has been diminishing. Currently, direct consumption is responsible for less than 53% of the total, compared to about 63.5% in the middle of the 2000s. At the same time, industrial consumption is growing. The use of sugar by the food and beverage industries is the main factor behind the overall increase. Since 2005, industrial use grew from 703,000 tons to 1.077 million tons.

3.5 China

Despite a marked growth in consumption over the past few years, the country belongs to the group of about 30 countries with the lowest (less than 12 kg) per capita sugar consumption. It can be also noted that China's sweetener market is comprised of three sectors: sugar, intensive sweeteners, and corn sweeteners (locally known as starch sugars). Sugar is the dominant but not the only sweetener. Currently, sugar's share of the total sweetener demand does not exceed 70% (ISO estimate). Even when other sweeteners (both caloric and artificial) are added, China's per capita consumption amounts to about 15.0 kg, compared with the 2012 Far East average of 16.0 kg (Fig. 3.3).

Although sugar consumption has been growing strongly in recent years, sugar consumed directly and via sugar-containing products accounts for less than 2.5% of the total calorie intake, as against the world average of 6.8% in 2011. In ISO 2010 survey, it was noted that the emerging national sugar market had a very interesting consumption structure. In contrast to the consumption patterns in most developing economies, direct consumption represented only about one third of the total and grew faster than industrial use.

As noted in a recent USDA GAIN report 12, the growth in industrial sugar consumption has slowed over the past 2 years, along with overall economic growth. However, in 2015, certain high-sugar processed foods showed a robust growth. Data from the National Bureau of Statistics suggest that in 2015 food manufacturing in China grew by 6.8%. Frozen pastry and dessert production grew by 5.1% to reach 2.8 million tons, and the beverage industry (including wine, soft drinks, and refined tea) grew by 8%.

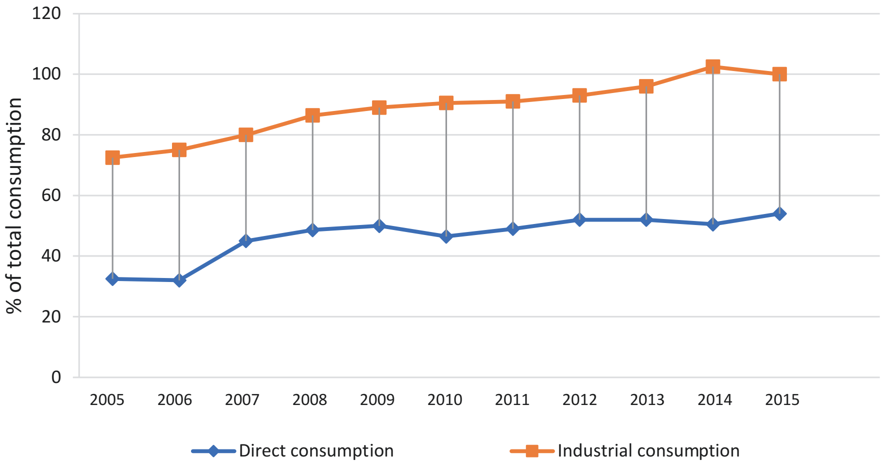

Fig. 3.3 China: Structure of sugar consumption

3.6 India

Coming to India which is the world's largest sugar consumer, the total sugar use in the country grew from 17.527 million tons in 2005 to 26.001 million tons in 2014, corresponding to an impressive average annual growth of 3.4%. Per capita consumption also shows an average annual growth of 1.6%, improving from 16.3 kg in 2006 to 19.8 kg in 2015, which indicates that consumption dynamics are driven by both population and income growth. According to a recent USDA report, the industrial users' share in total sugar consumption has shown a further increase to 65%. As suggested by ISMA and other reports available, bulk consumers contribute for 60%–65% of the total sugar consumption in the Indian market (ISMA 2005–2006; Mohan and Kanaujia 2019).

It is pertinent to mention that out of the 532 sugar factories in operation, only 30 odd sugar factories have facility to produce refined (sulfur-less) sugar, whereas others produce plantation white sugar in the conventional manner (Mohan 2018). With the industrial buyers in the domestic market demanding for a superior quality white sugar and other special sugar, namely, icing sugar, cube sugar, and pharmaceutical sugar, the same can be met easily by following the refined sugar route rather than playing around to modify the existing double sulphitation process of plantation white sugar which is also not considered as an environment-friendly process. The raw-refined sugar route has another distinct advantage of developing facilities to take care of excess or shortfall of sugar production by way of export or import of sugars as during the course of surplus of sugar production, either raw or refined sugar can be exported (most of the global trades are either in the form of raw and refined sugar only), while during shortage, the raw sugar can be imported for refinement and subsequent use (Fig. 3.4).

3.7 Conclusion

- Future of the sugar production lies in adoption of raw-refined sugar route keeping in view the sector-wise demand, particularly, industrial sector, and for better sustainability during both surplus and deficient sugar production scenarios.
- The quality of plantation white sugar being produced in the country is inferior to the refined sugar in terms of sucrose %, invert sugar %, ash %, and color value, and when the general consumer is more quality conscious, refined sugars can find their market easily. The consumer may not mind paying a higher price for the quality of the product.
- Refined sugars shall be the first choice of the food processing industry including beverage, confectionary, and pharmaceutical industry, and the sugar-producing units shall be able to earn price premium over the produce, nullifying the increased cost of production as compared with the plantation white sugar being produced at present.
- Development of refined (sulfur-less) sugar production will pave way for production of many other special sugars, namely, icing sugar, pharmaceutical sugar,

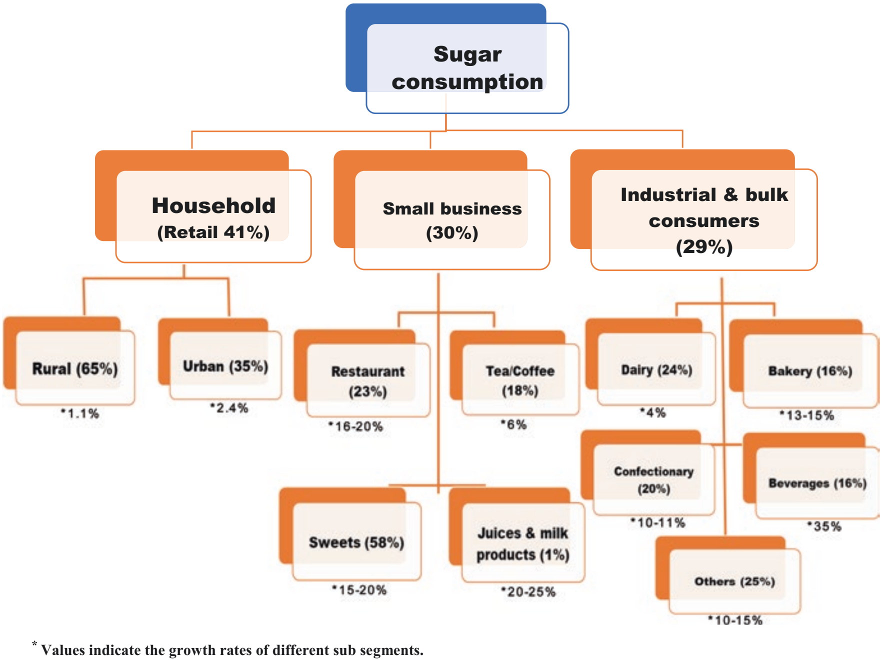

Fig. 3.4 India: Sugar consumption structure (values in brackets indicate the growth rates of different subsegments)

liquid sugar, candy sugar, cube sugar, golden sugar, and even the fortified sugars, thus earning price premium.

- There is need for developing the packaging methodology in consumer packs instead of packing it in gunny bags. This will give a sense of satisfaction to the consumer about the weight and being packed in hygienic conditions.

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Part II

Food Safety

4 Quality Issues in Meat and Poultry Processing Sector

Deepshikha Thakur, Vineet Shyam, and Varsha Singh

Abstract

Meat, poultry, and its associated products being highly perishable pose threat to transmit diseases from animals to human beings and thus are of zoonotic importance. India ranks eighth in the world for meat production, which is estimated to produce 8.89 million tons per year. In India, meat deteriorates quicker than other cold nations with humid climatic circumstances, with prevailing warm and humid climatic circumstances. Local health officials govern meat manufacturing and slaughtering under local legislation and remain a government topic. The current meat production is estimated to be 1.9 million tons; out of which about 21% is exported. The major factor contributing to foodborne disease including for meat is improper storage temperature which contributes to 63% among all other factors. The quality issues in meat and poultry processing are classified into biological, physical, and chemical. All food business operators involved in the manufacturing, processing, storing, and selling of meat, poultry, and their products are mandated to comply specific hygienic and sanitary practices provided in Part IV of the Schedule 4 of the FSSR 2011, which have been effective from 05/08/2011, and therefore contribute largely to the good quality and healthy meat for the consumers.

Keywords

Food quality · Meat · Poultry · Foodborne diseases · Hygiene and sanitary practices · Animal slaughter

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4.1 Introduction

Meat and other animal products being highly perishable in nature pose a great threat of transmitting diseases from animals to human beings. Meat deteriorates faster in India due to humid climatic conditions than in cold countries. Complex meat production parameters influence its quality during the manufacturing chain phase. Constitutionally, local health officials are tightly regulating the manufacture of meat and poultry as animal slaughtering is a state topic under local state law. With 485 million livestock population, India holds the potential for providing the growing demand for poultry meat's increasing population. Ranked eighth in the world for meat production, India provides the biggest market for poultry meat as animal protein. Of the whole production of poultry meat, merely 6%, about 100,000 million tons (MT), is retailed in the processed form, and 1% undergoes processing into value-added products as ready-to-eat and ready-to-cook form. India is showing an increase in the demand for meat, and it is expected to increase over the years. With economic growth rising with per capita income, enhancing trends in urbanization, and raising awareness of the dietary value of meat and its goods, meat and egg demand is estimated to achieve eight million tons by 2020. The existing meat production is approximately 1.9 MT and about 21% is exported. There is a lot of availability of raw materials for the meat and poultry processing industry. India ranks on top in the world buffalo population (97 million), second highest in number of cattle and goats (185 and 124 million, respectively), third highest in the number of sheep (97 million), fourth highest in the number of ducks (33 million), fifth highest in the number of chickens (457 million), and sixth highest number of camel population (632 million) (Animal Husbandry Statistics 2017).

The meat quality production and its export depend on the consumers' demands. The global meat industry seeks quality that becomes essential to provide full control of the manufacturing and processing of poultry in order to satisfy global norms and laws. Poor quality meat is posing more threat to human health in the coming times. Use of antimicrobials is ever increasing, but still not enough to destroy the microbes as the drug-resistant bacteria are passed through the food chain to the consumer.

Many pathogens of concern do not cause any clinical symptoms or lesions in affected animals. Microbes such as *Salmonella*, *Toxoplasma*, *Trichinella*, *Campylobacter*, and *Yersinia*, can solitary be detected through precise targeted monitoring systems.

Before the repealing of Meat Food Products Order (MFPO) 1973, the processing of meat was being licensed under MFPO of 1973 until 04/08/2011. The food business operators (FBOs) engaged in manufacturing, processing, storing, and selling of meat and its associated products shall be required to comply specific hygienic and sanitary practices provided in Part IV of the Schedule 4 of the FSSR, 2011 effective from 05/08/2011 (Kumari and Kapur 2018).

4.2 Quality Issues in Meat and Poultry

The meat quality is defined by many significant variables such as lean-to-fat ratio and palatability factors such as visual appearance, odor, firmness, juiciness, tenderness, and taste.

Age, sex, strain, diet, intramuscular fat of the animals along with meat moisture content, preslaughter conditions, and various other processing variables also affect the poultry meat color (Jooa et al. 2013).

Wholesome meat should be nutritious, with minimal microbial contamination. Chemical residues should not be above acceptable limits. The major factors affecting the number of characteristics that determine the overall quality of meat and poultry are as follows:

- Appearance—Color
- Texture—Tenderness
- Flavor—Taste and odor
- Availability—India is the ninth largest producer of poultry meat
- Ease of preparation—Type of animal, age, muscle, and origin
- Shelf life—Spoilage organisms, temperature history of the product
- Quality retention—Fresh, high-quality meat
- Safety—Healthy, 165 °C cooking temperature
- Purity—Antemortem and postmortem inspection
- Nutrient content—Magnesium, zinc, iron, vitamins (B and E)
- Nutrient availability—Protein rich, risk reduction for obesity, overweight, and diabetes
- Caloric value—272 calories/100 g

4.3 Types of Food Contamination in Meat and Poultry

4.3.1 Biological Contamination

The major contamination source of microbes comes from external sources specially during handling processes such as bleeding, skinning, and cutting. The main sources of microorganisms are intestinal tract and the edible parts of animals. Knives, cloths, air, hands, and clothing of the workers can also serve as an intermediate source of contaminants. Molds and bacteria of many genera may reach the surfaces of meats and grow on the meat to be processed. Most common bacterial species that contaminate meat are *Salmonella*, *Campylobacter*, *S. aureus*, *E. coli,* and *Listeria*; fungal species are *Cladosporium, Sporotrichum, Geotrichum, Thamnidium, Mucor, Penicillium, Altemaria,* and *Monilia* (Blackburn 2001). Mycotoxins, characterized as secondary metabolites from toxicogenic microscopic fungi, also contribute toward biological contamination of meats (Erdtsieck 1989). Some foodborne diseases in humans that occur after the consumption of meat and poultry are because of lack of proper management practices. Of the many, 12% occur due to food from unsafe sources, 63% due to improper storage temperature, 28% due to personal hygiene, 23% due to contaminated equipment, and 21% due to inadequate cooking (Bryan 1998).

4.3.2 Physical Contamination

Not only the biological contamination poses a threat to the health of consumers, but the animal products are also prone to physical hazards especially in the finished products. Various sources such as contaminated raw materials, badly designed and/or maintained facilities and machinery, defective meat handling processes, and unsuitable worker training and practices lead to meat physical contamination. Other physical contaminants also include glass, metals, stones, plastics, needle, among others.

4.3.3 Chemical Contamination

Chemical contamination can be caused by either intentional food additives or unintentional food additives. Some intentional food additives used directly are preservatives, artificial flavor enhancers, and color additives. Indirect food additives include boiler water additives, peeling aids, defoaming agents. Unintentional food additives are usually self-invited which include pesticides, antibiotics, animal hormones, harmful toxins, fertilizers magnified during grazing, fungicides, heavy metals in water contamination, color additives, inks, indirect additives, packaging materials, lubricants, paints, and coatings (Hui 2012).

4.4 Hygienic and Sanitary Practices

The following criteria shall be met by FBOs slaughtering big and small animals for the production of meat products for the distribution chain to the public:

- *General:* Receiving of no objection certificate (NOC) from the local authorities prior to the grant of the license.
- *Location specific:* Meat processing unit in regions not subject to periodic and frequent flooding should be situated. The place should be free from objectionable odors, smoke dust, and other environmental contaminants and should be provided with appropriate drainage and cleaning, and the units should be as such to control access inside.
- *Premise requirements:* Slaughterhouse should have separate room for separate purposes. After every operation, it should be sanitized thoroughly. The internal walls of the slaughterhouse and the nearby areas should be surfaced with impervious glazed tiles up to a height of1 m in case of poultry and small ruminant animals and 5 m in case of large ruminant animals. Epoxy-coated walls and

floors should be designed, and separate slaughter rooms and compartments shall be built for edible products for their processing and handling. The construction of the areas requires adequate ventilation, good natural or artificial lighting, and easy cleaning. The area should also facilitate proper supervision of meat hygiene including performance, its inspection, and control, and guard against the entry of insects, birds, rodents, or other vermin. Adequate facilities should be constructed to prevent the entry of aforementioned environmental contaminants. Buildings should be designed in a way such that it includes a separation between areas which may cause cross contamination. Waterproof, nonabsorbent, washable non-slippery floors should be constructed using nontoxic materials. Walls also should be of waterproof, nonabsorbent, washable, and nontoxic materials and with light colored paint. They should be smooth and without crevices and should be easy to clean up to a height of at least 1.5 m. Ceilings should be designed, constructed, and finished in a way to prevent accumulation of dirt and minimize condensation and mold development. Doors must have nonabsorbent surfaces and be self-closing and close fitting. Stairs lift cages, and supporting structures such as platforms and ladders should be situated and constructed as not to cause contamination of meat. Adequate natural or artificial lighting should be provided throughout the meat processing unit. The lighting should not alter colors, and the intensity should not be less than 540 Lux (50 foot-candles) at all inspection points, 220 Lux (20 foot-candles) in work rooms, and 110 Lux (10 foot-candles) in other areas.

- *Sanitary practices:* All surfaces, above the floor and pavement of slaughterhouses, should be regularly and thoroughly washed with hot lime wash. The premises of slaughterhouses should be regularly and thoroughly cleaned with effective disinfectants. Animals such as dogs, cats, or birds should be strictly prevented to have access to the slaughter hall. Supply of potable water under pressure should be available with facilities for its storage (Cartoni Mancinelli et al. 2018). Hot potable water supply should always be available during working hours. Ice should be made from potable water as well and should be properly manufactured, handled, and stored in order to avoid contamination. Steam used in contact directly with meat should be produced from potable water and should be free of hazardous materials and chemicals which may affect health or may contaminate the food. Facilities in the slaughterhouse should contain space for the storage of waste and inedible material prior to removal from the establishment. The facilities should be designed in a way to prevent access to waste or inedible material by pests and avoid contamination of food, potable water, and equipment or building. Changing facilities and toilets should be provided in all establishments. These facilities should always be properly maintained. Handwashing and drying area should have access to warm, hot, and cold water with hygienic means adjacent to the toilets and processing area. Appropriate facilities for hand disinfection should always be provided. All areas used for processing and handling of meat should be equipped with adequate cleaning and disinfecting facilities. Proper ventilation should be present to remove contaminated air and prevent excessive heat, steam condensation, and dust. The direction of the air flow should always be from a clean area to other areas. Ventilation openings should be provided with an insect screen or other protective enclosure of noncorrodible material.

- *Equipment and machinery:* The equipment, implements, and utensils used in the establishments which are exposed to meat and meat products should be smooth surfaced and corrosion resistant. These should be made of nontoxic material that does not transmit any odor or taste, is free from pits, is nonabsorbent, and capable of withstanding repeated exposure to normal cleaning and disinfection. All equipment and utensils should be so designed and constructed as to prevent hygiene hazards and permit easy and thorough cleaning and disinfection and where practicable be visible for inspection. Temperature measurement facilities should be available in all refrigerated spaces. Equipment and utensils used for inedible material or waste should be so identified and should not be used for edible products.
- *Infrastructure maintenance:* Buildings, rooms, equipment, and other physical facilities of the meat processing unit, including drains, should be maintained in good repair and in orderly condition. Amenities provided for the use of employee and the inspection service including changing facilities, toilets, and the inspection office space should always be kept clean. The temperature in rooms for boning out and trimming should be maintained so that the contamination is minimized. All equipment, implements, tables, utensils, mechanical instruments, and containers should be cleaned at regular intervals during the day in order to prevent contamination of meat or immediately cleaned and disinfected whenever they encounter diseased material, infective material. Immediately after the cessation of work for the day or at such other times as may be required, the floors and walls should be cleaned to remove contamination.
- It is desirable that each meat processing unit in its own interest designates a single individual whose duties are diverted from production, to be held responsible for the cleanliness of the meat processing unit. The staff should be a permanent part of the organization or employed by the organization and should be well trained in the use of special cleaning tools, methods of dismantling the equipment for cleaning, and in the significance of contamination and the hazards involved. A perpetual cleaning and disinfection schedule should be followed to ensure that all parts of the meat processing unit are cleaned appropriately. Waste material should be handled in such a manner so as to exclude contamination of food or potable water. Precautions should be taken to prevent access to waste by pests. Daily removal of meat handling waste should be done in all the working areas. Immediately after disposal of the waste, storage containers and other equipment which has come into contact with the waste should be cleaned and disinfected. At least daily, the waste storage area should also be cleaned and disinfected.
- *Pest control:* Meat processing units and adjoining areas should be routinely examined for evidence of infestation. Control measures involving treatment with physical or chemical or biological agents should only be undertaken by or under the direct supervision of personnel who have a thorough understanding of the

potential hazards to health resulting from the use of these agents. Pesticides should only be employed if other precautionary methods cannot be used effectively. Only pesticides approved for use in the meat processing unit by competent authority should be used, and the greatest care should be exercised to prevent any contamination of the meat equipment or utensils. Pesticides or other substance which may represent a hazard should be labeled with a warning about their toxicity and use.

- *Personal hygiene:* It is mandated that the person who meets meat handling units in the course of their work should have a medical examination prior to their employment. Medical examination of a meat handler shall be carried out routinely or when clinically or epidemiologically indicated, at least once in 12 months. The management should take care to ensure that no person, while known or suspected to be suffering from, or to be a carrier of a disease likely to be transmitted through meat or while afflicted with infected wounds, skin infections, sores, or with diarrhea, is permitted to work in any area in any capacity in which there is any likelihood of such a person directly or indirectly contaminating meat with pathogenic microorganisms. Every person engaged in a meat handling area should wash his hands frequently and thoroughly with a suitable hand cleaning preparation under running potable water while on duty. Hands should always be washed before commencing work, immediately after using the toilets, after handling contaminated material, and whenever else necessary (Hoffmann et al. 2017).
- Every person engaged in an area in meat processing unit where meat is handled should maintain a high degree of personal cleanliness while on duty and should always while so engaged wear suitable protective clothing including head covering and footwear. Aprons and similar items should not be washed on the floor. Any behavior which can potentially contaminate the meat such as eating, use of tobacco, chewing, and spitting should be prohibited in any part of meat processing unit used for the preparation, handling, packaging, or transportation of meat. Every person who visits an area in any meat processing unit where meat is handled should wear clean protective clothing and head cover.

4.5 Handling of Animal

- *Preslaughter*: Animals in healthy conditions should be transported unless they are meant for emergency slaughter. The concerned owners or corporations should receive proper certification from a qualified veterinary inspector indicating animals are free from infectious diseases and ectoparasitic diseases. The procedures of properly vaccination should be followed, and animals should be kept in quarantine for 30 days during transport from endemic areas of disease to nonendemic areas. Animals with advanced stage pregnancy should not be transported and provided with humane treatment and care during transportation. Binding and chaining of the animals should be avoided in order to support space large enough to stand or lie. Animals should not be subjected to overcrowding. Vehicles, prior to loading and transportation of animals, should be inspected for parameters such

as safety, suitability, and cleanliness. Each consignment should bear the following details: (a) the number and type of animals loaded; (b) the name, address, and telephone number, if any, of the consignor; (c) the address and telephone number, if any, of the consignee; and (d) feeding and watering instructions.
- *Slaughter:* Animal slaughtering is first carried by stunning and then getting them exsanguinated. Unconsciousness and insensibility are induced which can help avoid stunning and minimize fear and anxiety among the animals, minimizing their reactions to pain and suffering to a great extent. Anyone of the mechanical stunning in cattle is carried: captive bolt stunning, mushroom head percussive stunning, and pneumatic percussive stunning. Electrical head stunners are usually preferred for slaughtering sheep and goat. For gas stunning, carbon dioxide concentration should be 90% by volume and not be less than 80% by volume.

4.6 Precautions for Animal Welfare

Preventive measures should be taken for causing slipping and falling of animals. High pitch sounds cause much distress to the animals. Poultry animals for slaughter plants should be kept clean under hygiene conditions with continuous monitoring of their health conditions. Crate/cage damage should be avoided in order to prevent injuries to the poultry. Proper ventilation should be provided in the storage sheds with climate control fans and curtains. Equipment used for stunning should be properly maintained prior to slaughter. Following critical factors which should be properly designed and executed for animal welfare:

- Employee supervision and training model
- Animal transport cart and unloading bay
- Construction of holding/resting pen, stunning box, maintenance of stunning equipment, restraining systems, gates, and other animal handling equipment
- Avoiding distractions for animals, hence their refusal for movement
- Monitoring time arrival to the plant
- Equipment design in the slaughterhouse

4.7 Precautions for Poultry Welfare

A model welfare program is important for pick up, transport, and broiler/chicken processing sectors. To develop the model, processing units should well as in their own quality and manuals (Berghaus and Stewart-Brown 2013):

1. *Catching:* Clean and good health poultry should be chosen. The precautionary measure should be strictly followed in order to minimize harm to the poultry. Proper training should be given to the catcher.
2. *Transport:* Good quality crates should be used. Any damage can allow room for harm to the poultry or allowed crates to accidentally open during transportation.

No caret should be overfilled, but enough space should be provided to the poultry to lie down.

3. *Holding:* Adequate ventilation and climate control such as fans or curtains should be provided.
4. *Stunning:* Stunning equipment should be properly preserved. The time between stunning and slaughter should be minimized in case the poultry may regain consciousness prior to slaughter.

4.8 Antemortem Inspection

All animals shall be subjected to rest before slaughter. An antemortem examination should also be performed well in advance before slaughter. Animals should not be removed and be kept in the slaughter hall before being slaughtered until a written consent of the qualified veterinary doctor is obtained. The animal with afebrile condition should not be permitted for slaughter. Any animal with signs of any disease at the time of antemortem inspection shall be marked as condemned and rejected. Animals upon examination if found to be a suspect shall be removed for treatment to a special pen and kept there for observation for such period as may be considered necessary. Animals which are declared as condemned on antemortem inspection shall be marked as condemned and killed if not already dead.

4.9 Postmortem Inspection

Animals should be subject to postmortem examination after slaughter and have a thorough and detailed inspection of the carcasses. Every carcass or portion of it should be examined by a skilled veterinarian. Any portion found inappropriate for human consumption shall be labeled with inspection and condemnation.

Parts and organs discovered to be healthy and suitable for human consumption are marked as being inspected and passed (Leroy and Degree 2015). A detailed postmortem inspection shall cover all parts of the carcass, the viscera, lymph glands, and organs and glands. The postmortem inspection shall be in accordance with the general rules laid down in public slaughterhouses. It should be strictly under the control of local bodies. The licensing authority may issue special directions as needed. Parts of the condemned carcasses that are not fit must be demolished in the presence of the skilled veterinarian doctor. The components should be demolished by incineration or denatured after being freely slashed with a knife or crude carbolic acid, cresylic disinfectant, or any other prescribed agent (Hobbs et al. 2002). As consumers directly go to meat shops, sanitary and hygienic requirements for retail meat shops should be strictly followed in accordance with the standard guidelines. Following points should be considered carefully:

1. Preferably, the meat shop/sale outlet should be a meat market unit. It should be situated away from the markets for vegetables, fish, or other food. There should

be no unwanted odor, smoke, dust, or other contaminants in the neighboring region. The suggested minimum distance between the licensed meat store and any place of worship should be 50 m or more and 100 m if the premises are located directly opposite the entrance door of any community's religious location (Subramaniam and Wareing 2016).

2. The size of meat stores may differ. The size usually relies on the size of the company and the operations undertaken. The height of the meat shop should not be less than 3 m, whereas it should not be less than 2.5 m in the case of air-conditioned meat shops.
3. The shops' premises must be structurally sound. The walls are created of impermeable concrete material up to a height of at least five feet from the surface of the ground. All sides should be well equipped with easy washing and cleaning purposes having a slope for easy cleaning and removal of filth, waste, and dirty water. The slope of the floor shall not be less than 5 cm for a floor of 3 m. All the fittings in the stall should be of noncorroding and non-rusting type. All processing tables, racks, shelves, boards, etc., shall have zinc/aluminum/stainless steel/marble-granite top to facilitate proper cleaning. A signboard indicating the type of meat sold shall be displayed prominently. Meat, hence, should be sold at the premises.
4. Cross-ventilation devices such as an electric fan and an exhaust fan should facilitate the meat store.
5. Appropriate arrangements should be made in the form of air curtains, flytraps, etc., for fly proofing. It should have display cabinet-type refrigerator of size for maintaining a temperature of 4–8 °C or freezing cabinet if the meat is to be stored for more than 48 h. The weighing scales used shall be of a type which obviates unnecessary handling and contamination, and the plate sketch of the scale shall be made of stainless steel or nickel coated. The knives, tools, and hooks used shall be made of stainless steel (Marangoni et al. 2015).
6. Insulated refrigerated vans should be used for the transportation of carcasses from the slaughter house to the meat shops. Under no circumstances, carcasses should be transported in vehicles used for commuting of human beings or in an exposed condition.
7. The meat shop's surrounding region should guarantee that it is free of insects, birds, and rodents. The pest control measures adopted by the owner of shop should be kept as a record, and chlorinated hydrocarbons, organo-phosphorus compounds, and synthetic pyrethroids, rodenticides, etc., should neither be used as a pesticide.
8. No employee suspected of having fever, vomiting, diarrhea, typhoid, dysentery or boils, cuts and sores, and ulcers (although tiny) is allowed to work in meat stores. All the workers of the meat shop shall keep their fingernails short and clean and wash their hands with soap or detergent and hot water before the commencement of work and after each absence. Eating, spitting, nose cleaning, or using tobacco in any form or chewing betel leaves shall be prohibited within the premises of meat shop processing, packing, and storage area of the unit.

9. Once the sliced blocked has been cleaned, warm water should be cleaned at the end of the company activity and sanitized daily by covering its top with sea salt. It is important to frequently clean and maintain the refrigerated/freezing cabinet. Only meat stores shall sell wholesome meat acquired from the approved slaughterhouse.
10. Retail meat store permit shall be given subject to compliance with all the above technical and administrative trade-related orders.

Quality meat and poultry products can be achieved by following necessary criteria instructions closely. This improves effectiveness and investment in quality training for staff. Regulation of manufacturing and management procedures, from farm to plant processing in particular, plays a significant part in the quality of poultry and meat (Petracci and Cavani 2011). The use of techniques decreases risk factors throughout the manufacturing chain, enabling better quality poultry meat to be produced for both exports and domestic markets. Worldwide demand is high, and customers need secure, healthy, nutritious, abundant, and inexpensive protein supply norms. Several international and national bodies, such as the Codex Alimentarius Commission, Food and Agricultural Organization (FAO), the International Commission on Microbiological Specifications for Foods (ICMSF), Food Safety and Standards authority of India (FSSAI), develop and provide guidelines, which are required to be followed by the FBOs to protect consumer health and ensure fair practices in food trade.

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Studies on Knowledge and Practices Among Street Food Consumers

5

Jyoti Chaudhary and Tanupriya Sharma

Abstract

In India, food vending on streets pertains to unorganized sector of food processing. The incidence of poor hygiene and lack of knowledge and sanitation can cause contamination of street-vended food. The aim of this study is to assess the knowledge and practices among consumers; there were 50 subjects chosen, mostly college-going students. A questionnaire is a tool that is used for collecting knowledge of subjects. A questionnaire consists of questions regarding general information, observations of consumers about vendors, stalls, healthy practices, and consumer's knowledge regarding street food. Consumers have enough knowledge regarding street-vended food, but there is a need for awareness among consumers. Vendors do not follow safety and hygiene practices which lead to food contamination. About 74% of consumers observed personal hygiene of vendors, while 16% of consumers do not notice about vendor's hygiene while consuming street food. There were only 67% of consumers who used to observe stall hygiene, 33% of consumers were not aware of this practice. Around 88% of consumers think consuming street food is not safe for health, while 12% think it is safe to consume street food. To reduce the foodborne illness and economic losses, the education of street vendors and consumers is considered as an effective approach. In particular, the education programs should focus on various aspects of microbiological, chemical, and physical food risks so that consumers and food handlers will change their behavior associated with poor food hygiene practice.

Keywords

Knowledge · Practices · Street food · Food safety · Consumers · Vendors · Awareness

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5.1 Introduction

In developing countries, street foods are very popular; however, the statistical data existing on foodborne outbreaks attributed to street-vended foods is very little. Also, the conditions of preparation and marketing of street foods are usually unacceptable. The common cause is that most of the street vendors are often poor, uneducated, and lack attention for safe food handling. Nowadays, street food safety is potentially a large public health concern. Due to the lack of basic infrastructure and services, the street-vended foods are perceived as a major risk for public health. The street food seller's diversity, mobility, and temporary nature; low socioeconomic and educational status; and lack of knowledge of safe food handling also contribute to a public health risk. The source of contamination of street food is mainly unsanitary handling practices of food. As far as World Health Organization is concerned, personnel involved in food handling act as a key role for incurrence of food safety in the process of food production, processing, storage, and final retail use. Unavailability of cleanliness and ignorance of food sellers allows various pathogen-borne diseases to consumers due to the consumption of those unclean foods. Biological hazards can also happen due to cross contamination by some food handlers after handling raw materials that suffer from various diseases. Poor food handling practices lead to several physical hazards.

5.2 Material and Methods

1. Sample selection and design of study—A sample is a part of population which is studied in order to make inferences about the whole populations. A group of people in the age category of 18–21 years were targeted to form sample for this study.
2. Stratified random sampling—The method involves dividing the population in homogeneous strata and then selecting simple random samples from each of the stratum. The division of the population into homogeneous strata based on one or more criteria (e.g., sex, age, class, occupation, among others).
3. Questionnaire method—Questionnaire is described as "a document that contains a set of question, the answers to which are provided personally by the respondents."

   Questionnaire contains:

- *General information*—It included information regarding name, age, gender, and socioeconomic status.
- *Consumer practices related to street food*—This part of the questionnaire is used in terms of collecting information regarding the practices of consumers.
- *Consumer consumption pattern*—This part of the questionnaire is related to information regarding the consumption pattern of consumers.

- *Observation practices of consumers regarding vendor*—This part of the questionnaire aims at collecting information regarding the vendor's personal hygiene, habits, practices, and knowledge.
- *Street food knowledge of consumers*—This part of the questionnaire aims at collecting knowledge and information of consumers regarding street food.

5.3 Observations and Discussion

About 96% of consumers have enough knowledge about street food, while 4% of consumers do not have knowledge about street food (Table 5.1). Approximately 94% of consumers have knowledge of safe food, while 6% of consumers do not have knowledge of safe food. Moreover, 90% of consumers know laws related to street food, 6% of consumers do not know, while 4% of consumers do not. Around 94% of consumers were aware about food laws, 2% were not, while 4% of consumers do not know about any law. About 86% of consumers think healthy habits can reduce the risk of diseases, while 14% do not know about this. Additionally, 88% of consumers think clean utensils decrease the risk of food contamination, 4% of consumers do not think so, while 8% of consumers do not know about this. Furthermore, 44% of consumers think it is necessary to have knowledge of safe food, 4% do not think so, while 8% of consumers do not know about this. Finally, 90% of consumers think there is a need for safety practices, 6% of consumers do not think so, while 4% of consumers do not know about the need of safety practices (Table 5.2 and Fig. 5.1).

About 94% of consumers observed personal hygiene of vendors, while 6% of consumers do not observe personal hygiene of vendors. Majority of consumers (i.e., 62%) observed hand cleanliness of vendors, 10% of consumers do not observe, and 28% of consumers do not know about the hand cleanliness of vendors. Around 62% of consumers notice that vendors wear gloves while serving food and 38% of consumers do not notice about these practices of vendors. Approximately 78% of consumers notice that vendors wear head cover while serving food, 12% of consumers do not notice, while 10% of consumers do not notice this practice of vendors. Additionally, 68% of consumers notice about the clothes of vendors, 18% of consumers do not notice, while 14% of consumers do not show interest in noticing

Table 5.1 Knowledge of consumers regarding street food ($n = 50$)

S. no	Consumer's knowledge	Yes	No	Don't know
1	Knowledge of street food	48	2	–
2	Knowledge of safe food	47	3	–
3	Laws related to street food	45	3	2
4	Name any food law	47	1	2
5	Healthy habits reduce risk of diseases	43	–	7
6	Clean utensils decrease risk of food contamination	44	2	4
7	It is necessary to have knowledge of safe food consumption	44	2	4
8	Need for awareness of safety practices	45	3	2
	Total	363	16	21

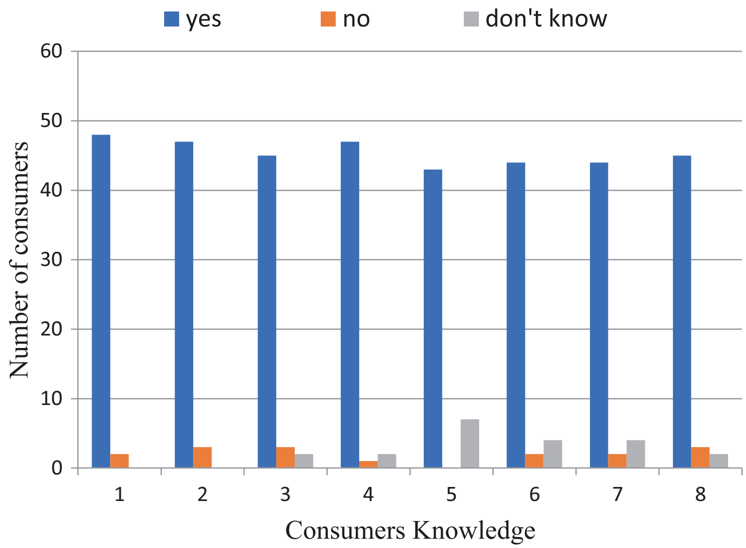

Fig. 5.1 Percentage for knowledge of consumers regarding street food

Table 5.2 Observation of consumers regarding vendor's hygiene ($n = 50$)

S. no	Observations	Yes	No	Don't know
1	Observe personal hygiene	47	3	–
2	Hand cleaning	31	5	14
3	Wear gloves	31	19	–
4	Wear head cover	39	6	5
5	Clothes are presentable	34	9	7
6	Handle money while serving	41	6	3
	Total	223	48	29

clothes of vendors. Further, 82% of consumers observe the practice of handling money while serving money, 12% of them do not observe while, 6% of consumers do not notice about this practice (Table 5.2 and Fig. 5.2).

A total of 74% of the consumers notice cleanliness of vendor's stall, while 26% of consumers do not notice about the cleanliness of stalls. About 76% of the consumers observed that food is placed in a covered condition, while 24% of consumers do not observe that food is placed in covered conditions or not. Around 68% of consumers notice about the clean cutlery, 8% do not notice, while 24% of consumers do not know about this practice. In addition, 56% of consumers observe that vendors were using clean water, 28% of consumers do not notice this, while 16% of consumers do not notice whether the vendors are using safe water or not. About 60% of consumers notice that vendors were using clean cooking utensils, 20% of consumers do not notice, and 20% of consumers do not observe this practice. Around 66% of consumers notice that there was a waste bin near the stall, 14% of

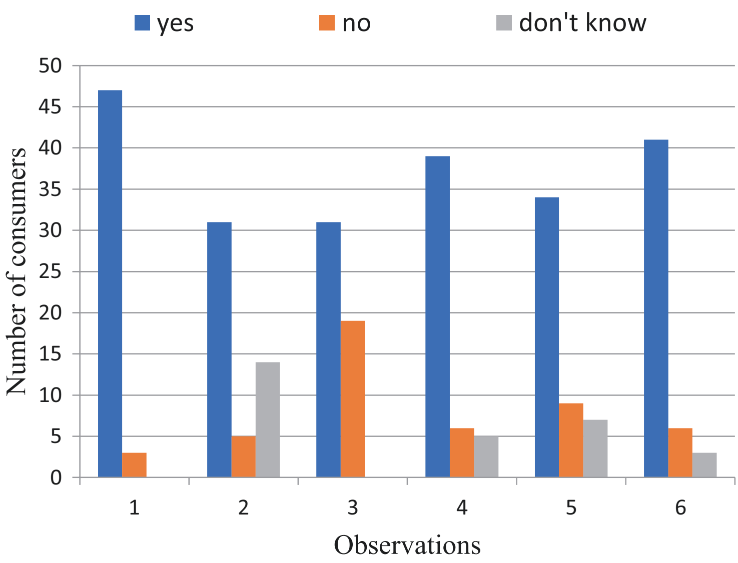

Fig. 5.2 Percentage of consumers regarding vendor's hygiene

Table 5.3 Observation of consumer's regarding stall hygiene ($n = 50$)

S. no	Stall hygiene	Yes	No	Don't know
1	Maintain stall clean	37	13	–
2	Food is covered	38	12	–
3	Cutlery is clean	34	4	12
4	Using safe water	28	14	8
5	Use clean cooking utensils	30	10	10
6	Covered waste bin	33	7	10
	Total	200	52	48

consumers do not observe, while 20% of consumers do not notice the waste bin (Table 5.3 and Fig. 5.3).

About 88% of consumers consume street food, while 12% do not consume. Around 12% of consumers think that consuming street food is safe for health, while 88% think that it is not a safe practice. Additionally, 88% of consumers think street food consumption leads to health hazards, 4% think no they do not, while 8% do not have knowledge regarding this. About 72% of consumers consume street food because it is cheap, while 28% do not think like this. Moreover, 88% of consumers consume street food because of its good taste, while 12% do not think so. Around 42% of consumers consume street food due to lack of time, while 58% do not think so. Approximately, 8% consumers always consume same food from the same place, while 92% do not. Lastly, 68% of consumers think that the amount they paid is sufficient, 12% do not think so, while 20% do not notice this (Table 5.4 and Fig. 5.4).

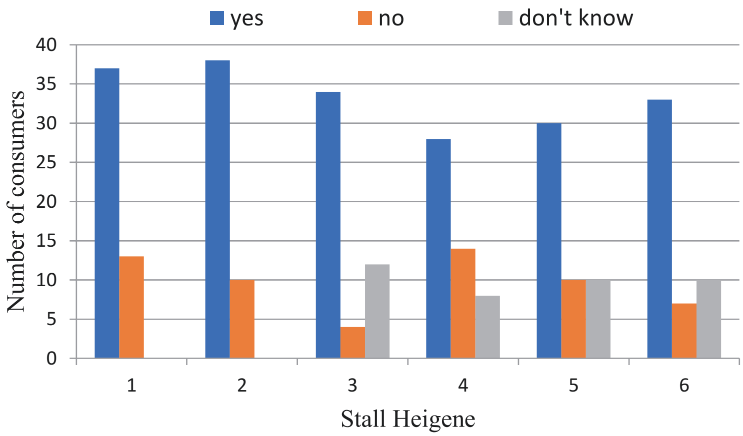

Fig. 5.3 Percentage of consumer's regarding stall hygiene of vendors

Table 5.4 Consumer practices related to street food ($n = 50$)

S. no	Consumer practices	Yes	No	Don't know
1	Consume street food	44	6	–
2	Consuming is safe for health	6	44	–
3	Consumption leads to health hazards	44	2	4
4	Consume because it is cheap	36	14	–
5	Consume because of its good taste	44	6	–
6	Consume due to lack of time	21	29	–
7	Always consume same food from same place	4	46	–
8	Amount they paid is enough	34	6	10
	Total	233	153	14

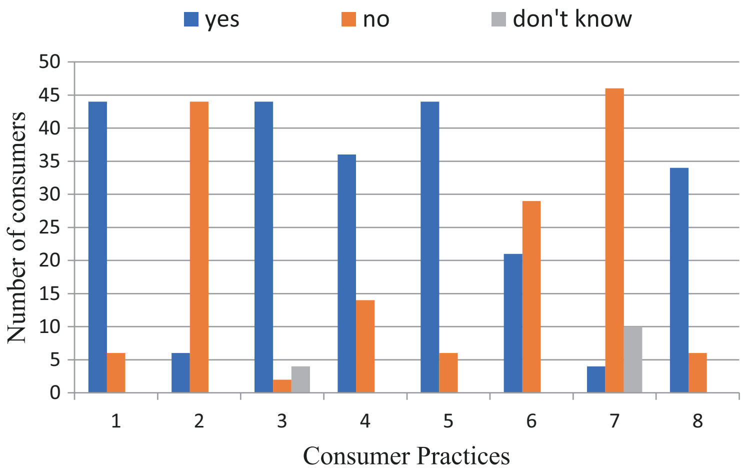

Fig. 5.4 Consumer practices related to street food

5.4 Conclusion

Based on the present study, it is concluded that there is an urgent need for awareness of consumers and vendors regarding adopting healthy habits of food preparation, storage, and serving so that the chances of contamination can be decreased. Government agencies and NGOs can also take initiatives in the direction to layout guidelines for selling and consuming safe and hygienic street food.

6

Analysis of Food Safety and Quality Measures in Indian Trends

Karunendra Singh

Abstract

The food service sector is one of the renowned sectors in India because of its traditional dishes with large potential for growth, employment, and income generation. Food safety is the process of taking certain steps to maintain the purity and freshness of the food before making it available to the consumer as per the food regulation. In India, food safety and regulations are maintained by food safety and standards of Indian authority (FSSAI) and have been implemented and promoted by the Ministry of Health and Family Welfare under the Government of India. Through food safety and regulations, the government lays down mechanisms for accreditation for certification bodies they interfere in the matters by making and implementing the policies and rules in areas that have a direct or indirect bearing on food safety. The data collected are regarding food consumption, the prevalence of biological risk, and contaminants in food products. The main aim is to analyze food safety and suggest some effective scientific methods for handling, preparation, and storage of food and prevention of foodborne diseases in the above review article.

Keywords

Food safety · FSSAI · Contaminants · Food security

6.1 Introduction

Today's food safety is one of the major challenges globally, the effective food supply chain framework not only safeguards the national food supply chain but has also the various hazardous microbial and chemical agents (Uyttendaele et al. 2016). The food

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safety problem is more prevalent in the least industrialized world than in the industrialized world (McIntyre et al. 2009). Always, food safety requires a scientific method during its handling, preparation, and storage which may prevent foodborne illness (Motarjemi and Käferstein 1999). Children younger than the age of four may be prone to infections from some foodborne pathogens, including *Campylobacter, Cryptosporidium, Salmonella, Escherichia coli, Shigella*, and *Yersinia* species, among others.

The world health organization (WHO) estimates that around 2.2 million people worldwide die because of bacterial, viral, and parasitic microbial diseases that are spread by contaminated water. People aged 50 are at high risk because of poor immunity (World Health Organization 2006a). In India, around 20% of deaths among children which are under five are because of waterborne diseases (i.e., diarrheal disease) (World Health Organization 2006b). Food can become contaminated at any point during production, distribution, and preparation. Therefore, it needs to ensure the quality at every stage from producer to consumer that the food is not contaminated and also ensure that the laboratories follow the standards of testing and analysis as per the government guidelines for food safety. Even in the presence of effective food policies in the country, India is struggling to enforce the food safety norms and standards effectively because of the little hinge in implementing those policies and the unavailability of advanced laboratories in the requisite number as compared with developed countries. Now it is really time to upgrade the technology of food storage and safety infrastructure in most of our food testing laboratories. Therefore, there is a need to focus more on modern agriculture to achieve growth in the food sector. The Indian food industry is poised for valued growth at approximately USD 500 billion, which is an indicator of sustainable growth and development at the farm and nonfarm levels in the Indian economy. The chapter includes the food safety and quality measure in today's scenario and suggests some strong scientific perspectives and recommendations for food protection in the country.

6.2 Food Safety System

The food security concept came in existence in 1974 when the first world food conference was held in Rome. Every human being has the inalienable right to be free from hunger and malnutrition in order to develop fully and maintain their physical and mental abilities.

6.2.1 Food Surplus Disposal

Surplus food is food that is not actually the true waste but the food which is generated throughout the food value chain from farm to fork and is safe and edible to human consumption. Despite being suitable for human consumption, surplus food is often treated as waste. For this to be avoided, surplus food must be

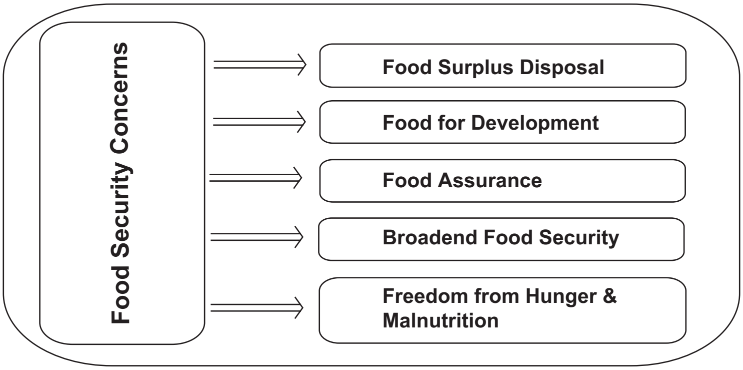

Fig. 6.1 Food security concerns

separated at the point at which it is considered not for sale through traditional channels but redistributed before it deteriorates. Framing edible food waste as surplus food reorients the discussion toward the potential of this food as food for human consumption (Fig. 6.1).

6.2.2 Food for Development

The product development process is an important systematic approach to get innovation in food products and economic returns. If economic returns are to be realized from agricultural production, the development of the agro-industry sector, as well as commercial farming and related agricultural enterprises, is important in all countries. The consumer's perception of product depends on the location of the consumer and the types of food product availability in the market. Product development is a method of industrial research in its own right. It is a combination and application of natural sciences with the social sciences of food science and processing with marketing and consumer science into one type of integrated research whose aim is the development of new products (Capone et al. 2014; Nadia Bhuiyan 2011; Booz et al. 1982; and Kumar et al. 2012).

The four basic stages for the development of the new product are as follows:

1. Strategy development
2. Design and development
3. Commercialization
4. Launch and post-launch

6.2.3 Food Assurance

Food assurance can be defined as the maintenance of the desired level of food quality in a service or product, especially by means of attention to the entire chain of gaining, food processing, and distribution up to the consumer. The modern systems of health-related food safety are based on a concept of creating appropriate conditions during food production processes and turnover procedures which permit the food product to be of the optimal quality. Under such systems, it is necessary to identify levels of quality distinguishing features, potential hazards, and quality of the final product. In addition, quality assurance is applied to those systems which guaranteed meeting the quality as per the consumer expectations. In case of food health and safety, assurance producers and introducers of food onto the market must implement and follow assurance systems for food safety. The food assurance may also include the good manufacturing practice along with good hygienic practice and hazard analysis.

6.2.4 Broadened Food Security

Food security is a complex phenomenon that manifests itself in numerous physical conditions resulting from multiple causes. It is mainly expressed in terms of availability, accessibility, utilization, and vulnerability. These concepts determine how food secure a country is or how adequate, steady, and risk-free food consumption is at the household and individual levels (Cooper and Kleinschmidt 1987). Now there is a need to understand the proper perspectives of insecure persons with the contradiction of high economic growth. The availability focuses not only on the quantity but also the quality and diversity of food. Slow reduction in the quantities and continuously inadequate quality diet may reduce physical capacity, lower productivity, and stunts growth, and even it may affect the learning processes. The major security component is the food availability, which means there must be enough physical quantities or supplies of food available to provide everyone with an adequate number of calories.

6.2.5 Freedom from Hunger and Malnutrition

The persistence of hunger is mainly due to the socioeconomic conditions, fluctuating food prices in the market, low wage structures, and inadequate income. The Freedom from Hunger Campaign was first launched in 1960 by the Food and Agriculture Organization of the United Nations (FAO). The main objectives have been based on two main points: first, to create a worldwide awareness of the problems of hunger and malnutrition which afflict more than half of the world's population and second, to promote a climate of opinion in which solutions to these problems can be organized both on a national and on an international basis. Food insecurity, starvation deaths, hunger, malnutrition, and undernourishment have increased substantially and are sustained by inefficient government policies, making it imperative for the whole world to address these issues emergently since allowing the most vulnerable to have a dignified and unthreatened access to food, supporting their physical and emotional health, and assisting them in having an active healthy life in inevitable for a healthy economic scenario. Malnutrition is one of the most important health problems around the world, and it is estimated that between one-half and two-thirds of the world's population suffer from it. This is the result either of chronic insufficiency of food or of the inadequacy of the protective foods necessary for a healthy life or a combination of both situations.

6.2.6 Food Safety in Indian Context

In India, the food processing industry is ranked fifth in the world in exports, production, and consumption, an important sector, and has large potential for growth, employment, and income generation. Major parts of the food processing sector include milled grain, sugar, edible oils, beverages, and dairy products. The food processing industry has grown annually at 8.4% for the last 5 years. In fruits and vegetables, the processing levels in India remain at 2–3% compared to 23% in China, 65% in the USA, and 70% in Brazil. India processes 8% of its marine products, 6% of poultry, and 20% of buffalo meat, against 60–70% in developed countries. FDI is permitted in the automatic route for most food products except for items reserved for micro and small enterprises, up to 2012–2013. Investment in fixed capital in registered food processing sector had grown annually at 18.8% during last 5 years ending.

6.2.7 Principles of Food Safety

A food safety usually refers to take precautions and preventive measures from any infectious agents and contaminants within the food. The seven basic principles of food safety (Fig. 6.2) are as follows.

6.3 Corporate Responsibility

Corporate responsibilities are ensuring that the products within their area of responsibility are in perfect condition. This must be done using appropriate measures not only at the corporate level but also at local controls. The responsibility of corporate engaging in the food industry is that they may ensure before the recommendations of any food according to the desired requirements for hygiene, residues, or labeling as per the government standards.

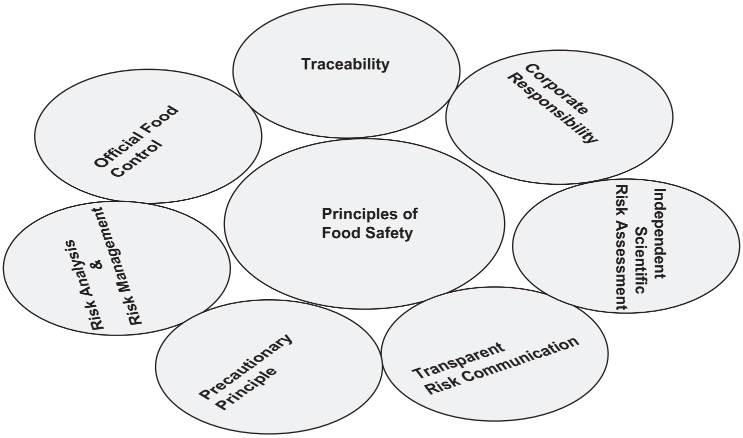

Fig. 6.2 Basic principles of food safety

6.3.1 Traceability

For food safety assurance, it is important to implement the trace system which affords the possibility to follow all the food chain backward (e.g., from final product to raw materials including all stages of production and distribution). In case of any contamination within the food packets found then, manufacturers and control authorities can quickly come to an action by identifying them by batch, and even they can withdraw from the retailers. For this reason, all food packaging contains a batch number or a date. A batch refers to a certain quantity of food that is manufactured and packaged under the same conditions within a particular time frame.

6.3.2 Official Food Control

The food control authorities are responsible for checking whether food law requirements have been complied with. This is done through risk-oriented reviews and targeted sample collection with varying focuses each time. Sensitive foodstuffs are inspected at more regular intervals. There are special control plans in place for different product groups. Establishments that are operated in an exemplary manner will not be inspected as regularly as those where deficiencies have been identified.

6.3.3 The Precautionary Principle

The Precautionary Principle is an important established principle for making practical decisions under conditions of scientific uncertainty. Its employment involves the identification of risk, scientific uncertainty, and ignorance, and it also includes transparent and inclusive decision-making processes. A risk cannot always be conclusively expressed in terms of science, for instance, but needs a previous knowledge about the contaminant which is already in existence.

6.3.4 Risk Assessment and Risk Management

Risk assessment is a tool to discuss and identify a systematic approach and challenges for physical, socioeconomic, institutional, and environmental risks and providing risk information. Risk management addresses the use and advancement of science and technology to minimize potential harm and loss. The qualitative model and the quantitative model are thereby which risk assessment can be understood. The qualitative analysis is based on the priorities which explained the potential risk factors and their impacts. The main characteristic is the use of subjective indexes, such as ordinal hierarchy, low–medium–high, vital–critical–important, among others. While the quantitative risk analysis is based on numerical results that express the probability of each risk factor and its consequences on the objectives of the project, but also the risk on the entire project level.

6.3.5 Transparent Risk Communication

Risk communication is discussed under risk analysis and an inseparable element of the risk management framework in which risk managers exchange information and perceptions, among risk assessors, risk managers, consumers, and other interested parties. Through transparent risk, it can easily ensure that consumers are aware of the risks associated with a product and thereby use it safely. The important case related to the transparent risk communication is one which the British press reported on the utilization of contraceptive pill by women to minimize the risk of unwanted pregnancies, but the contraceptive pill increased their risk of thromboembolism means blockage of a blood vessel. After the bad news, thousands of British women panicked and stopped taking the pill, which led to a wave of unwanted pregnancies.

6.3.6 Independent Scientific Risk Assessment

The independent scientific risk assessment has been proved to be useful in making scientific decisions. Their main aim is to minimize and eliminate a health risk by opting systematic methodology for the determination of effective actions to protect health. The continuous efforts have been made to improve the food standards, specifications, formulations, and novel foods, and increasing international trade would require more sophisticated risk management measures for food safety without compromising advanced methodology. Intelligent packaging or labels are examples of the most recent advances in the food safety field.

6.3.7 Food Security Pillars

The main pillars of food security are as follows:

(a) *Food availability*: Food availability refers to the physical existence of food. As regards food production, water resources are required for it in farms, and therefore pressure for existing natural resources increases.
(b) *Access to food*: Access of food is ensuring that all the households had enough resources to get food.
(c) *Proper utilization*: One of the important aspects of household food and nutrition security may be determined by the knowledge and habits. Another aspect is the biological utilization of human being.
(d) *Stability*: Stability refers to the constant supply of households throughout the year and in the long term.

6.3.8 Food Laws and Regulations

The Food Safety and Standards Authority of India (FSSAI) is the regulatory body responsible for food safety and quality issues across the country. Food safety laws and regulation under standards act (2006) consolidates various laws which are as follows:

- Meat Food Products Order (1973)
- Vegetable Oil Products (Control) Order (1947)
- Edible Oils Packaging (Regulation) Order (1998)
- Solvent Extracted Oil, De-oiled Meal, & Edible Flour (Control) Order (1967)
- Milk & Milk Products Order (1992)
- Essential Commodities Act (1955)

6.3.9 Food Sustainability

Food sustainability aims to maintain and increase the output and protect the biodiversity of our plants, animals, and the environmental benefits. It also helps to enhance soil fertility for future food production. Today, some of the challenges of our food system which may affect health include body resistance to antibiotics and reduction of pollination of plants by bees because of the utilization of excessive pesticides.

6.3.10 Factors Which Contribute to Food Security

Various factors contribute in food security as mentioned below:

6.3.10.1 Climate Change

As we know that agricultural processes are generally based on climatic conditions, the climate gets affected as the emissions of greenhouse gases may increase the average temperature of the earth, changes in precipitation timing, rising sea levels, and many other changes which may directly or indirectly affect the quality and quantity of crops. The other food-system activities also get affected such as food processing, packaging, transportation, storage, consumption, among others.

6.3.10.2 High Food Price

Rising food costs have direct effects generally on the health of low income and poor people. India plays an important contribution to global food nutrition security. The things which may be the causative agents for price hiking are lack of investment in agricultural processes and insufficient attention to food and nutrition security-related issues and ignorance of small-scale farmers, especially in agro-ecologically remote areas. The food prices may be controlled by opting necessary steps such as to make appropriate policies and infrastructure for the farmers and also higher agricultural prices can raise farmers' incomes and rural wages, improve rural economies, and stimulate investment for longer-term economic growth.

6.3.10.3 Poor Infrastructure, Roads, and Communications

Infrastructure is an important factor not only to produce goods and services, but also it is required for storing to any industry. Infrastructure may be considered as an important factor for economic growth. Infrastructure also contributes to emergency aid, working stocks for regular distribution, and also as buffer stocks to stabilize domestic prices. Infrastructure may also include input supply, processing, and output marketing operations but still needs to focus more on the investments of rural roads, logistics systems, potable water, electricity, information and communication technologies, and waste disposal facilities.

6.3.10.4 Livestock and Crop Diseases

Livestock contributes one-third of the protein. Peoples prefer animal source food especially dairy products which ensure the essential nutrients for cognitive and physical growth. Agriculture is the utmost importance for inclusive development because it produces food as well as economic wealth which contributes improved livelihoods through better healthcare, education, and infrastructure improvements for any nation. The economic growth and wealth get affected when the bacteria and viruses are attacked over agriculture worldwide. A few examples of bacteria and viruses are *Pseudomonas* sp. and Barley yellow dwarf, respectively, which are damaging the crops of potato and wheat, barley, rice, and maize, etc.

6.3.10.5 Human and Wildlife Conflict

Human and wildlife conflicts are more common in those areas where wildlife and human population coexist and share limited resources which result in threatening the economic security and livelihood of people. Since the existence of human beings, there has been an exponential increase in the human population, and the consequential expansion of human activities may be the cause of human–wildlife conflicts. Other factors also responsible for the human and wildlife conflicts such as regular land encroachment, increased biotic pressure coupled with overlapping of the declining resource base, shifting cultivation, mining of forests for exploration of mineral wealth, forest fires, poaching, retaliatory killings, climate change, floods, and droughts may be the major contributors.

6.3.11 Food Packaging

The packaging industry is one of the important sectors for food safety. Packaging of food, beverages, fruits, vegetables, drugs, and medicines and even to highly dangerous product disposal and storage requires greater specialization and sophisticated packing.

6.3.12 Food Inspection and Storage System

(a) Wash your hands before and after eating.
(b) Hands in contact with the nose and genital parts should not be directly applied to food.
(c) Eat only fresh and clean food.
(d) Eating place and table should be hygienic.
(e) Always try to make or cook food as per the requirement.
(f) Ensure to cook meat in the right temperature in order to cook properly.
(g) When dining out, always find out the cleanliness in the surrounding.
(h) Keep food covered to protect from contamination.

6.3.13 Recommendations for Food Protection

6.3.13.1 Sustainable Food and Nutrition Security

It is an utmost important multidimensional concept which includes the availability of food through agricultural production, physical and economic access to food, and sufficient utilization of available food by individuals, throughout the year.

6.3.13.2 Promotion of Nutrition-Sensitive Agricultural Production

The agricultural advancement not only improves total productivity but also improves the individual incomes with health, education, and social status, as well as improves family caring capacities.

6.3.13.3 Empowering Women for Nutrition and Food Security

The social status of women and their educational levels plays an important role being the determinants of malnutrition among the children. Women who take care of their families especially the young children may also play a major role in agricultural production, food processing, and food preparation. Therefore, it is necessary to empower women for food and nutrition security in today's scenario.

6.3.13.4 Strong National Policies, Strategies, and Plans

There is a need to be considered for the strong national food policies by introducing food and nutrition security-related programs. The funding opportunities and the necessary budget is required for nutrition-related surveys which help in the food safety and food security policies, and action plans are of utmost need to overcome food insecurity and malnutrition in the country.

6.4 Conclusion

In the future, the main focus is to find out an effective scientific method for food safety and will also find out the gaps for implementing government policies for food safety in the country. The amendments and new laws for the food-related issues at a microlevel in the country will have to be focused. Food safety is an important aspect of food security for billions of people who are suffering from hunger and malnutrition. The growth of the food safety and certification industry in India is growing rapidly. However, the food safety regulation, administration, and implementation are at a critical point in India. Consumers are increasingly demanding better, safer, and healthier products in both urban and rural areas. There is a need for a strong strategy to ensure food safety for all beings and to find out the major constraints in methods for handling, preparation, and storage of food.

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7 Street Foods: Safety and Potential

Prabhjot Kaur Sabharwal, Vandana Arya, and Chaynika Verma

Abstract

Street food industry plays a vital role especially in developing countries by feeding millions of people. Street foods provide substantial amount of nutrients at relatively cheap prices. Street foods include ready-to-eat food and beverages, which are easily accessible and available at great convenience, giving them huge market potential. In recent years, the informal sector of street food vending has grown in competition with the formal sector. The safety and hygiene of street foods has become a global concern. Various instances of pathogenic contamination and food borne epidemics have been reported. The use of additives in excess limits such as benzoate and artificial colors, contaminants in raw materials, process contaminants, handling, and trading practices ascertain to the huge safety risk. Lack of education, knowledge in food safety and control, poor sanitary practices, and high ambient temperatures are some of the factors facilitating microbial contamination. The present review focuses on the economy of street foods, hygiene practices followed by street vendors and microbial contamination in India and globally, and ascertaining potential risk factors. Huge numbers of studies have reported the presence of bacterial pathogens in street food samples calling for stricter implementation of good manufacturing practices. Regular monitoring and safety intervention of the quality of street foods can safeguard the consumers from any possible food hazard.

Keywords

Street food · Street food quality · Street vendors · Microbial contamination · Adulteration

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7.1 Introduction

As per WHO, street foods can be defined as foods and beverages (including fresh fruits and vegetables) prepared and/or sold by vendors in streets and other public places for immediate consumption or consumption at a later time without further processing or preparation. Street foods can be embraced as a new addition to food industry in the category of convenience foods. Street foods pose potential benefits especially for low-income population thriving in urban cities of developing countries, workforce it employs, and students. Street foods are not only nutritious but also sizeable, provide exclusive flavor and employment (Ghosh et al. 2007), and fulfill adequate nutrient requirement. Apart from providing convenience, street foods play pivotal part in maintenance of social and cultural legacy (Tambekar et al. 2011).

The street food industry has advanced and grown exponentially in the current realm. Street food vending business is growing popular as it requires very low initial investment and setup with sufficient income generation (Lues et al. 2006). Apart from the generation of employment avenues for illiterate and unemployed people, it also fulfills adequate nutrient requirement as per individual's RDA. Steyn et al. in their study concluded that substantial daily energy intake in terms of energy and protein is met by consumption of street foods. With respect to micronutrients, various street foods are high in iron and vitamin A but offer calcium and thiamin in low quantity (Steyn et al. 2014).

Authorities in many nations fail to recognize the street food industry officially. Street food vendors and hawkers are unaware of good hygiene practices (Tambekar et al. 2011). There are no fixed regulatory structures to control food quality served by street vendors, and hence, chances of occurrence of food hazard are high. Each nation/country has its own indigenous street food; thus, to formulate laws at a global platform is difficult. Individual countries and municipalities must form a body to regularize in zones of procurement, preparation/processing, and distribution. Street foods are heavily loaded not only with pathogenic and nonpathogenic microorganisms but also adulterated and/or contaminated with nonpermissible chemicals.

7.2 Safety Risk Associated with Consumption of Street Foods

7.2.1 Microbial Contamination

Varied health hazards have been reported in the literature with pathogenic microorganism, which is a global health concern. *Shigella, Salmonella,* and *Staphylococcus aureus* have been frequently found in street foods. For instance, in India Tambekar et al. (2011) observed high contamination in samples of panipuri water with *Escherichia coli, Staphylococcus aureus, Klebsiella* sp., *Pseudomonas* sp., and yeast. They also concluded samples collected from crowded areas than non-crowded areas showed high amount of microbial contamination (Tambekar et al. 2011). Initial contamination of pathogenic bacteria adds to subsequent contamination in preparation of street foods. Bhel and panipuri samples collected from Buldana District reported high contamination by fecal *E. coli* and *Salmonella* (Garode and Waghode 2012).

The chances of contamination are especially high in ready-to-eat salads with major contamination by *S. aureus* and *Shigella* (Ghosh et al. 2007). Raw vegetables can be potent vehicles of contamination for foodborne diseases. The presence of coliforms and enterococci has been reported in street foods fingering fecal contamination (Bhaskar et al. 2004).

A large number of populations consume freshly squeezed fruits and vegetable juices sold on street considering it as a healthy option. Popular street fruit juices such as carrot and mandarin have also reported high log coliforms and *Staphylococcus*, thus implying high contamination by animal or human waste and absence of any processing to inhibit or kill microorganisms if present (Mudgil et al. 2004). Research for contamination of *Salmonella* in fresh juices has also been reported. Fresh juice samples from pineapple, sweet lime, and vegetables in Nagpur city have shown significant *S. aureus* and coliform load. About 50% of juice samples tested positive for *S. typhi* (Titarmare et al. 2009).

Contact surfaces and bare hands are important sources of contamination by *S. aureus* in street foods. Often microbial load is contributed by personnel. In a study conducted by Lues et al. (2006), *Salmonella* was isolated from hand and food preparation surfaces.

7.3 Presence of Hazardous Chemical/Additive

Street foods have been reported to contain mostly nonpermissible colorants and additives. Street foods are usually kept on the roadside uncovered, which might get contaminated with lead and thus could be vehicles of contamination, foodborne diseases, and outbreak. Mudgil et al. reported contamination of carrot juices by salmonella. It can be hypothesized that salmonella gained entry in juice either from water, which is used to dilute juice, or from sources such as colorant (e.g., beetroot) (Mudgil et al. 2004) and dressing with ice (Lewis et al. 2006). High amounts of benzoates in tomato and chili sauces served at street food joints have also been reported. These sauces were detected with banned artificial colors such as amaranth, carmoisine, erythrosine, tartrazine, etc. (Dixit et al. 2008).

7.4 Possible Causes of Health Hazard

There are nine main reasons of the health hazards from the street foods (Fig. 7.1). All the reasons have been enlisted and explained below:

1. *Personal hygiene*: Poor personal hygiene of vendor especially inadequate handwashing before preparation and serving.
2. *Lack of training in food-related matters*: Most of the street vendors especially on developing countries such as India are uneducated and unaware of food safety

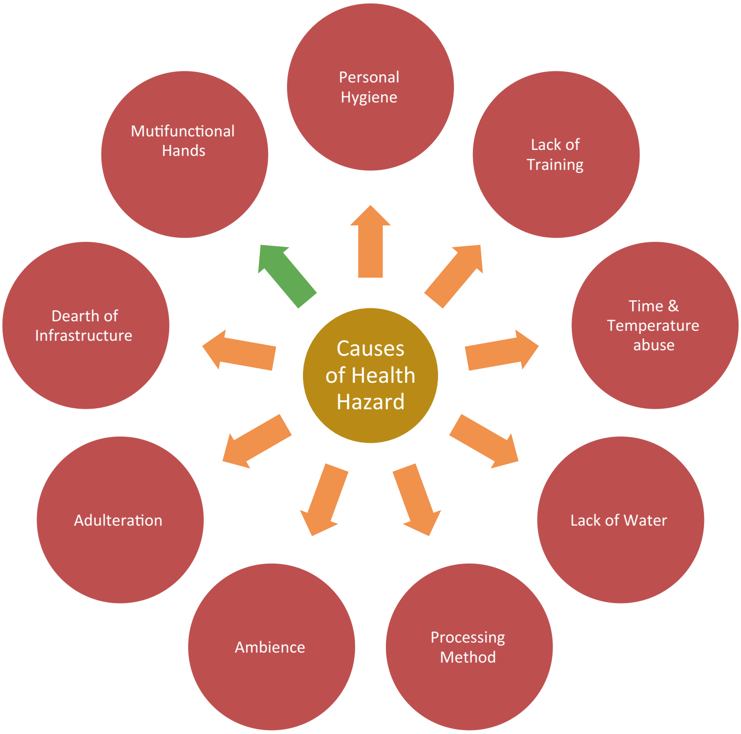

Fig. 7.1 Illustration of various causes of health hazard in street foods

and hygiene. They often are potential carriers of pathogen such as *E. coli* and *S. aureus* (Tambekar et al. 2011).

3. *Time and temperature abuse*: Street vendors do not maintain optimum conditions such as time and temperature often needed to maintain sterility of food.
4. *Lack of potable running water* (Ghosh et al. 2007): It is also reported due to limited access to potable water, street vendors procure water from nearby public toilets, shops, on site taps, or bring from home (Lues et al. 2006). Vendors lack water for washing and cleaning.
5. *Processing method*: Often street foods undergo inadequate or no food processing operation before preparation and consumption. It is quite commonly seen in Indian street foods such as bhelpuri, raw vegetable and fruit salads, coconut slices, etc.
6. *Ambience*: Often street foods are left open without lids on roadside exposed to vehicular transmission and lead deposition.
7. *Adulteration*: To maintain low cost, the chances are high that street vendors may use cheap raw ingredients and hazardous chemicals (additives such as colorants, flavor enhancers), which may possess risk on food safety. In many cases, food is served in paper cut from newspaper, which is of debatable source.

8. *Dearth of infrastructure*: In most cases, street vendors do not have distinct area for raw material storage, processing, and utensils washing. Excessive movement (Tambekar et al. 2011) makes street food more susceptible to food hazard. Waste and garbage disposal area are not clearly defined. Sometimes they are in very close vicinity to preparation and procurement area that it may be utilized as source of nutrients for pathogens, insects, and rodents (Tambekar et al. 2011).
9. *Multifunctional hands*: From preparation to final serving, street food gets in contact with the hands of a number of people contributing to microbial load.

7.5 Steps to Improvise Street Food Quality

1. Education and knowledge enhancement of street food vendors with respect to the quality and safety of food.
2. Appropriate waste disposal and sanitation.
3. Potable good quality of water for cooking and washing.
4. Ensuring safe food storage temperatures.
5. Improvisation of infrastructure especially including wash basin on sample with sufficient soap and water facilities.
6. Regularizing vending practices.
7. Cooking and storing food with enclosure.

7.6 Conclusion

Thus, there is a need for stricter implementation of food sanitation practices, which can ensure safety and wholesomeness of street food. Regulations by developing nations or/and municipalities should ensure any false practices, and contamination with hazardous additives is not made. The safety of drinking water should be ensured prior. The practice of preparing food from home should be discouraged. As in most cases, food is prepared on previous day without any adequate storage/refrigeration systems.

Authorities should organize and provide workshop, training, and seminars to food vendors on food safety.

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8 Microbial Safety of Fresh Produce Sold in Delhi Markets and Implementation of Risk Management Approach

Shalini Sehgal

Abstract

Fruits and vegetables are unique foods since they are often consumed raw or with minimal preparation. To date, there have been no effective intervention strategies developed which can completely eliminate food safety risks associated with the consumption of uncooked produce. In this study, an initial survey of 100 retail outlets was done to assess the prevalent food safety practices of the food handlers in the various retail outlets. Then, a total of 61 samples from selected retail outlets of West Delhi were analyzed for their surface microbial load. Majority of the samples were found to be contaminated, but the level of contamination was variable. The three antimicrobial dips comprising of different organic acids having GRAS status in varying concentration and dip time were tested for their efficacy in reducing the surface microflora. The aim was to find a cost-effective and simple method for the consumer to use as an intervention to reduce the microbial risks associated with the fresh produce. The antimicrobial dip of citric acid was found to be the most effective. The study also revealed that the handling practices of the food handlers and their awareness about food safety also play a critical role in the microbial safety of fresh produce. Thus, the safety and quality of fresh produce require implementation of a risk-based management system approach through all stages of production, distribution, storage, transportation, and marketing of food products in the complete food chain.

Keywords

Fruits and vegetables · Microbial load · Contamination · Antimicrobial dips

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8.1 Introduction

Fruits and vegetables being an exceptional source of nutrients, micronutrients, vitamins, and fiber for human beings are important for health and fitness. A balanced diet rich in fruits and vegetables is valuable for its ability to prevent deficiencies of vitamin C and vitamin A and also reduce the risk of several diseases (Kalia and Gupta 2006). In spite of promoting good health, fruits and vegetables harbor a wide range of microbial contaminants, which undermine their nutritional and health benefits, and thus their consumption either in fresh or minimally processed form has increased the outbreaks of human infections (Altekruse and Swerdlow 1996; Beuchat 1998, 2002; Hedberg et al. 1994). Bacteria, viruses and parasites on fruits and vegetables have been associated with illness. Typhoid fever outbreak has been observed in several cases of eating contaminated vegetables grown in/or fertilized with contaminated soil or sewage (Beuchat 1998). The percentage of affected persons varies from a few persons to many thousands in these outbreaks. There have been reports on increase of diseases as twice associated with the consumption of fruits and vegetables between 1973–1987 and 1988–1992 (Olsen et al. 2000). In the developing countries such as Nigeria, one of the major contributing factors for the outbreak of diseases is the continued use of untreated wastewater and manure as fertilizers for the production of fruits and vegetables (Amoah et al. 2009; Olsen et al. 2000).

Generally, the fruits and vegetables vendors don't follow the good hygienic practices. Fruits and vegetables are sold in trays, wheel barrows, or on tables by vendors and lack appropriate storage conditions. Vendors not maintaining personal hygiene carry microorganisms on their skin, hair, hands, or cloths and may unintentionally contaminate fresh fruits or vegetables resulting in creating the opportunity to transmit foodborne illness. It therefore signifies that to escalate all health benefits from adequate consumption of fruits and vegetables, handlers (vendors) should be free from microbial contamination. A qualitative survey based on microbiological criteria of two common market foods was contemplated consequently. In order to maximize the health benefits promised by adequate consumption of these produce, microbiologically safe fruits and vegetables are essential. To avoid or prevent decontamination, proper washing of fruits and vegetables is essential. The aim was to reduce the surface microbial load of fresh produce of both fruits and vegetables by using different types of antimicrobial dips.

8.2 Methodology

The study was conducted in the local and retail markets of south zone of Delhi. The microbiological quality of approximately 200 samples of different fresh fruits and vegetables was analyzed during the course (6 months) of this entire study (cucumber, carrot, tomato, coriander, bottle gourd, cauliflower, brinjal, tori, cabbage, spinach, peas, beetroot, capsicum, lettuce and French beans, apple, grapes, sapota, papaya, and pears). A total of 10 ($n = 10$) samples were taken in each case. In order to study the efficiency of antimicrobial dips, samples apart from the abovementioned were also used. The samples were randomly aseptically collected in a sterilized container maintained in cold conditions and delivered to laboratory immediately where they were analyzed. All the samples were used for detection of aerobic plate count (APC), total coliforms, *E. coli*, and yeast and mold (YMC). The elapsed time between the sample collection and the analysis did not exceed 3 h. Results were interpreted using SPSS16 and variance analysis methods (ANOVA).

8.3 Results and Discussion

The microbiological quality of 61 samples of fruits and vegetables from South Delhi local market (LM) and retail market (RM) was analyzed.

8.3.1 Microbiological Analysis

All the samples tested were found to be contaminated with varied level of contamination. In case of vegetables, the highest level of contamination was found to be in beetroot and the lowest was in case of cucumber, whereas in fruits, the highest level of contamination was found to be in papaya and lowest in case of pears.

8.3.2 Effect of Antimicrobial Dips

Maximum reduction was shown by all the antimicrobial agents. The efficacy of three antimicrobial dips—chlorine, citric acid, and benzoic acid at 1% concentration for 5 min—was determined in this study, and their suitability and cost-effectiveness were analyzed in order to reduce the microbial load in the fresh produce. Antimicrobial effects of different sanitizing treatments were assessed for ten samples. All the three antimicrobial dips had equal effect.

Microbial load was considerably reduced by citric acid and benzoic acid (Figs. 8.1, 8.2, 8.3, and 8.4).

8.3.3 Vegetables

The cucumber sample was found to have 4.2 log cfu/g of initial APC load, and it was reduced to 3.73 with chlorine, 3.82 with citric acid, and 3.83 with benzoic acid. In case of tomato, initial APC load was 4.32 log cfu/g which was reduced to 3.97 log cfu/g with chlorine, 4.02 with citric acid, and 4.01 using benzoic acid. In case of carrot, initial load was as high as 4.71 log cfu/g which was effectively reduced using chlorine to 3.96 log cfu/g, citric acid to 4.01 log cfu/g, and benzoic acid to 4.02 log cfu/g. For coriander, initially, the APC load was 4.6 log cfu/g, and it was reduced to 4.12 log cfu/g with chlorine, 4.16 with citric acid, and 4.15 using benzoic

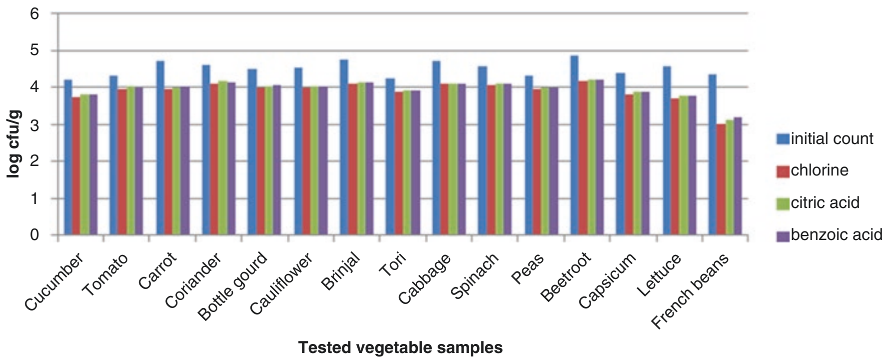

Fig. 8.1 Antimicrobial effect of different antimicrobial dips on Aerobic Plate Count of selected vegetable samples

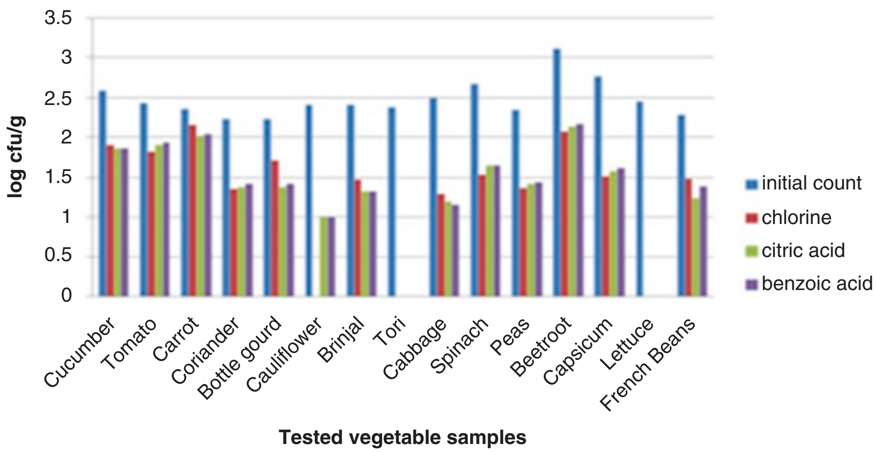

Fig. 8.2 Antimicrobial effect of different antimicrobial dips on total coliform load of elected vegetable samples

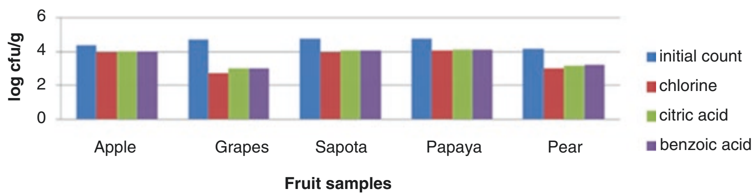

Fig. 8.3 Effect of different antimicrobial dips on the Aerobic Plate Count of selected fruit samples

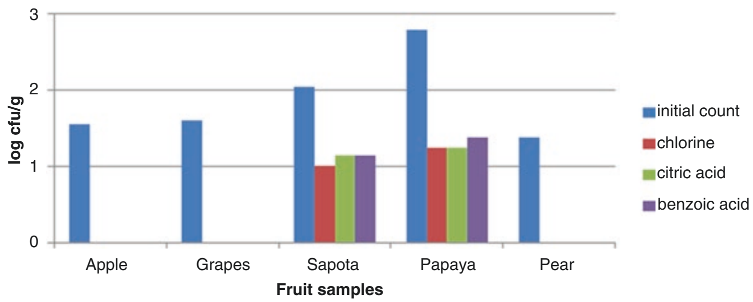

Fig. 8.4 Effect of different antimicrobial dips on the total coliform load of selected fruit samples

acid. Initially, the TPC load on bottle gourd was found to be 4.52 log cfu/g, and the use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to 3.99, 4.03, and 4.05 log cfu/g, respectively. For cauliflower, initial APC load was 4.55 log cfu/g and was reduced to 3.98 log cfu/g with chlorine, 4.04 with citric acid, and 4.04 using benzoic acid. Brinjal had the initial load of 4.76 log cfu/g which was effectively reduced using chlorine to 4.09 log cfu/g, citric acid to 4.13 log cfu/g, and benzoic acid to 4.13 log cfu/g. For ridge gourd (*tori*), initial APC load was 4.25 log cfu/g, and it was reduced to 3.88 log cfu/g with chlorine, 3.93 with citric acid, and 3.92 using benzoic acid (Fig. 8.1).

Cabbage had the initial load as high as 4.73 log cfu/g which was effectively reduced using chlorine to 4.09 log cfu/g, citric acid to 4.12 log cfu/g, and benzoic acid to 4.12 log cfu/g. For spinach, initial APC load was 4.58 log cfu/g and was reduced to 4.05 log cfu/g with chlorine, 4.09 with citric acid, and 4.09 using benzoic acid. Peas had the initial APC load of 4.33 log cfu/g but use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to 3.95, 4.0, and 3.99 log cfu/g respectively. For beetroot, initial APC load was 4.85 log cfu/g. It was reduced to 4.19 log cfu/g with chlorine, 4.23 with citric acid, and 4.22 using benzoic acid. Initially, the APC load on French beans was found to be 4.35 log cfu/g, use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to 3.02, 3.14, and 3.19 log cfu/g, respectively. In case of capsicum, initially the APC load was 4.39 log cfu/g which was effectively reduced by using chlorine to 3.8 log cfu/g, citric acid to 3.88 log cfu/g, and benzoic acid to 3.89 log cfu/g. Initially, the APC load on lettuce was found to be 4.56 log cfu/g, use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to 3.72, 3.78, and 3.77 log cfu/g, respectively. All the three antimicrobial dips were found to be equally effective for spinach, peas, and capsicum.

The initial coliform load on all the vegetable samples ranged from 2.24 to 2.77 log cfu/g which was effectively reduced by using chlorine ranged from nil to 2.08 log cfu/g, citric acid -nil to 2.14 log cfu/g, and benzoic acid -nil to 2.17 log cfu/g. In case of tori and lettuce, all three antimicrobial dips were found to be equally effective (Fig. 8.2).

The initial load of yeast and mold was ranged from nil to 1.98 log cfu/g in all vegetables. Use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to zero. All the samples were initially positive for *E. coli,* and reduction was seen in *E. coli* load after using all three antimicrobial dips as found negative in all the samples.

8.3.4 Fruits

The initial APC load on apple sample was found to be 4.38 log cfu/g, and it was reduced to 3.97 with chlorine, 4.01 with citric acid, and 4.01 with benzoic acid. For sapota, initial APC load was 4.74 log cfu/g. It was reduced to 3.96 log cfu/g with chlorine, 4.03 with citric acid, and 4.04 using benzoic acid. Initially, the APC load on grapes was found to be 4.71 log cfu/g. Use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to 2.73, 3.01, and 3.01 log cfu/g, respectively. In case of pears, initially the APC load was 4.18 log cfu/g which was effectively reduced by using chlorine to 2.99 log cfu/g, citric acid to 3.16 log cfu/g, and benzoic acid to 3.2 log cfu/g. Initially, the APC load on papaya was found to be 4.76 log cfu/g. Use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to 4.04, 4.09, and 4.09 log cfu/g, respectively (Fig. 8.3).

The initial coliform load on apple sample was found to be 1.56 log cfu/g which was effectively reduced to nil log cfu/g by using chlorine, citric acid, and benzoic acid (refer to Fig. 8.4). Initially, the coliform load on sapota was found to be 2.04 log cfu/g. Use of chlorine, citric acid and, benzoic acid resulted in microbial load reductions to 1.00, 1.15, and 1.15 log cfu/g, respectively. In case of papaya, initially the coliform load was 2.79 log cfu/g which was effectively reduced to 1.24 log cfu/g with chlorine, 1.24 with citric acid, and 1.39 using benzoic acid. In case of grapes and pears, initial coliform loads were found to be 1.61 and 1.38 log cfu/g, and it was reduced to nil by using all three antimicrobial dips (Fig. 8.4).

The initial loads of yeast and mold were found to be 1.48, 1.98, 1.23, 1.52, and 1.48 log cfu/g in case of apple, sapota, grapes, papaya, and pear, respectively. Use of chlorine, citric acid, and benzoic acid resulted in microbial load reductions to zero. All the samples were initially positive for *E. coli,* and reduction was seen in *E. coli* load after using all three antimicrobial dips as found negative in all the samples.

8.4 Conclusion

In the present study, the microbial status of various vegetables and fruits samples was assessed, and they were found to be contaminated. In case of vegetables, the highest microbial load was found in case of beetroot followed by brinjal, cabbage, carrot, coriander, spinach, lettuce, cauliflower, bottle gourd, capsicum, French beans, peas, tomato, *tori*, and then cucumber, and attributed to the various internal and external sources of contamination. Similarly, in fruits, the highest microbial load was found in case of papaya followed by sapota, grapes, apple, and then pears. Usually fruits and vegetables growing closer or within the soil are more contaminated (Sehgal 2013). Similar trend was observed in this study too. Beside soil microbes, other sources of their contamination are improper handling, unhygienic storage, and transportation conditions. Coliforms were present on most of the samples. Yeasts and molds are the natural microflora of the fruits and vegetables, and hence they were detected in majority of the samples. Presence of *E. coli* indicates poor water quality and untreated manure for the production of these crops. Vegetables and fruits may be contaminated with pathogenic microorganisms during growing in the field or during harvesting, post-harvesting, handling, processing, and distribution. Therefore, vegetables and fruits may act as a source of many microorganisms from which they will be colonized inside these fresh produces and infect susceptible host. There was a requirement of finding an easily available and cost-effective antimicrobial dip, since majority of the samples were found to be contaminated. Three solutions, that is, 200 ppm of chlorine solution, 1% citric acid solution, and 1% benzoic acid solution, were studied for their antimicrobial property. All the three antimicrobial dips were found to be effective, but citric acid was the most effective as per statistical analysis (paired test). Thus, it can be introduced as a cost-effective antimicrobial dip for a developing country like India.

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Part III

Nutritional Security and Sustainability

Check for updates

9 Fruit Waste: Potential as a Functional Ingredient in Foods

Shikha Goel, Mrigya Bansal, Priya Pal, and Priyanka Prajapati

Abstract

The world's second-largest producer of fruits is India, and the fruit processing industries generate tons of fruit waste in the form of peels, stones, seeds, and pomace, which comprise about 30–40% of fruit weight. Being high on biological oxygen demand, this waste if left untreated is a potential hazard to the environment. It is a major contributor to foul odor and soil pollution and harbors microorganisms and insects which can engender various environmental issues. Outer skin or peels of fruits possess higher bioactive compounds to evade insects and microorganisms that spoil the inner content of the fruit. Bioactive components in fruit wastes have been reported to have multiple biological effects, including antioxidant, antibacterial, antiviral, anti-inflammatory, anti-allergic, antithrombotic, and vasodilatory actions. The potential carcinogenicity of commonly used synthetic antioxidants such as BHA and BHT in food has revived the search for antioxidant from natural sources. In view of this, a tremendous increase in investigations on exploiting the potential natural antioxidants from fruit wastes has been observed as fruit wastes are inexpensive and easily available in abundance. This chapter is a comprehensive review of the antioxidant potential and other functional properties of bioactive components extracted from different fruit wastes and exploring their applications in developing value-added food products.

Keywords

Fruit waste · Bioactive components · Polyphenols · Antioxidant

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9.1 Introduction

A FAO statistical report states that India is the second largest producer of fruits in the world, owing to the diverse agroclimatic condition of India which supports the mass production of various fruits (Pathak et al. 2017; Babbar et al. 2011). During last 25 years, there has been tremendous rise in demand for processed fruits and vegetables (Gowe 2015). These food industries produce huge tons of wastes as high as 50% both solids and liquids at various stages of processing (Gowe 2015). About six million tons of solid waste are being solely generated by preservation of fruits with the aid of techniques such as canning, freezing, and drying every year. However, Chawan and Pawar (2012) and Joshi and Sharma (2011) reported that 5.5 million tons of solid waste is generated during the production of juices from fruits annually. Huge quantities of lingocellulosic biomass are left behind after processing of fruits as peels, seeds, and pulp (Pathak et al. 2017; Babbar et al. 2011). Babbar et al. (2011) state inappropriate infrastructure for handling of biomass as one of the reasons for alarming environmental pollution problems due to disposal of fruit industry biomass in open spaces or in municipal bins.

These large volumes of wastes are valuable in terms of nutrients and functional properties. Based on research, Gowe (2015) concluded that several researches have come up with the fact that peels and seeds which are by and large considered as nonedible portion of fruits have high quantities of bioactive components. Antioxidant activities found in inedible portions of fruits are due to numerous active dynamic phytochemicals such as vitamin, flavonoid, phenols, terpenoid, carotenoid, coumarins, curcumins, lignin, saponins, tannins, plant sterol, among others (Parashar et al. 2014). High levels of phenolic actives are found in peel, and seeds in comparison with flesh are studied by Al Mashkor (2014). Utilization of bioactive constituents of these fruit residues in the production of food, cosmetic, nutraceuticals, etc., is the most efficacious, coherent, economical, and nature-friendly way to reduce fruit residues (Babbar et al. 2011). By various techniques, nutritional and rheological properties can be exploited to provide a helping hand to the country's economy by extraction of bioactive compounds which requires setting up of new commercial units, ultimately creating new jobs and mitigating problems due to environmental pollution (Hui 2006; Babbar et al. 2011).

The main objectives to present this review:

- Conduct a comprehensive study of different fruit by-products that are a rich source of antioxidants.
- Create awareness about levels of waste produced by major food industries and amounts of inedible portions of some fruits.
- Provide certain potential effective, efficient, inexpensive, and eco-friendly solutions to utilize these tons of by-products.

- Suggest role of utilizing these fruit residues in the country's economy and mitigation of environmental problems.
- Shift the interest of consumers for more natural ways to eat healthy.
- Potential carcinogenicity of various artificial and synthetic food additives such as BHT, BHA, among others.
- Shift the focus of researchers to use of residues as source of antioxidants.
- Most importantly, utilize the huge tons of by-products released from fruit processing industries.

9.2 Jackfruit

Artocarpus heterophyllus is the scientific name of the national fruit of Bangladesh, popularly known as jackfruit or Ceylon. It is an evergreen tree belonging to the family Moraceae (Madruga et al. 2014; Hossain and Haq 2006). Tropical countries such as Brazil, Thailand, Indonesia, India, the Philippines, and Malaysia are the major centers for its cultivation (Madruga et al. 2014).

9.2.1 Components

Various products such as jams, compotes, frozen fruit pulps, juices, canned product, candid jackfruit, baby food, chips, desserts, soft drinks, among others, are prepared by processing of edible ripe and unripe bulbs of jackfruits which can also be consumed fresh (Madruga et al. 2014; Begum et al. 2004; Vazhacharickal et al. 2015). Outer prickly rind, inner nonedible perianth, and central core form 60% of inedible portion of the whole fruit which is unutilized waste (Begum et al. 2004). Central core alone is about 25–30% of the whole fruit (Islam et al. 2015). Yellow pulp bulb sand brown seeds encased in a hard shell form the edible portion of the fruit (i.e., 15–30%) (Madruga et al. 2014). A smooth, oval, light brown seed covered by a thin white membrane is enclosed within each pleasant flavored yellow sweet bulb. These seed accounts for about 5–6% of the total fruit ranging in number from 100–120 to 500 seeds per fruit with dimensions of about 2–4 cm length and 1.5–2.5 cm thickness (Islam et al. 2015).

9.2.2 Production

As per data provided by Sawe (2017), India is the largest producer of jackfruit accounting for about 1.4 million tons; Bangladesh is the second largest producer of about 926 tons, and other producers are Thailand, Indonesia, and Nepal. As per Agri exchange APEDA (2016), Kerala is the largest jackfruit producing state of India in 2014–2015 followed by Tripura, Orissa, and the remaining state producers are in Fig. 9.1.

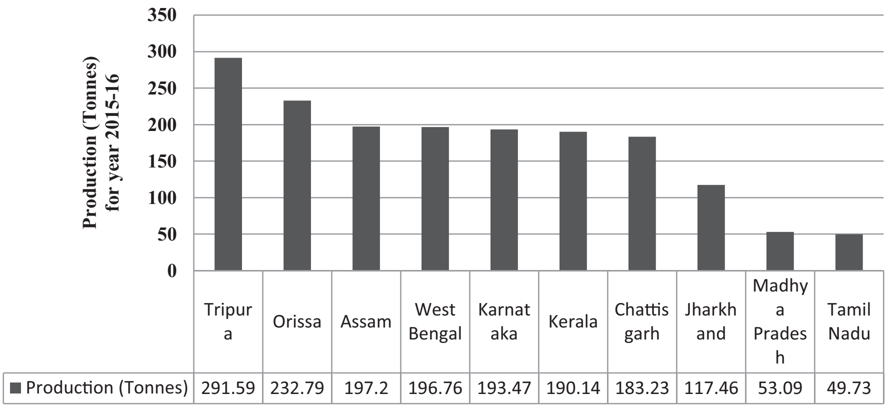

Fig. 9.1 Top 10 leading producer states of jackfruit in India. From Agri exchange (Source APEDA 2016)

9.2.3 Nutritional Composition

Jackfruit is a rich source of phytonutrients such as lignans, isoflavones, saponins, phenolic compounds. Preventing the formation of cancer cells in the body and fighting against stomach ulcers are some functions performed by these phytonutrients. They are also known to lower blood pressure and slow down the degeneration of cells which rejuvenate the skin (Swami et al. 2012).

Gupta et al. (2011) analyzed that jackfruit seeds contribute more than 70% to the total antioxidant activity and phenolic content of the jackfruit. Jackfruit seed contains manganese, magnesium, zinc, and all phytonutrients. Seeds also contain two lectins: jacalin and artocarpin (Swami et al. 2012; Gupta et al. 2011). The immune status of human immunodeficiency virus infected patients is evaluated using these lectins (Swami et al. 2012). Gupta et al. (2011) observed that the major protein, isolated from jackfruit seeds, is jacalin which possess immunological properties. Also, it shows that the extracts of jackfruit seeds possess appreciable DPPH, ABTS scavenging effects, and metal ion chelating activity. These seeds are good constituents of fat-free diet, owing to their negligible fat content. Begum et al. (2004) analyzed that calcium pectate content of 1.14–1.60% in edible portions (bulb) of jackfruit is comparatively lower than that of its inedible portion (rind and core).

9.2.4 Applications

Several studies have shown utilization of jackfruit inedible portion. Some of them are as follows:

- Seeds of jackfruit which hold large amounts of nutritional and antioxidant components that could be potential for value addition and nutraceutical development are discarded during fruit processing. These seeds contain huge amounts of starch that has industrial application as thickener and binding agent in the sector of food, pharmaceutical, bionanotechnology, paper, and cosmetics. These seeds have shorter shelf life; hence, these are converted to flour which is used in preparation of biscuits, sweets, and breads and several other bakery products (Chawan and Pawar 2012; Swami et al. 2012; Gupta et al. 2011).

- Various experiments of Swami et al. (2012) and Begum et al. (2004) have shown that rind and the core portion of jackfruit yield good amounts of highly esterified pectin with low solubility and high ash content in comparison with the commercial pectin. Hence, new research is going on in order to investigate the gelling properties and enhance the solubility of extracted pectin of this pectin.
- A research by Soetardji et al. (2014) was carried out to obtain bio-oil from jackfruit peel through pyrolysis. Further, this bio-oil by GC-MS analysis showed that it consists of acids, ketones, ethers, alcohols, sugars, furans, aldehydes, esters, phenols, oxygenated cyclic compounds, hydrocarbons derived, and nitrogen compounds. Conclusion from the research was that the oil obtained was acceptable but, certain work needs to be done to control its viscosity.
- Studies of Inbaraj and Sulochana (2004, 2006) proved that carbon prepared from jackfruit peel is effective in the removal of rhodamine-B dye, malachite green dye, and metal ions such as Cd(II), Hg(II), and Cu(II) from aqueous solution.
- Dam and Nguyen (2013) developed a new value-added beverage with 11°Brix, pH 4.35, 1.28% total acids, and 5.5% (v/v) ethanol by fermentation of rags of jackfruit which is a waste and forms about 25.3% of fruit weight. Beverage was even acceptable in terms of sensory quality attributes.

9.3 Pomegranate

Punica granatum is the scientific name of the national fruit of Iran which is popularly known as pomegranate, Grenadier, Granada, or Chinese apple. It belongs to Punicaceae family (experts from The Mayo Clinic et al. 2002). Fresh fruit and commercial products such as wines, juices, and candies are widely consumable forms of pomegranate (Al Mehder 2013).

9.3.1 Components

Arils and seeds account for (40% and 10%, respectively) 50% edible portion of pomegranate (Sreekumar et al. 2014). The remaining 50% is inedible portion (i.e., peels which are most often discarded as waste) (Al Mehder 2013; Sreekumar et al. 2014). After processing of pomegranate into juice, large part of the fruit is recovered as by-products which chiefly consist of peels and seeds (Çam et al. 2013).

9.3.2 Production

Statistical analysis by daily report (2018) reported that Iran is the largest producer of pomegranate followed by the USA and China, and India is the fourth largest producer of pomegranate. Within India, Maharashtra is the leading producer of pomegranate followed by Karnataka as per reports of APEDA (2012) (Fig. 9.2).

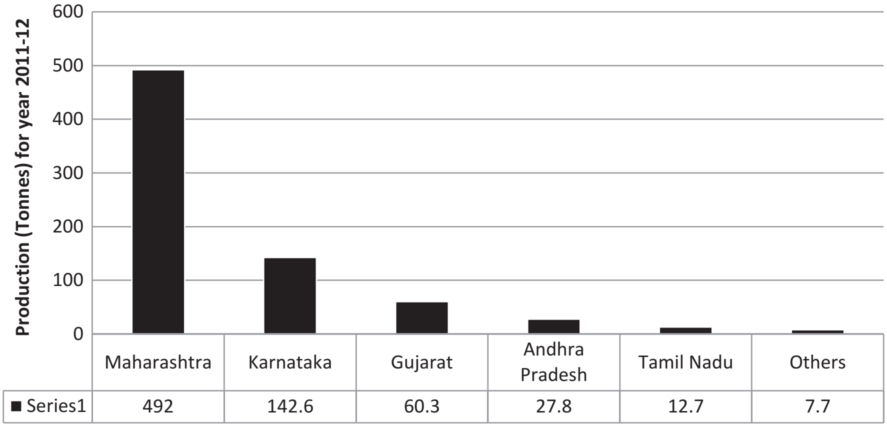

Fig. 9.2 Top six pomegranate producer states in India (Source, APEDA 2012)

9.3.3 Nutritional Aspects

Nutrients of pomegranate are unevenly distributed in peel, arils, and seed. Tannins, flavonoids, and other phenolic compounds especially punicalagins which contribute to antioxidant property are major nutrients in pomegranate peels (Ismail et al. 2012; Al Mehder 2013). Peel extract possess a wide range of biological actions such as anti-genotoxic properties, anti-tyrosinase activity, anti-inflammatory antioxidant property, anticancer activity, antimicrobial activity, anti-diarrheal activity, apoptotic properties, and antidiabetic activities owing to these nutrients. Pomegranate fruit peels are a good source of crude fibers which deliver various health benefits such as reduce hyperlipidemia and hypertension, decrease serum LDL-cholesterol level, contribute to gastrointestinal health, improve glucose tolerance and the insulin response, and eliminate the risk of certain cancers such as colon cancer (Ismail et al. 2012). Arils of pomegranate contain 85% water; 10% total sugars, mainly glucose and fructose; 1.5% pectin; organic acid such as citric acid, ascorbic acid, and malic acid; and bioactive compounds such as phenolics, flavonoids, and anthocyanins which are delphinidin, cyanidin, and pelargonidin (Ramadan et al. 2009; Sreekumar et al. 2014).

Rowayshed et al. (2013) reported that nutraceutical components such as sterols, γ-tocopherol, punicic acid, and hydroxyl benzoic acids contribute to anti-diarrheal and antioxidant bioactivities of pomegranate seed. Seed oil comprises 12–20% of total seed weight of pomegranate of which 65–80% is punicic acid which is an exceptional conjugated fatty acid (Sreekumar et al. 2014; Al Mehder 2013). Sterols, steroids, and cerebroside form minor component of seed oil (Sreekumar et al. 2014). Studies conducted showed that phenolic components and other nutrients are more in peel and rind portion of fruit as compared with juice.

9.3.4 Application

- In a study, Singh and Immanuel (2014) extracted antioxidants from fruit peels of orange, pomegranate, and lemon. When paneer sample with 2% of these peel extracts were put through, sensory studies showed greater acceptability and ability to suppress peroxide formation. Pomegranate peel extract showed greater ability to inhibit peroxide formation in paneer sample than extract of lemon peel which showed greater ability than orange peel extract. From the study, it was concluded and proven that synthetic antioxidants can be substituted with (natural safe antioxidant) pomegranate peel extract for extending shelf life of food containing fat and oil owing to their high antioxidant activity and phenolic content.
- In general, polyunsaturated fatty acids and phenolic components are poorly present in ice creams; therefore, in a study by Çam et al. (2013), incorporation of pomegranate peel phenolics (extract) and seed oil improved the functional properties of ice cream. Significant change in pH, total acidity, and color of the ice cream samples were observed upon incorporation of the peel phenolics at the levels of 0.1% and 0.4% (w/w). Incorporation of pomegranate by-product phenolic components sharply improved antioxidant, anti-diabetic activities and phenolic content of ice creams. It was concluded that the utilization of pomegranate by-products for functional properties of punicalagins in pomegranate peel and punicic acid in pomegranate seed oil in enrichment of ice creams might deliver consumers with humongous health benefits.
- Fruit fibers are considered as potential ingredients of foods due to their ability to reduce residual nitrite level which would possibly form nitrosamines and nitrosamides on processing. Hence, pomegranate fibers have been used in meat products processing as binder, fat replacer, bulking agent, volume enhancer, stabilizer, and fat absorption reducing agent during frying (Al Mehder 2013).
- Al Mehder (2013) showed that pan bread staling was enhanced with increase in pomegranate peel level addition. Sensory evaluation of the tested samples showed that 1% pomegranate peel pan bread seemed to be more closed to the control sample than the other pan bread (2.0% or 5.0% pomegranate peels) samples. Finally, it was concluded that nutritional, physical, and sensory quality of pan bread could be improved with just 1% pomegranate peel addition.
- The antioxidant activity of peel, rind, and juice hydroalcoholic extract showed significant decrease in peroxide value, malondialdehyde, p. anisidine, and carbonyl values at the 7th, 14th, 21st, and 28th day of storage at 60 °C and also DPPH at 200 μg for peels and at 1000, 500, 250, 200, 100 μg for rind and juice in comparing with BHT (Ramadan et al. 2009).
- In a study by Iqbal et al. (2008), it was proven that stabilization of sunflower oil and lard can be effectively done at all the concentrations of pomegranate peel extract. Stabilization efficiency comparable to legal limits of BHT a typical synthetic antioxidant can be achieved at concentration of 800–850 ppm of pome-

granate peel extract. Resistance of sunflower oil to oxidative rancidity and lard peroxidation is improved and inhibited respectively by anti-peroxidant activity of the pomegranate peels. Hence, it was concluded that stabilization of various food systems can be effectively achieved by utilization of pomegranate peel as a potent source of antioxidants (Iqbal et al. 2008).

9.4 Apple

Apple (*Malus domestica*) is the fruit grown widely in temperate regions of the globe and is the most favored fruit for millions of people. India is the ninth largest producer of apples in the world, presently contributing approximately one-third of the total apple production worldwide with an annual production of 1.42 million tons on an area of 0.25 million Ha Anon (2004). Apple is the fourth major fruit crop of India (Shalini and Gupta 2009).

Being profoundly biodegradable, the disposal of these squanders represents to a genuine ecological issue and exhibits many difficulties. Often just 20% is recovered as animal feed, and the remaining 80% goes to landfill, is burned, or is sent to fertilizing the soil locales which brings about arrival of greenhouse gases. Be that as it may, headway in innovation has prompted the option alternatives of use of apple pomace. For extraction of bioactive components and bio-production of high value-added products, for example, natural acids, enzymes, biofuels, among others, apple pomace can be used as a bestowed promising material, thereby gaining in biotechnology and enzyme technology at a much faster pace (Garry and Kaur 2013). Pomace contains 5% of seeds, which contain 15% of fat and are a good source of oil. Apple seed oil can be either cold-pressed or hot extracted. The main component of apple seed oil is linoleic acid—about 50% (Markowski et al. 2007).

9.4.1 Production

Jammu and Kashmir, Himachal Pradesh, and Uttrakhand are the major apple-growing states. The largest area under production of 1.39 million ha is by Jammu and Kashmir, having 48.72% of the total area of the country. The total production of apples is about 1.935 million tons in India which accounts for 3.0% of the total global production of apple (National Horticulture Board 2010; Shalini and Gupta 2009). The total production in Indian continent of apple pomace is approximately one million tons per annum, and out of this, only about 10,000 tons of apple pomace is being utilized.

9.4.2 Nutritional Index

The waste generated from fruit processing industries: the waste from apple includes pomace consisting of seeds, pressed shreds, peels, and core which largely comprises of nutrients that can be used as an additive and animal feed. One of the richest sources of nutrition is apple pomace. The contents of carbohydrates, crude fibers, fermentable sugars, pectin, minerals, etc., mainly add to its high nutritional value. Cellulose, hemicellulose, and pectin present in apple pomace are generally not digested by human enzymes coming under the category of dietary fibers. Apple pomace imparts nutritional benefits in soluble dietary fibers which function in lowering blood cholesterol levels (Mahawar et al. 2012).

Apple cider and juice processing industries have apple pomace as the main by-product, and it accounts for about 25% of the original fruit mass at 85% (wb) moisture content (Shalini and Gupta 2009).

9.4.3 Properties and Utilization of Apple Pomace

Apple peels are found to have high contents of phenolics contained up to 3300 mg/100 g of peels. The role of antioxidant phytochemicals obtained from apple pomace is mainly aimed in preventing LDL oxidation using a scavenging activity that works against peroxyl and hydroxyl radicals that are formed during this oxidation process to prevent diseases. These radicals have high affinity to lipids. Different dietary phytonutrients with strong antioxidant capacities such as phenolics, carotenoids, and vitamins are loaded in apple, which may protect against free radicals. Apple peels have high concentrations of phenolic compounds and may assist in the prevention of chronic diseases (Joshi et al. 2012).

- Effect of nitrogen and carbon source given by apple pomace-based medium by micrococcus was seen for the production of carotenoids, and 20 g/L of apple pomace gave best results.
- Pectin extraction using ethanol under acidic conditions, precipitation from liquid phase of pressing.
- Solid-state fermentation of apple pomace was carried out for 96 h at 30 °C. Sugar concentration reduced from 10.2% to less than 0.4%, and final concentration of ethanol was more than 4.3% and fermentation efficiency of 89%.
- Production of organic acid (citric acid) using apple pomace from *Aspergillus niger*.

9.5 Banana

Banana (*Musa paradisiaca*, family Musaceae) is a major cash crop and is a central fruit crop of the tropical and subtropical regions of the world.

9.5.1 Production

Following the citrus, banana is the second largest produced, contributing about 16% of the world's total fruit production. India is the largest producer of banana, with 29,780 million tons, contributing to 27% of world's banana production followed by

China and the Philippines with 9848.90 and 9101.34 million tons of production, respectively, according to 2010 FAO report (Mohiuddin and Saha 2014). Production of banana in India has surpassed mango production incidentally. In India, Tamil Nadu is the leading producer of banana, followed by Maharashtra, Maharashtra, Kerala, Tamil Nadu, Gujarat, Bihar, West Bengal, Assam, Andhra Pradesh, and Karnataka Mohapatra and Mishra (2010).

9.5.2 Nutritional Profile

Mohiuddin and Saha (2014) in their findings studied that chemical composition of banana fiber is majorly cellulose (50–60%), hemicelluloses up to 25–30%, pectin 3–5%, lignin 12–18%, water-soluble materials 2–3%, fat and wax 3–5%, and ash 1–1.5%. Banana peel is another source rich in starch, that is, 3%, crude protein 6–9%, crude fat 3.8–11%, total dietary fiber 43.2–49.7%, and α-linolenic acid, pectin polyunsaturated fatty acids, particularly linoleic acid and essential amino acids (leucine, valine, phenylalanine, and threonine), and micronutrients.

The following are some specific diseases that are cured by banana:

- Blood pressure: Due to high content of potassium than low in salt in banana, it makes them the best food to beat blood pressure.
- Depression: Tryptophan is an amino acid that converts serotonin and is contained in banana in high amounts. It makes body feel relaxed, improves mood, and makes feel happier.
- Heart burn: Banana is a source of natural antacid which soothes and reliefs the body with pain caused by heartburns.
- Morning sickness: Regular snacking on bananas between meals helps to keep blood sugar levels up and maintained, thus avoiding morning sickness.
- Mosquito bites: Applying/rubbing the affected area with the inner portion of a banana skin aids effectively at reducing swelling and irritation caused by mosquito bite.
- Nerves: Bananas are rich sources of B vitamins that help calm the nervous system.
- Smoking: Bananas are high in vitamin C, A1, B6, B12, as well as potassium and magnesium which help in recovering body from nicotine withdrawals and therefore help people who are trying to give up smoking.
- Stress: A vital mineral (i.e., potassium) is present in banana, which has the capability to normalize the heartbeat; it sends oxygen to the brain and helps in regulating the body's water balance (Ehiowemwenguan and Emoghene 2014; Tin and Padam 2014).

About 90% of production of banana is consumed as fresh fruit. Around 5% is processed, about 2.5% is processed as banana products purely, and the rest part is added as an ingredient in other foods. About 17 varieties of processed products could be made and developed from banana. The primary product of banana in the market is "fried chips and candy" which constitute around 31%, the rest as banana puree which accounts for 9%, banana pulp stands at 3%, banana beer at 3%, banana wafers 3%, banana powder at 6%, and others. The tender stems of banana plant are used as a vegetable and have high medicinal values. Sweet candy is prepared from the tender banana pseudostem (Rona 2015).

9.5.3 Uses of Banana By-Products

Generally, banana by-products include the pseudostem, leaves, inflorescence, fruit stalk (floral stalk/rachis), rhizome, and peels. Most of these by-products are used rarely as an undervalued commodity with a limited commercial value, application, and in some cases it is taken to be as an agricultural waste. The pseudostem and leaves after banana harvesting are commonly left to rot in farms to replenish some of the nutrients in the soil. Although young shoots, pseudostem piths, and inflorescence can be consumed as vegetables by the indigenous people in parts of Southeast Asia and Indo-Malayan Region (Waste Management Review 2017). The banana inflorescence values were quite low because of the inconsistent demand and limited acceptance. In Southeast Asia, banana leaves are still used in wrapping of traditional foods, but its application is only limited to some ethnic foods. A slightly better application can be utilization of banana waste as animal feed which can reduce the production cost significantly. A process by which carbohydrates are broken down in absence of air and releasing methane gas and CO_2 mixture is initiated by action of bacteria on damaged banana and bunch stalks. This product is a gaseous fuel generated by anaerobic respiration Vigneswaran et al. (2015).

Food industry uses starch, pectin, and cellulose as gelling agent, thickening agent, and stabilizers. Starch, a group of carbohydrates, is commercially available and produced from plants such as corn, rice, potato, cassava, and wheat.

Pith of pseudostem and the green culled banana which are removed during fruit selection and processing are banana by-products that are used to convert into edible starches (AgropedialabsIITK 2015). Banana starches have low quantity of amylase; therefore, they possess high resistance to heating and amylase attack, low swelling properties, low solubility in water, low retrogradation, and proved to be slightly superior to modified and unmodified corn starch giving it a potentially higher market value (Tin and Padam 2014).

Banana fibers spun with other fibers make excellent ropes suitable for agricultural purposes. Banana fiber being excellent sorbent has highest potential to absorb spilled oils in refineries. Pseudostem and petioles have medium to low amounts of ash, lignin, and high amounts of holocellulose, therefore making them a suitable raw material for pulping in paper industry. Both banana and its pseudostem contain pathgenesis-related protein which possesses antimicrobial properties (Ehiowemwenguan and Emoghene 2014; Vigneswaran et al. 2015).

9.5.3.1 Banana Peel Usage

Banana oil (amyl acetate) can be extracted from the utilization of skins and can be used for food flavoring. Banana peels are also a good source of lignin (6–12%), pectin (10–21%), cellulose (7.6–9.6%), hemicelluloses (6.4–9.4%), and galacturonic acid. Banana peel can also be used in wine, ethanol production, and can also be used as substrate for biogas production. Pectin extracted from banana peel also contains glucose, arabinose, galactose, rhamnose, and xylose. Peels could be used as a good feed material for cattle and poultry as it contains higher concentrations of micronutrients (Fe and Zn) than pulp itself (AgropedialabsIITK 2015).

9.5.3.2 Banana Leaf Usage

Dried banana leaves possess high potential to be used as fuel and a good substrate to grow and culture oyster mushrooms (Mohapatra and Mishra 2010). The leaves of banana can be fed to ruminants with addition of some protein extract for better digestibility. Addition of protein content which is substantial in leaf blade could make an ideal cattle feed (Wadhwa and Bakshi 2013).

9.5.3.3 Banana Sheath and Pith Usage

Lectins, present in abundance in banana plant tissues, can be efficiently exploited for its use in human consumption. Pseudostem can be used as a biofertilizer after its recyclization. Pith of banana is widely consumed as food after boiling and addition of spices and condiments in different parts of India. Sheath and pith are composed of dry matter, 6.4%; crude protein, 3.4%; cellulose, 34.6%; hemicelluloses, 15.5%; crude fiber, 31.4%; and lignin, 6% contained in banana sheath can be used as a suitable feed for ruminant (Mohapatra and Mishra 2010).

Banana peel wastes are readily available as it is one of the most heavily produced agricultural waste; however, they are underutilized as they have potential to be growth medium for local yeast strain, despite their rich carbohydrate content and other basic nutrients that can support yeast growth. The yeast grown indigenously with banana peels as a medium possesses good fermentation attributes, which may enhance ethanol yield and minimize the overall cost of production (AgropedialabsIITK 2015).

9.6 Dates

The date palm (*Phoenix dactylifera*) is used as a staple food by many people in the world (especially in the region of North Africa and the Middle East Asia). Date palm tree is a dioecious monocotyledon and belongs to the family Arecaceae (Ahmad et al. 2012). The fruit is composed of a fleshy pericarp which is an edible part of fruit; this fleshy part is protected by a thin outer covering known as skin and an inedible pit that is considered as waste (Al-Orf et al. 2012).

Besides their direct consumption, a variety of semifinished and ready-to-use products are manufactured from date palm fruit. These products include a date paste which is used in bakery and confectionary industry to impart characteristic sweet flavor, and fermented date products such as vinegar, organic acids, alcohol, and concentrated date juice are used to manufacture spread, syrup, and liquid sugar. Unacceptable low-grade date fruits, date press cake, and date pits generate tons of waste during processing. Date press cake obtained after the extraction of juice and poor-quality palm dates having blemishes or defects that cannot be packaged for marketing are mostly utilized as substrate for fermentation products and in animal food because of their good nutritive values such as sugars, proteins, minerals, and fiber. Al-Farsi and Lee (2008a, b) has found that date pits generally constitute between 10% and 15% of date fruit weight. In 2010, worldwide date production reached to 7.2 million tons, and approximately 720,000 tons of date pits could be produced annually (i.e., considering 10% of the total fruit mass) (FAO 2011). Thus, utilization of dates by-product/waste is very important to promote cultivation of palm date and to increase the income to this sector (Shrafand and Esfahani 2011).

9.6.1 Date Pits Used as a Precursor of Activated Carbon

Commercially available activated carbon is considered expensive, due to the use of bituminous coal which is nonrenewable and relatively expensive precursor. Coconut shells, wood, almond shell, peanuts, apricot stone, date stone, olive stone, oil palm shell, and nutshell which is regarded as waste/by-products of fruits and vegetables have been used as sources for activated carbon (Ahmad et al. 2012).

Date pits are cheap and easily available unconsumed part of dates which has good absorbing capacities as compared with other absorbents. Date pits have been found good and effective absorbents which help in removal of heavy metals and could be used in water and wastewater treatment (Hilal et al. 2012). Girgis and El-Hendawy (2002) developed a low-cost activated carbon by the process of chemical activation of date pits with phosphoric, and it was determined the BET–adsorption surface area with nitrogen and adsorption capability. Activated carbon obtained at 300 °C having low porosity showed good capacity to remove iodine, methylene blue, and phenol.

Activated carbon and date pits powder made from date pits are used to remove toxic compound such as heavy metals, pesticides, boron, dyes, and phenolic compounds from wastewater (Hossain et al. 2014).

9.6.2 Edible Oil Extracted from Date Pits

Al-Farsi and Lee (2008a, b) have showed that the fat content in the date seed range from 5.7% to 12.7%. Different date varieties, different harvesting time, different origin, and the use of fertilizer affects the oil content of date pits which in turn affects its oil quality. The difference in oil content may occur due to the effect of nutrient content of the date. Lauric, myristic, palmitic, stearic, oleic, and linoleic acids are the major fatty acids found in date seeds. It was observed that mayonnaise made by using date pits oil has superior sensory qualities as compared with control manufactured from corn oil.

9.6.3 Date Pits Used as an Alternative to Coffee Drink

In the Middle Eastern region, date pits drink is used as an alternate to coffee drink. Date seeds are roasted to produce naturally caffeine-free drink which could provide an alternative to normal coffee, when caffeine is a concern. It was presumed that consumption of date pits drink helps in the reduction of blood pressure, increase in body protein by decreasing fat, and relaxation of the uterine and intestinal musculature. It was found out in studies that glucomannan present in date seeds helped to normalize blood sugar, mitigate blood sugar abnormalities such as hypoglycemia, relieved stress on the pancreas, and prevented many chronic diseases (Ishrud et al. 2001). Optimum processing conditions and methods have to be developed to manufacture date pits drink because white skin present on date seeds should be removed before roasting since it could form foam in the drink. However, this white skin could be used in bakery products or in other foods as a natural foaming agent (Ahmad et al. 2012).

9.6.4 Date Pits as an Antimicrobial Agent

Saddiq and Bawazir (2010) have shown that water and alcoholic extracts of date seeds possess antimicrobial activity against *Escherichia coli, Klebsiella pneumonia, Staphylococcus aureus, Bacillus subtilis, and Proteus vulgaris*. As compared with antibiotics, date pits are most effective in inhibiting the growth of bacteria, mainly because of two reasons: (a) differences in resistance of bacteria to anti-tested materials and (b) membrane permeability of bacterial cell is changed, thereby hindering the enzyme's entry or excreted by the change in the chemical composition of the constituent chemical.

9.6.5 Date Pits as a Source of Dietary Fiber

Several fiber-rich products such as bread, biscuits, and cakes and dietary supplements can be produced using date pits because of its nutritional value based on its dietary fiber content (Ahmad et al. 2012). Date seed contains 58% dietary fiber, with 53% of insoluble dietary fiber, namely, hemicelluloses, lignin, and cellulose (Aldhaheri et al. 2004; Al-Farsi and Lee 2008a, b; Abdul Afiq et al. 2013). Several researches on the effects of pits in animal diets have shown that substantial amounts of tannins, resistant starch, and natural anabolic agents are present in date pits. Date pits can be used as an alternative source of dietary fiber to wheat bran and can substantially increase the dietary fiber intakes (Hadarmi 1999; Elgasim et al. 1995; Almana and Mahmoud 1994; Hamadaa et al. 2002).

9.6.6 Date Pits as a Source of Antioxidants

Al-Farsi and Lee (2008a, b) have reported that date pits contain high levels of antioxidants (580–929 mL trolox equivalents/g), phenolics (3102–4430 mg Gallic acid equivalents/100 g), and dietary fiber (78–80 g/100 g) which could be a potential scope for curing various chronic diseases. Date seeds have the potential to be used in nutraceutical, pharmaceutical, and medicinal products as a supplement for antioxidants.

9.7 Citrus Fruits

Citrus fruits belong to the family of Rutaceae which include about 17 species such as lime, orange, lemon, mandarin, sour orange, and grapefruit throughout the tropical, subtropical, and temperate regions of the world (Rafiqa et al. 2016). Citrus fruits are highly consumed worldwide with the approximate production of 121273.2 thousand tons in 2013–2014 (FAO). China is the largest producer of citrus fruit (42.17%) followed by Nigeria (31.3%) and India (6.17%) (APEDA 2014). Citrus peels are divided into the epicarp, or flavedo which is colored peripheral surface underneath to this white soft middle layer known as mesocarp or albedo is present. Citrus fruit's by-product is a rich source of potential bioactive compound, which are generally considered as waste and discarded in the environment. Citrus fruits are generally consumed fresh or used in juice extraction. Oranges account for 60% of the total citrus fruit production, and the major utilization is processing for juice recovery. About 34% of the total citrus fruit production is used in juice extraction which yields approximately 44% peels as a by-product (Rafiqa et al. 2016). Dried pulp, washed pulp solids, molasses, and essential oils are the major by-products of citrus fruit obtained after processing which represents about 50% of the raw processed fruit (Chaudry et al. 2004; El-Adawy et al. 1999). Therefore, every year a large amount of waste is generated and discarded in the environment.

9.7.1 Phenolic Content of Citrus Peels

A major class of secondary metabolites are derived from pentose phosphate, shikimate, and phenylpropanoid pathways in plants (Balasundrama et al. 2006). By-products or wastes generated by citrus industry are rich in phenolic compounds, particularly peels, and have potential to be used as antioxidant supplementation. Citrus peels have higher contents of total phenolics compared with the edible portions (Balasundrama et al. 2006). Studies have shown that citrus peels of lemons, oranges, and grapefruit peels have high total phenolic content in peels (Balasundrama et al. 2006). As compared with other parts of citrus fruit, peels contain high amount of flavonoids. These flavonoids belong to the six different classes that are flavonols, flavones, flavanones, isoflavones, anthocyanidins, and flavanols. These potential bioactive compounds present in citrus peel possess a wide range of physiological properties, such as antiatherogenic, anti-allergenic, antioxidant, anti-inflammatory, anti-thrombotic, vasodilatory effect, and cardio protective (Balasundrama et al. 2006).

9.7.2 Oil Present in Seed and Oil

The citrus peels contain a significant amount of oil that is present in numerous oil-bearing glands that are enclosed in peels (Sikdar et al. 2016). Citrus seeds contain about 36% oil and 14% protein. Mainly three peculiar classes of compounds are found in citrus oils: terpene hydrocarbons, oxygenated compounds, and nonvolatile compounds (Chanthaphon et al. 2008). Pharmaceuticals, food, and other industries use citrus peel essential oil, and it is generally regarded as safe (GRAS). Citrus peel oil because of its pleasant odor is used in perfumery but is also seen to be gaining application in sweets, beverages, and cakes. The citrus oil has around 95% of D-limonene content which could be extracted and can be used in many applications such as for food flavoring agents and in cosmetic products (Sikdar et al. 2016). The refined oil can be used for cooking purposes while crude oil found its application in detergent and soap manufacturing industry. Balasundrama et al. (2006) have shown the following characteristic for the citrus seed oil: saponification value ranged from 186.8 to 191.3, iodine value ranged from 91.4 to 99.3, acid value ranged from 0.21 to 1.2, refractive index ranged from 1.4681 to 1.4662, and specific gravity ranged from 0.912 to 0.923 at 258 °C. Researchers have shown that essential oils obtained from citrus fruits exhibit antimicrobial effect against both fungi and bacteria. Citrus peel oil can be used to increase the shelf life of minimally processed fruits, low fat milk, and skim milk (Chanthaphon et al. 2008). In some researches, it has been reported that the essential oils of bergamot, orange, and lemon are more antiseptic than phenol (Oreopoulou and Tzia 2007). Terpenoids can be recovered from oil extraction of citrus fruits, while the meal remaining after oil extraction can be used as a source of proteins (Balasundrama et al. 2006).

After extraction of ether soluble fat from citrus fruit, the meal obtained has high protein content. El-Adawy et al. (1999) reported that citrus seed meals have high amount of cysteine, glycine, methionine, and tryptophan and lower level of lysine as compared with soybean meal. Citrus seeds have an excellent amino acids profile. Therefore, this type of waste has potential to be used in development of oil and protein supplements. Pectin compound and dietary fiber are also extracted from the citrus peel by acid extraction and mechanical processing, respectively, (Oreopoulou and Tzia 2007).

9.8 Results and Discussion

The data on waste production from various food categories in South and Southeast Asia is shown in Fig. 9.3. Figure 9.4 depicts the percentage of inedible portion of different fruits which is highest in citrus fruits followed by pomegranate and least is in dates. Figure 9.5 showed the phenolic content in various fruits and depicts the phenolic content of different parts of different fruits. It clearly shows that peel portion of all six fruits have maximum phenolic content. Table 9.1 enlists the inedible portions of fruits left during processing and their applications.

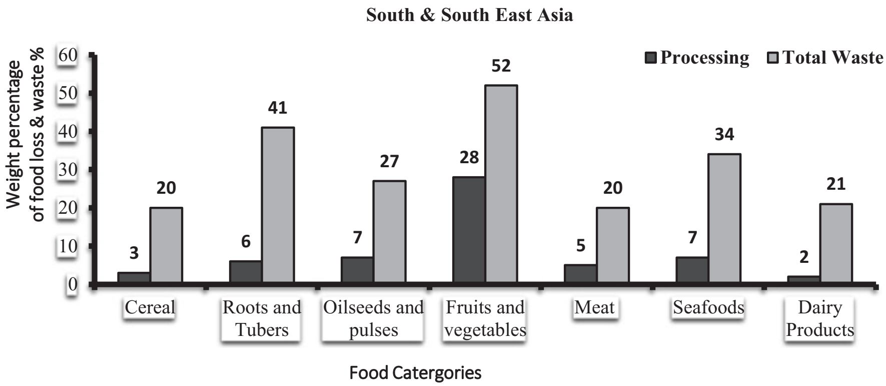

Fig. 9.3 Waste production from various food categories in South and Southeast Asia (Source: Gustavsson et al. 2009)

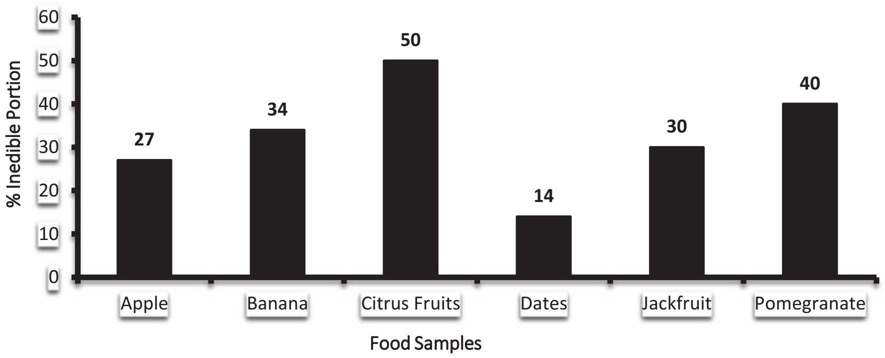

Fig. 9.4 Percentage of inedible portion of six fruits (Source: Joshi and Sharma 2011; McCance et al. 1991; Chengappa et al. 2007; Yahia 2011)

9.9 Conclusion

In the near future, seeing the current economic situation of horticulture will be most affected as waste from fruit processing industry would exceed what they produce. Natural resources wastage and unnecessary landfill formation are two major problems resulting from inability to reuse this fruit waste. Disposition of large amount of agro-industrial waste possess threat to environment. Fruit waste is a rich source of several nutrients and disposing it off is shear wastage of natural resources. With this review, we concluded that peels and seeds of pomegranate, dates, apple, jackfruit, citrus fruit, and banana contain more active compounds than their flesh. These peels and seeds can be used for extraction of various antioxidant compounds which can be utilized to extend the shelf life of food and food ingredients like sunflower oil etc. The active

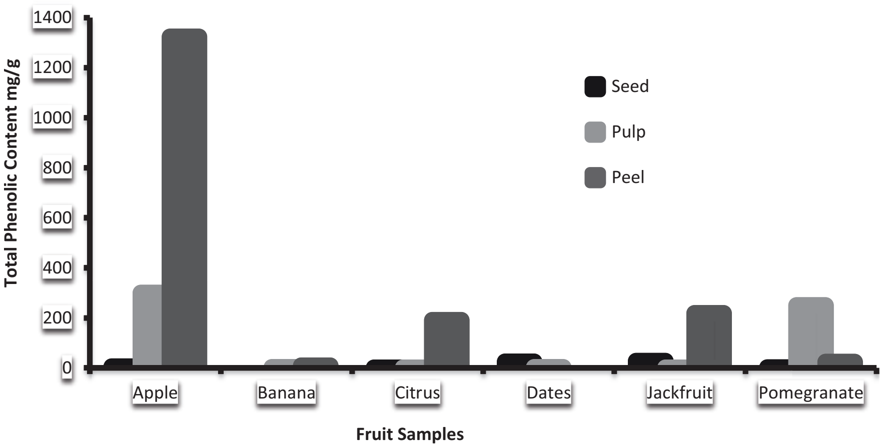

Fig. 9.5 Phenolic content of different fruits (Source: Gowe 2015; Tsao et al. 2005; Emna et al. 2009; Xu et al. 2016; Al Meqbaali et al. 2017; Sharma et al. 2013; Al Juhaimi and Ghafoor 2013; Malacrida et al. 2012)

Table 9.1 Inedible portions of fruits and their application (Source: Chawan and Pawar 2012; Hui 2006)

S. no.	Fruit	Inedible portions left during processing	Application
1.	Apple	Peel, pomace, and seed	Vinegar, jelly, powdered pectin, natural flavorings, various enzymes
2.	Banana	Peel	Banana cheese, paper pulp
3.	Citrus fruits	Peel, rag, and seed	Animal feed, citrus seed, and peel oil, pectin
4.	Dates	Seed, waste pulp	Animal feed, fibers, oil
5.	Jackfruit	Rind (peel), core	Pectin
6.	Pomegranate	Peel, seed (sometime)	Oil, medicinal uses, stabilization of sunflower oil

compounds extracted from fruit waste can be used for fortification. Date Pits can be used for fortification by dietary fiber and citrus peel extract is used in paneer to increase its antioxidant content. This scenario gives an idea that fruit processing industries can generate additional profits by turning previously considered waste in to valuable products like antioxidants, antimicrobials, flavoring, colorants, texturizer, dietary fiber, proteins etc. This area still needs lot of research for effective utilization of waste generated after fruits processing. All these efforts of fruit processing industries will improve their environmental profile and competitiveness in the market.

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10 Dietary Supplements for Weight Loss and Their Mechanism

Nikita Narang and Renu Khedkar

Abstract

Overweight and obesity are known to be one of the most prevalent lifestyle disorders. Different factors including genetic or molecular factors, age, and sex of an individual, eating habits and food behavior, physical activity, stress, endocrine factor, trauma, modernization, and civilization when interact led to obesity. Despite growing recognition of the problem, change in lifestyle pattern and food behavior is hardly adopted. This has led to the development of nonsurgical health approaches in order to treat the disease. These approaches involve the use of foods that hold special health use, namely, dietary supplements. Different supplements adopt a different pathway for their mechanism and function. The most commonly adapted ones promote to control appetite and reduce absorption of particular nutrients, thereby promoting weight reduction and elevate fat burning. Dietary supplements or food supplements for weight loss are one of the most effectively prevailing weight loss methods. The overall outcome of the use of these supplements has shown a positive shift with effective results. The study covers different dietary supplements that are available in the market with their active ingredients. The mechanism of action of the active ingredients with the harmful effects clearly brings out the market demand for each supplement. The study also highlights that the regulatory bodies for dietary supplements, namely, FSSAI and FDA, have laid down certain recommended dietary allowances (RDAs) in order to regulate the consumption of food supplements.

Keywords

Sedentary lifestyle · Dietary supplements · Market demand · RDAs

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10.1 Introduction

Health supplements or dietary supplements are added sources of nutrition to a normal diet of a person above the age of 5 years. Health supplements intend to comprise of concentrated source of one or more nutrients, specifically, amino acids, enzymes, minerals, proteins, vitamins, other dietary substances, plants or botanicals, prebiotics, probiotics, and substances from animal origin or other similar substances with known and established nutritional or beneficial physiological effect, which are introduced as such and are offered alone or in combination but are not drugs (The Gazette of India 2016).

A dietary supplement is a material containing a "dietary ingredient" that aims to elevate the nutritional value of the diet. A "dietary ingredient" may be one, or any combination, of the following substances:

- A vitamin
- A mineral
- An herb or other botanical
- An amino acid
- A dietary substance for use by people to supplement the diet by increasing the total dietary intake
- A concentrate, metabolite, constituent or extract

Tablets, capsules, soft gels, gelcaps, liquids, or powders are the most prevalent forms available. Some dietary supplements can help ensure that one gets an adequate dietary intake of essential nutrients; others may help in reducing risk of diseases (FDA U.S. Food and Drug Administration 2015).

The US Dietary Supplement Health and Education Act of 1994 defines dietary or food supplements based on certain principles. They are:

- A product (besides tobacco) that attempts to supplement the diet with any of the following dietary ingredients: a vitamin, a mineral, an herb or other botanical, an amino acid, a dietary substance for use by man to supplement the diet by increasing the total daily intake, or a concentrate, metabolite, constituent, extract, or combinations of these ingredients.
- A product that is ingested in a form of pill, capsule, tablet, or liquid form.
- A product not characterized for use as a conventional food or as the sole item of a meal or diet.
- Anything labeled as a "dietary supplement."
- Products such as a newly approved drug, certified antibiotic, or licensed biologic that was marketed as a dietary supplement or food before approval, certification, or license (Cencic and Chingwaru 2010).

Table 10.1 Difference between functional foods, dietary supplements, and nutraceuticals (Cencic and Chingwaru 2010)

Functional foods	Dietary supplements	Nutraceuticals
Foods that provide health benefits other than essential nutrition needs	An item with additional dietary ingredient aiming to raise the nutritive value of diet	A product segregated from food and sold usually in medicinal form
They are taken as a part of an individual's normal diet	Unlike functional foods, supplements are not be taken as a part of normal diet, that is, these cannot be recognized as the sole constituent of the diet	Nutraceuticals are products that are made to be a sole constituent of one's diet when required under certain medical treatment and concerns
In addition to act as conventional food, these add extra health benefits	Dietary supplements are not supposed to impart any therapeutic or curative assistance	They portray dual function of supplementation of a diet and prevention or treatment from any disease or disorder

10.2 Functional Foods, Dietary Supplements, and Nutraceuticals

The following review suggests commonly used ingredients in different dietary supplements. The need to study the mechanism arises as a part of awareness. The knowledge and awareness of action of different ingredients helps individuals to choose a product that can help them achieve their goals (Table 10.1).

10.3 Market Trends of Dietary Supplements in India

With growing time, people in India are becoming more conscious about their health and physical appearance. They are ready to spend on their looks. This emerging trend has encouraged the use of various health and dietary supplements. Their growing demands are encouraging companies to formulate new products that help them in weight maintenance and looks.

In growing industries in India, these products or nutraceuticals are referred to as Fast Moving Healthcare Goods (FMHG). The Indian nutraceutical industry is expected to grow at 20% to 6.1 billion USD by 2019–2020. This has a direct relation with increasing awareness and inclination of people into the use of supplements. Factors influencing the growth are awareness to be fit and healthy, ageing population, and changing lifestyle patterns from moderate to sedentary.

Dietary supplements hold 32% shares in the Indian nutraceuticals market. These supplements are vitamin based, mineral based, based on phytochemicals, and fruit extracts. Protein powders and extracts from shellfish are all commonly used ingredients in dietary supplements. The global nutraceutical market is expected to reach 241.1 billion USD by 2019 from 160.6 billion USD and 171.8 billion USD in 2013 and 2014, respectively. The growing rate of the market is at a little pace in India and Indian subcontinents, but with urbanization and young population, it is expected to reach great heights in the coming years (Table 10.2).

Table 10.2 Opportunities and challenges faced by nutraceutical companies

Opportunity	Challenge
Size of the market in India at rupees 65 billion is just 2% of the global nutraceutical market	Product development: companies should formulate new and better products
Rising incidence of diet-related health issues	Product differentiation: companies should take lead by building the credibility and lowering prices
Growing consumer awareness with mass media.	Product promotion: companies should promote products through advertisements and consumer awareness

Dietary supplement and nutraceuticals are an emerging trend which will catch great attention and gain immense profit in the coming years. The manufacturing companies and new product development should play an effective and important role in future growth of the business (Nutraceutical Products in India—A Brief Report, ASA and Associates 2015).

10.4 Obesity

Obesity is a complex, multifactorial chronic disease that develops due to interactive influences of various factors: social, behavioral, psychological, metabolic, cellular, and molecular. In simple terms, obesity occurs when the intake of calories is more than the expenditure of energy. This establishes a positive energy balance and eventually leads to obesity. It is a condition wherein there is generalized accumulation of excess adipose tissue in the body leading to more than 20% of the desirable body weight. Along with obesity, there is also a term often referred as overweight; a person is known to be overweight when he/she is at the verge of becoming obese that is where the body weight is 10–20% greater than the mean standard weight for age, height, and sex.

Obesity and overweight hold the potential to bring a lot of diseases and disorders along. Excess body weight is an obstruction or a barrier that may eventually lead to breathlessness on moderate exertion and introduces an individual to a predisposition of diseases such as atherosclerosis, high blood pressure, stroke, diabetes, gall bladder diseases, and osteoarthritis of weight bearing joints and varicose veins (Srilakshmi 2014).

10.4.1 What Leads to Obesity?

Obesity or weight gain is a result of failure of the homeostatic mechanisms. This rudimentary approach is explained by the integrated functioning of the gut and the adipose tissue. The gut and the adipose tissue send signals to the central nervous system. The central nervous system integrates both the signals to affect appetite and energy homeostasis. Any alteration in these mechanisms results in obesity.

These alterations are based on several factors such as social, behavioral, psychological, metabolic, cellular, and molecular and eventually become the causes of obesity (Sikaris 2004).

10.4.2 Causes of Obesity

As said above, different factors when interact lead to obesity. The following article discusses these factors in more detail:

1. **Genetic or molecular factors**—genetic inheritance holds about 50–70% of a person's chance of becoming fat as compared with any other factor. Any mutation in the human gene for the B3 receptor in adipose tissue, involved in lipolysis and thermogenesis, markedly increase the risk of obesity.

   Genes such as UCP1, UCP2, and UCP3 play a role in energy expenditure; others such as MC3R, MC4R, and CCKAR are involved in food intake regulation; NPYRS regulates appetite, and thus, these genes are responsible for the occurrence of obesity.
2. **Age and sex**—obesity can occur at any age irrespective of the sex as long as the individual is under positive energy balance. However, hormonal predisposition put women at higher risk of obesity as compared to men.
3. **Eating habits**
   (a) Nibbling between meals is a potential cause of obesity.
   (b) Obese people respond to external cues to eat rather than internal hunger signals. They eat when it is meal time or when surrounded with tasty foods instead when they are hungry.
   (c) Noninclusion of fruits and vegetables and more of nonvegetarian diet favors weight gain.
   (d) Consumption of sugar-added beverages also is a contributing factor in weight gain.
   (e) People who enjoy eating fried, concentrated, and processed foods are at a high risk of becoming obese.
4. **Physical activity**—adapting sedentary lifestyle trends and involving less in physical activity is also a growing cause of obesity. Therefore, it may be more common during middle age because then the physical activity decreases without a corresponding decline in food consumption.
5. **Stress**—food stimulates the "feel good" neurotransmitter endorphin. Self-gratification, depression, anxiety, and stress may lead to excess calorie intake. Chronic sleep deprivation may increase appetite in some.
6. **Endocrine factor**—obesity is found in hypothyroidism, hypogonadism, and Cushing's syndrome. It is common at puberty, pregnancy, and menopause, indicating that endocrine may prove to be a factor in obesity.
7. **Trauma**—hypothalamus regulates appetite or satiety. Any damage to the hypothalamus may be because of a head injury may lead to obesity.

Table 10.3 Classification of BMI (kg/sqm)

Category	WHO (2004)	Asians
Underweight	<18.5	<18
Normal	18.5–24.9	18.0–22.9
Overweight	25.0–29.9	23.0–24.9
Obese	≥30	>25

8. **Prosperity and civilization**—obesity is common in countries such as the UK and USSR where people from higher socioeconomic status have a high purchasing power and surplus food. It is uncommon in primitive countries.

10.4.3 Assessment of Obesity

1. **Body weight**—an adult weighing 10% more than standard weight is overweight and 20% more is obese.
2. **Body mass index**—BMI is accepted as a better estimate of body fatness than body weight. BMI is weight in kg divided by height in square meters.
3. Other assessment methods may include waist circumference, measurement of body fat, waist to hip ratio, Broca's index, etc. (Srilakshmi 2014) (Table 10.3).

Overweight and obesity are very interrelated terms that are growing rapidly and in turn are leading to progressive and severe health conditions such as diabetes, atherosclerosis, etc. Thus, they require a strict and prompt approach. One of the many ways to fight weight gain and obesity is the use of different dietary supplements accompanied by moderate exercise.

The following review puts forward different supplements—synthetic, semisynthetic, and herbal—that can help achieve weight reduction. The article talks about the harmful effects, if any, of each supplement under the concerned regulatory bodies. The growing market trend of these supplements is also highlighted in the following review article (Table 10.4).

10.5 Dietary Supplements in Weight Loss

With the emerging trends of weight management, the use of dietary supplement is regarded as a way to contribute in weight reduction. These supplements are available in various brands and forms with respect to their user's convenience. Different supplements adopt a different pathway for their mechanism and function. The most commonly adapted ones promote to control appetite, reduce absorption of nutrients thereby promoting weight reduction, and elevate fat burning. The following review talks about different dietary supplements, their use and action, and the harmful effects, if any.

Table 10.4 Different weight loss supplements based on different mechanism of action

Increase energy expenditure	Increase satiety	Block dietary fat absorption
Ephedra	Guar gum	Chitosan
Bitter orange	Glucomannan	Increase water elimination
Caffeine	Psyllium	Dandelion
Yerba mate	Increase fat oxidation or reduce fat synthesis	Cascara
Guarana	L-carnitine	Enhance mood
Modulate carbohydrate metabolism	Green tea	St. John's wort
Ginseng	Vitamin B_5	Miscellaneous
Chromium	Conjugated linoleic acid	Laminaria
	Hydroxycitric acid	Spirulina

10.5.1 Caffeine-Based Supplements

Caffeine, a methylxanthine, is known to affect the energy expenditure of an individual. Caffeine increases the energy balance by reducing the energy intake. It considers all the three parameters including thermogenesis, fat oxidation, and energy intake. All the necessary process of energy balance and lipolysis is coordinated by the sympathetic nervous system.

10.5.1.1 Mechanism of Action in the Body

Though metabolized in the liver, it crosses the blood brain barrier (as it is lipid-soluble compound), thus affecting neural functioning and as a result accounts for energy balance.

Caffeine increases sensitivity of the sympathetic nervous system that has a significant role in energy homeostasis through hormonal and neural control. The stimulation of SNS results in enhancing satiety and in increasing EE, in part by increasing fat oxidation. Cyclic adenosine monophosphate, a derivate of adenosine triphosphate, that plays an important role in signal transduction influences lipolysis, heat production in skeletal muscle, and putative satiety signals in the liver. Increased cAMP response is short-lived, because it is rapidly degraded by phosphodiesterase (PDE). If PDE is inhibited by compounds such as methylxanthine (caffeine), there is an increased intracellular signal because of increased cAMP response, and thus, these results in increased lipolysis heat production in skeletal muscle and putative satiety signals in the liver. Apart from the above, SNS is involved in indirect effects of via cathecolamine, epinephrine, and non-epinephrine. These are released by the adrenal medulla into the blood. Caffeine counteracts the effectiveness of adenosine by reversing the adenosine-mediated inhibition of the release of CA and thereafter, suppressing hunger (Fig. 10.1).

The famous products that are based on caffeine action and function in combination with other stimulants are MuscleTech Hydroxycut (USA), Black Mamba by Nutrex Research Inc. (USA), and NutrexLipo 6 by Nutrex Research Inc. (USA).

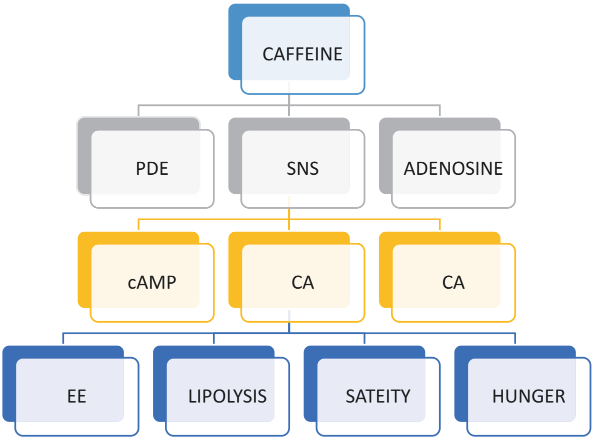


Fig. 10.1 Role of caffeine in thermogenesis and energy intake (Harpaz et al. 2017)

10.5.1.2 Harmful Effects

Caffeine-based supplements when used properly in moderate amount by healthy people are safe and show only few or minor side effects. The supplements may cause tremors, dizziness, and insomnia, but these effects last for a short duration and are temporary. Headaches and arrhythmias may also be seen in individuals consuming supplements containing caffeine. Caffeine can prove to be toxic when taken in high doses. High-dose intake may result in nausea, vomiting, tachycardia, and cerebral edema (Dietary Supplements for weight loss 2017).

There have reported cases of caffeine-induced seizure in individuals who are consuming an over-the-counter weight loss supplement (Pendleton et al. 2013). Caffeine, when combined with other stimulants, potentiates the adverse effects.

10.5.2 *Ephedra sinica*

Ephedra sinica is an evergreen shrub that is native to central Asia. *Ephedra sinica contains* Ephedrine, an active compound which has shown to work in achieving weight reduction. Ephedrine may be used as a sole ingredient in dietary supplements or in combination with caffeine. Similar to caffeine, ephedrine also functions to regulate energy expenditure by decreasing energy intake.

10.5.2.1 Mechanism of Action

Ephedra extracts act as stimulants of central nervous system. Ephedrine works to increase the cAMP levels because it is a beta-adrenergic receptor agonist like norepinephrine. Therefore, it is bound to induce the classical beta-adrenergic-dependent synthesis of cyclic adenosine monophosphate (cAMP) and thus, promote thermogenesis. Whereas caffeine increases cAMP levels by inhibiting phosphodiesterase (PDE).

According to some follow-up studies conducted on rat adipose tissue in the presence of either PDE inhibitors or adenosine antagonists, the results showed that the

Table 10.5 Harmful effects of ephedra extracts

Organ systems	Potential adverse effects
General manifestations	Numbness, tingling, dizziness, fatigue, lethargy, weakness, myopathy
Cardiovascular effects	Mild to severe hypertension, palpitation, tachycardia, arrhythmias, angina, myocardial infarct, cardiac arrest, myocarditis, sudden death
Central nervous system effects	Stroke, seizures, transient, ischemic attack
Neuropsychiatric effects	Anxiety, nervousness, tremor, hyperactivity, insomnia, altered behavior, memory changes, altered or loss of consciousness, mania, psychosis, suicide
Gastrointestinal effects	Nausea, vomiting, diarrhea, constipation, altered liver enzymes, hepatitis, ischemic colitis
Renal effects	Urinary retention, renal stones, rhabdomyolysis, leading to acute renal failure
Dermatological reactions	Rashes, exfoliative dermatitis

PDE inhibition, and not adenosine antagonism, has a more substantial role in facilitating ephedrine and caffeine interactions.

The famous products containing ephedra extract that are used in the markets these days are Black Mamba by Nutrex Research Inc. (USA). The products are usually present in combination with a certain amount of other stimulants, usually caffeine.

10.5.2.2 Harmful Effects

Ephedra extracts have known to show many harmful effects. The intensity of the harmful effects can range from minor to adverse. Most of the adverse conditions involve cardiovascular and central nervous system (Table 10.5).

It has also been reported that ephedra extracts downregulate the beta and regenic receptor that may cause refractory hypotension after anesthesia. Tachyphylaxis and preoperative hemodynamic instability can also occur in adverse conditions of prolonged use of the extracts.

10.5.3 *Yerba Mate*

An evergreen tree that is native to South America is used in a combination preparation with guarana (*Paullinia cupana*) and damiana (*Turnera diffusa*). *I. paraguariensis* and in particular *P. cupana* contain relatively large amounts of caffeine and have been shown by ultrasound scanning to prolong gastric emptying time. Definite results of the study indicate that this combination preparation might potentially be effective in lowering body weight (Pittler and Edzard 2004).

10.5.3.1 Harmful Effects

Adverse events were not reported. However, it may exhibit minor side effects such as caffeine as discussed above.

10.5.4 Green Tea Extracts

Green tea composes of flavanols, flavandiols, flavonoids, and phenolic acid. Flavanols are the ones present in abundance and are referred to as catechins. These catechins present in green tea are of four types, namely, epicatechin, epigallocatechins, epicatechin-3-gallate, and EGCG.

10.5.4.1 Mechanism of Action

EGCG, the tea catechin, plays a major role in weight reduction. It is regarded to not only possess anti-obesity properties but also antidiabetic properties. EGCG is known to enhance metabolism. It increases energy expenditure and oxidation of fat, simultaneously reducing lipogenesis and fat absorption. EGCG inhibits an enzyme that contributes to degradation of norepinephrine. As a result of the inhibition caused to the enzyme, norepinephrine levels increase.

Norepinephrine, the hormone, is used by the nervous system as a marker for the breakdown of fat cells. Thus, more norepinephrine results in fat cell breakdown. Therefore, EGCG alone has a potential in increasing fat breakdown and as a result, adds to anti-obesity properties of green tea.

10.5.4.2 Harmful Effects

Harmful effects of green tea arise due to three main factors:

- **Caffeine content of green tea**—patients suffering from cardiovascular diseases, pregnant, and lactating mothers are affected by the amount of caffeine content. The caffeine present may possibly increase the heart rhythm. It is advised that these individuals do not consume more than two cups a day.
- **Presence of aluminum**—tea plants tend to accumulate aluminum. This accumulation poses a major threat to renal patients and can result in neurological defects. Thus, a controlled intake of such foods is recommended.
- **Effect of polyphenols present in the tea on iron bioavailability**—the catechins present in green tea extracts display an infinity toward iron and therefore, affects its bioavailability.

Also, EGCG present in green tea extracts holds cytotoxic properties and may result in acute cytotoxicity in the liver cells, which is a major metabolic organ in the human body (Chacko et al. 2010).

10.5.5 *Garcinia cambogia*

Garcinia cambogia, native to India, is a Malabar tamarind tropical fruit. Hydroxycitric acid (HCA) is an extract derived from the fruit that helps in reducing synthesis of fat. The fruit proves to be one of the herbal adaptations in weight loss (Saper and Phillips 2004).

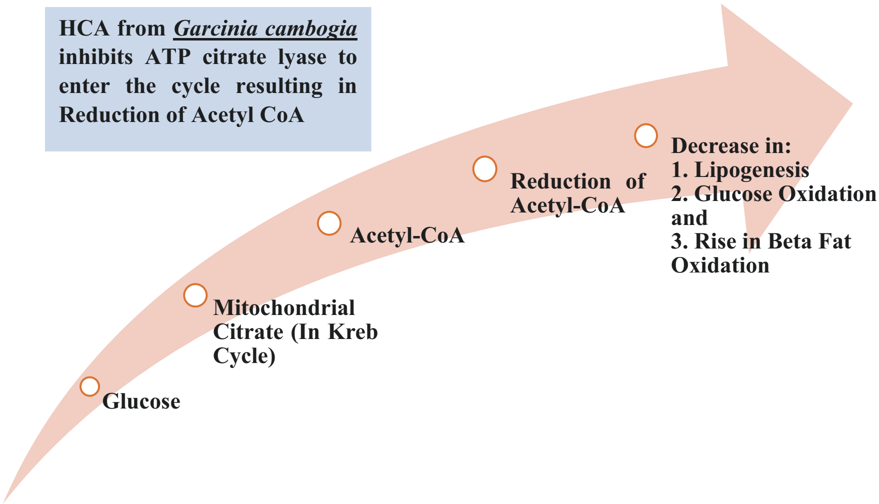


Fig. 10.2 Mechanism of action of *Garcinia cambogia* (Mechanism of action for hydroxycitric acid (HCA) 2017)

10.5.5.1 Mechanism of Action

HCA that is hydroxycitric acid acts as an inhibition to an enzyme that helps the body synthesize fat for storage in the adipose tissue. It also acts as a contributing factor in suppressing appetite and increasing thermogenesis. Under normal conditions, human body converts carbohydrate sources to ATP, which is a source of energy for body functions. The excess amount of carbohydrate is then stored in the liver and muscles in the form of liver glycogen and muscle glycogen, respectively.

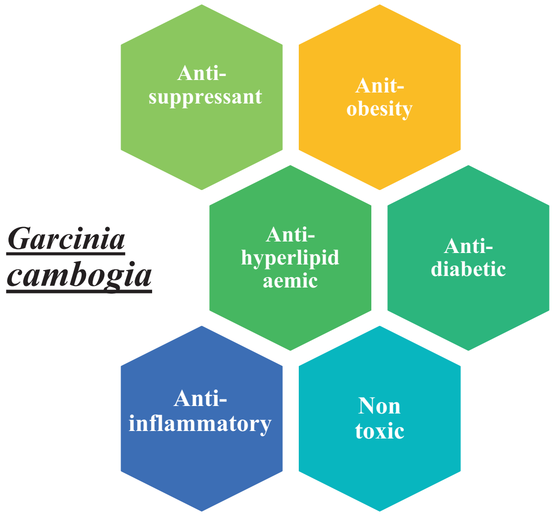
In addition, when the glycogen stores are also abundant, the excess carbohydrate is then converted to extra mitochondrial acetyl-CoA. Acetyl-CoA in the presence of ATP citrate lyase enzyme is responsible for the synthesis of fatty acid. HCA or hydroxycitric acid found in rinds of the fruit *Garcinia cambogia* is said to be an effective inhibitor of ATP citrate lyase. On account of the inhibition caused by HCA, the availability of acetyl-CoA decreases, thus, limiting the synthesis of fatty acid and lipogenesis during a high carbohydrate diet. As a result of the liver glycogen load, a longer lasting neuro-signal from the liver to the brain is stimulated, which indicates satiety and helps to suppress appetite for a longer period. This is how *Garcinia cambogia* helps in promoting weight loss (Figs. 10.2 and 10.3).

The famous dietary supplement available in the market that constitutes *Garcinia cambogia* as an active ingredient is SNT Slim and Healthy by Afflatus Pharmaceutical Pvt. Ltd. (INDIA).

10.5.5.2 Harmful Effects

HCA, the extract from the garcinia fruit, is regarded quite safe to be used for human consumption. According to studies conducted on HCA, no serious or significant effects are reported. During some animal studies, acute oral toxicity, acute dermal

Fig. 10.3 *Garcinia cambogia*



toxicity, primary dermal irritation, and primary eye irritation have been assessed (Rasha et al. 2015).

10.5.6 Chromium Picolinate

Chromium is an important trace element. It serves as a cofactor of insulin enhancing insulin activity. Chromium picolinate is believed to increase lean body mass, a decline in percentage of body fat, and increased basal metabolic rate. Since it is known to modulate carbohydrate and lipid metabolism, it influences weight and body composition (Saper and Phillips 2004).

10.5.6.1 Mechanism of Action

Chromium picolinate, a widely used supplement in today's time, is known to stimulate neurotransmitters that control the regulation of food cravings, mood, and eating behavior. It boosts glucose metabolism, body composition, and insulin sensitivity.

Increasing insulin sensitivity of the cells throughout the body has been regarded as a key goal in enhancing weight loss. Chromium acts as a helping agent for insulin to facilitate glucose uptake in the cells. Chromium picolinate increases the percentage of lean body mass and thus, a decrease in body fat. Also, it is said that greater muscle mass has a high potential in burning of fat. Therefore, following the above mechanism chromium performs its function and aids in weight loss. Chromium supplementation has also reported to lower cholesterol and triglyceride levels. The commonly used chromium-based supplement in demand these days is Universal Nutrition Fat Burner by Perfect Nutrition (USA).

10.5.6.2 Harmful Effects

Chromium picolinate demonstrates nonspecific and well-tolerated after effects. Nausea, watery stools, dizziness, and weakness are very common responses to chromium intake. In some cases, under adverse conditions, chromium picolinate has been known to cause chromosomal and renal damage following long-term ingestion of high doses. Some theoretical concerns suggest that chromium may also generate free radical damage. In adverse conditions, high doses may result in rhabdomyolysis and renal failure.

10.5.7 L-Carnitine

L-carnitine is an amino acid made from methionine and lysine. It is known to increase fat oxidation in the body and as a result is expected to bring weight reduction or weight loss.

10.5.7.1 Mechanism of Action

L-carnitine plays a very important role in transporting long-chain fatty acids into the mitochondria. It has an active role in energy expenditure and energy metabolism of tissues such as cardiac and skeletal muscles that acquire their energy from fatty acid oxidation.

Fatty acids cross mitochondrial membranes to enter pathways for oxidation, acylation, chain shortening, or chain elongation, as acylcarnitine derivatives. Thus, fatty acid transfer that is dependent on L-carnitine is central to lipid metabolism. The above discussion suggests that L-carnitine supplementation may improve the utilization of fat and therefore provides marked reduction in triglycerides levels. Earlier studies suggest that carnitine supplementation show no increase in muscle carnitine in a healthy individual. A recent study conducted by Wall and colleagues that has found its way in the Journal of Physiology suggests that muscle carnitine can be increased by dietary supplementation. The supplementation with carnitine allows the human body to spare muscle glycogen by using more fat and delaying time to exhaustion. However, the muscle lactate is reduced with high intensity exercise. Therefore, carnitine can be a helpful supplement in fat oxidation and thus, weight reduction (Sahlin 2011) (Fig. 10.4).

The popular product that uses L-carnitine as one of the active ingredients is MuscleTech Hydroxycut (USA).

10.5.7.2 Harmful Effects

Oral supplementation of L-carnitine may cause diarrhea. Except for this, no other adverse effect has been reported.

10.5.8 Chitosan

Chitosan is cationic polysaccharide, produced from a fibrous substance called chitin, which is further derived from the exoskeleton of crustaceans. It works very well

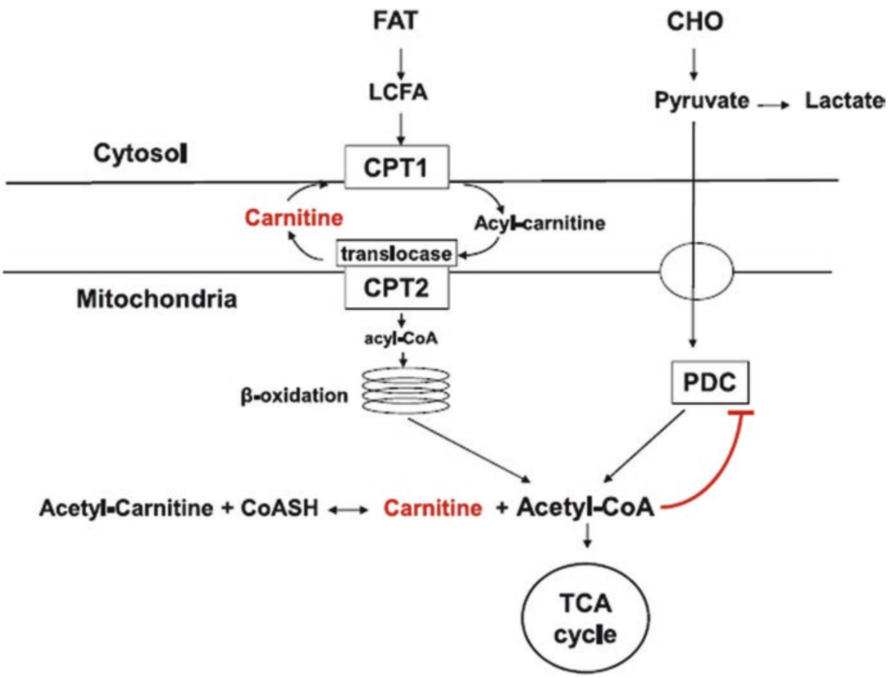


Fig. 10.4 Intracellular metabolism of fat (Sahlin 2011)

in achieving weight loss. It works to block fat absorption and thus, promotes weight reduction.

10.5.8.1 Mechanism of Action

Chitosan, being positively charged and at the same pH as the gastrointestinal tract, is thought to bind with the negatively charged fat molecules in the intestinal lumen. This binding prevents digestion and storage of dietary fat. Chitosan also plays a role in maintaining cholesterol levels. It works to decrease low density lipoproteins in the body while increasing high density lipoproteins.

10.5.8.2 Harmful Effects

Chitosan consumption causes mild gastrointestinal complaints such as nausea, bloating, indigestion, and abdominal pain. Constipation and flatulence may also occur. There is a risk of steatorrhea and malabsorption of certain nutrients. Chitosan is regarded safe to use, and the possible effects are not severe enough to cause discontinuation of chitosan use (Esteghamati et al. 2015; Shields et al. 2003).

10.6 Regulatory Bodies in Dietary Supplements

In India, the body that regulates the consumption and imparts safety tag to different functional foods, nutraceuticals, and health supplements is FSSAI (Food Safety and Standards Authority of India). Under the Food Safety and Standard Act of 2006, Ministry of Health Welfare and Family, the FSSAI has framed the Food Safety and Standard (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, Functional Food and Novel Food) Regulations, 2016.

The enforcement of these regulations is expected to come in execution from January 1, 2018. Under these regulations:

- The food sold in capsule form, whether hard, soft, or vegetarian, should meet the quality requirements specified for them in Indian Pharmacopoeia with the use of approved color, permitted additives, and flavors in accordance with the regulation under Food Safety and Standard Act of 2006.
- The quantity of nutrients added should be in accordance with the Recommended Dietary Allowances as per ICMR. In case any such standard is not specified, the standards laid by CODEX Alimentarius Commission shall apply.
- In case of food articles falling under health supplements, the individual nutrient content should not be less than 15% of the RDA. If higher nutrient is claimed, the nutrient content should not be less than 30% of the recommended dietary allowances.
- The food article that is nutritionally complete is required to hold a composition delivering the desired level of energy, protein, vitamins, and minerals along with essential nutrients with respect to age, group, gender, and physiological state based on the guidelines of ICMR.
- Every food article is required to hold nutritional and health claims. Nutritional claims include ingredient content.

10.6.1 Regulations Specific to Health Supplements

- The health supplements must be marketed in single-use packaging to maintain quality and integrity of the product or in dosage forms such as capsules, tablets, pills, gels, sachets, or powders designed to be taken in measured unit quantities.
- Health supplements must not include any of such product or ingredient for which specific standards have been formulated under any part of this regulation.
- The quantity of nutrient added to these supplements shall not exceed the recommended dietary allowances set under Indian Council of Medical Research. If any such standard for a specified article is not present, standards laid down by Codex Alimentarius Commission shall apply.
- For inclusion of a nutrient that holds no history of use in India, the food business operator shall apply to the Food Authority of India, establishing the physiological and nutritional benefits of the nutrient.
- The labeling, presentation, or advertisements of health supplements should not claim that the supplement holds any property of preventing, treating, or curing any human disease.
- Every package of the food supplement must carry the following information on its label:
  - The word HEALTH SUPPLEMENT.
  - The common name of the health supplement or a brief description indicating the true nature of the supplement.

  - A declaration as to the amount of nutrients with its nutritional and physiological effect.
  - An adversary warning "NOT FOR MEDICINAL USE" prominently written.
  - The quantity of nutrients in terms of percentage of the relevant recommended dietary allowances as specified by ICMR and also displays a warning, "Not to exceed the recommended daily usage."
  - A statement suggesting that the supplement is not to be used as an alternative to any varied diet.
  - Any other precautionary measures that need to be taken.
  - A statement notifying that the product should be stored out of reach of children.
- No food business operator is allowed to use any other food additive except for those mentioned in schedules issued under Food Safety and Standard Act of 2006 (The Gazette of India 2016).

Permitted ranges of usage for some of the ingredients used in health supplements, as mentioned in different schedules of the act, are as follows:

1. **Tea catechins or green tea catechins**—the permitted range of usage for adults per day (given in terms of raw herb/material) is 0.5–1 g.
2. **Ephedra extracts**—the permitted range of usage for adults per day (given in terms of raw herb/material) is 2–5 g.
3. **Garcinia fruit**—the permitted range of usage for adults per day (given in terms of raw herb/material) is 10–20 mL (as juice) and 5–10 g (as powder).
4. **Caffeine**—it is to be consumed within levels specified in FSS regulation.
5. **Chromium picolinate**—the permitted range lies within 200–400 mg/day.
6. **Spirulina**—the permitted range lies within 500–3000 mg/day.

- Apart from FSSAI, there is an international organization also working to regulate and keep a check on the quality and efficacy of health supplements such as the FDA (Food and Drug Administration). FDA regulates dietary supplements under a different set of regulations than those covering "conventional" foods and drug products. It regulates under the Dietary Supplement Health and Education Act of 1994 (DSHEA).

10.7 Conclusion

The review highlighted different dietary and health supplements. Their use, dosage, and market growth are topics of recent world and a huge discussion. Though promoting desired weight management results, one should never forget the harmful effects with high dose use. Therefore, the use of dietary supplement can be called an effective alternative method for weight maintenance in today's fast-moving world. The changing lifestyle trends that involve less of physical activity do require some alternate treatment and concern in maintaining health, and health supplements can prove to be one method.

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11 Traditional Foods: The Inheritance for Good Health

Vandana, Chaynika Verma, and Prabhjot Kaur Sabharwal

Abstract

The term "traditional food" refers to the foods which have been eaten for centuries and have been passed through many generations. Such foods are believed to be in their original form without any interference of modern technology, processing, or packaging. They are whole, nutrient dense, simple, basic, and thoughtfully prepared. They are an expression of culture, history, and lifestyle. Moreover, they have a long background of supporting good health. In the present scenario, changing food patterns and lifestyle has led to a prominent drift toward processed food and junk food due to the convenience and preference, but it has deleterious effect on health due to its consumption for a prolonged period. This significant transition is believed to be responsible for the chronic diseases such as diabetes, obesity, and cardiovascular diseases. The treasured knowledge of traditional food can play a significant role in improving and restoring the well-being and health of the people. Emphasis must be laid on creating awareness about the importance of traditional foods of one's own culture and society to combat the modern-day health issues arising because of irrational eating habits. To bridge the gap between ancient times and the present day, efforts need to be done in the direction of adapting the inheritance to today's modern society requirements through existing scientific knowledge and experimentation. As the health conscious and health problems both are raising among consumers, the food sector should recognize potential market and profits in traditional foods for the benefit of all.

Keywords

Traditional foods · Chronic diseases · Heritage · Health

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11.1 Introduction

Traditional foods are an important part of the culture, history, and lifestyle. Traditional foods demonstrate cultural, identity, various cooking styles and methods, and have left their mark on concurrent dietary patterns. They also provide meaningful deep insight of the world's rich history, values, culture, and religion. They have existed for a long time and have nutritional benefits which have been proven and tested for several centuries. Some of the foods have become synonymous with specific culture and have made a profound mark which helps in describing our globalized society. Time and again, various definitions of traditional foods have been given. To simply put, these foods are typically whole, naturally raised or grown, ancient and used in their original form, and have not undergone much processing. They are nutrient rich and have a long history of supporting health and wellness. Traditional foods may be appealing to different consumers in different ways depending on their cultural framework and position. "A traditional food is a product frequently consumed or associated to specific celebration and/or seasons, mediated from one generation to another, made in a specific way according to the gastronomic heritage, naturally processed and distinguished and known because of its sensory properties and associated to a particular tradition and promotes a certain culture. According to the numerous studies it has been established that, traditional food is not an absolute concept rather it's a relative term which continuously evolves and grows. There are four basic dimensions that help in exploring the traditional food in detail. First dimension is "habits and naturals" which defines traditional food is a food that are consume frequently in a daily life and have their roots anchored in the past and transferred from generations. Second dimension includes "origin and locality", these foods *underlines the historical, cultural, originality, focuses on the typicality of the products from the place.*" Third dimension is pertaining to "processing and elaboration," according to this, traditional food not only contains traditional ingredients but also is processed in a traditional way. Sensory properties are the fourth dimension and are very crucial and important as it helps in recognizing and identifying the originality and authenticity of traditional food. Due to today's traditional food, knowledge, and innovative practices, different concepts of traditional food system can be combined, and notable new ingredients can be created. These combinations and emergence of new ingredients provide great potential for health-boosting foods.

11.1.1 Importance and Benefits of Consuming Traditional Foods

Over the years, a significant change has been observed in one's dietary pattern due to the urbanization, higher incomes, affordability, and globalization. The transition is from traditional food or common staples to the westernized diet due to the various contributing factors. This change leads to the reduction of intake of complex carbohydrates, vegetables, and fiber, driven toward the increased consumption of junk and fast foods which are rich in trans fats, refined sugars, and salt. However unfortunately, the utilization of these foods poses various health risks. Diseases such as type II diabetes, cardiovascular disease, cholesterol, high blood pressure, among others have seen an acute rise. Hence, to address these problems, more emphasis is given on health education which highlights the nutritional aspects and healthy eating habits for better living. In the recent decades, the people are now becoming aware of the link between nutritious foods and health. The consumers are concerning more about their health. To overcome the burden of noncommunicable diseases, there is a nutrition transition, and consumers are looking for healthier options and shifting toward the traditional methods and food.

Traditional foods foster our forefather throughout history. Traditional foods as our ancestors knew them were unprocessed, unpackaged, unrefined, original, raw, simple, and basic. These foods represent the natural diet of humankind and are rich in nutrients and provide a good source of the dietary needs for physical health and mental well-being. These foods are of low cost in comparison with the organic foods and genetically modified food because they are harvested from the natural environment.

11.1.2 Some Popular Indian Traditional Foods and Beverages

- ***Kahwa***—It is an aromatic, revitalizing, and stimulant traditional drink of Kashmir region of India. It is made by boiling green tea leaves along with various fragrant constituents such as saffron strands, cardamom, cinnamon, clove, and liquorice. Its use depends on the ingredients added, which may have different health benefits. Studies have indicated promising antioxidant and antigen toxic potential of kahwa due to an appreciable amount of polyphenols (7.41 mg GAE/g) and flavonoids (1.39 mg QE/g), which may be responsible for its biological activity.
- ***Saag***—It is a dish mostly prepared in the north and northeast part of India. It is a leaf-based dish which can be made from the combinations of different leaves such as spinach, mustard leaves, finely chopped broccoli, or other greens, along with added spices. Its preparation includes washing, boiling, and cooking of chopped green leafy vegetables and other vegetables including radish, tomato, and ginger. It may be blended with maize flour to improve smoothness and flavor. It possesses a significant amount of minerals and vitamins.
- ***Idli***—It is a cereal pulse-based naturally fermented traditional food belonging to particularly Southern India but has gained very wide acceptance. The ingredients required to prepare this snack include rice and black gram dhal. These are soaked separately in drinking water overnight and ground to a fine paste. The paste is fermented overnight at room temperature followed by steaming to obtain the spongy idli. A mixed LAB culture dominates the batter flora. Idli is nutritionally dense with approximately 3.4% protein composed of essential amino acids (lysine, cysteine, and methionine) and nonprotein nitrogen, soluble vitamins (folate, vitamin A, vitamin B1, vitamin B2, and vitamin B12) content, and also

contains appreciable levels of enzymes (amylase, proteinase) with reduction in antinutrient phytic acid on account of fermentation.

- Various studies have suggested the consumption of Idli substantially reduces the risk of noncommunicable disease such as cardiovascular diseases, high blood pressure, and stroke. The good quality protein content makes it a viable dietary supplement for the treatment of protein calorie malnutrition in children. It is hugely packed with micronutrient content such as iron, zinc, folate, and calcium which provides the prevention against anemia and facilitates the blood oxygenation and muscle and bone nourishment. The carbohydrate and dietary fiber content promotes healthy digestion and formation of bulky stools.
- ***Kahudi* or *PaniTenga***—It is a unique Assamese fermented product made from the mustard seeds. The preparation includes coarse grinding of mustard green and black seeds followed by mixing with tamarind extracts or lime juice and kneading to dough. This dough is shaped into small balls and wrapped with a plantain leaf which is then inserted into a bamboo cylinder and fermented above the fire flame to make it malleable. It is ready after 3–4 days. *Kahudi* has a strong taste and mostly served along with an Assamese meal.
- ***Dhokla***—It is a popular breakfast item of western India. It originates from the Indian state Gujarat. The texture is soft and spongy, and it is an acid fermented cake made from rice and split chickpeas (Bengal gram dhal). A thick paste is prepared by soaking the raw materials in a prescribed ratio and allowed to ferment overnight at room temperature. The fermented batter is poured into the flat dishes and steamed in open conditions for approximately 15 min. Yeasts and bacteria are mainly responsible for the volume and sponginess in the batter.
- The dominant bacteria present in dhokla are *L. fermentum*, *L. mesenteroides*, *Pichiasilvicola*, *S. faecalis*, etc. Dhokla is high in water content. Each serving of *dhokla* (213 g) contains 384 cal, 59 g of carbohydrate, 6.6 g of free sugars, 10.6 g of dietary fiber, 11.7 g of protein, 11.8 g of fat, 89 mg of sodium, 551 mg potassium, an adequate amount of minerals (calcium, iron), and vitamins (oleic acid, vitamin A and vitamin C). It has low glycemic index (34.96) which makes it suitable for diabetic patients. It also helps to reduce blood cholesterol and body weight and protects from cardiovascular diseases. In this era, antibiotics are frequently prescribed which disturbs the gut microflora; these fermented foods replenish the microflora of the digestive tract and do so much more.

11.2 Conclusion

The sheer convenience inclines us to buy these processed foods which in turn have major consequences on health and lead to higher incidences of chronic diseases. There are numerous benefits of consuming traditional foods and ultimately remains the best food available to them. The knowledge base for the traditional foods describes its huge potential for the production and marketing. It also plays a vital role in food security.

12 Mango Peels: A Potential Source of Nutrients and a Preservative

Nisha and Vibha Bhatnagar

Abstract

Consumption, usage, and inclination toward ready-to-eat food item have dramatically heightened in past few years. Due to changing in living style, increase in purchasing power dependence on processed food has seeped deep into a person's eating habits. This has led to the flooding of the market with processed foods containing synthetic antioxidants. Though these synthetic antioxidants increase the shelf life of the product, it may have severe ill effects on the health of the person consuming it. Numerous studies have advocated about the devastating effects of these synthetic additives that are used in food products, indicating the need for natural antioxidants. In the present, investigation and initiative were taken to find a natural source of antioxidant which would be cheap and would also enhance the nutritional value for the food product. Mango peels which form a part of waste in the food industry but is otherwise a good source of nutrients and antioxidants were studied after incorporating it into biscuits at a rate of 5%, 10%, 15%, and 20%. Results revealed that an addition of 15% of mango peel powder (MPP) in the biscuits was well accepted by the consumers, and the nutrient composition was observed to be significantly increased when compared with control at 5% level of significance.

Keywords

Mango peel powder · Biscuits · Ready-to-eat foods · Natural antioxidant

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12.1 Introduction

During the past few decades, a considerable change has been observed in the eating habits and patterns of individuals in India. Several factors might have contributed to this change. The gigantic shift in the lifestyle of Indians might have been due to the modern routine in the upbringing of the newer generation. Increase in the per capita income, urbanization, fascination from the western culture of life style and eating patterns, lack of time, and the hustle and bustle that an individual goes through each day. These changes in lifestyle have led to the dependency on processed foods; moreover, the lucrative advertisements and sense of style and status statement which this food provides have also contributed to an increased demand and consumption of ready-to-eat product. According to NSW, "RTE foods may be defined as foods that are ordinarily consumed in the same state, in which it is sold and does not include nuts in the shell and whole, raw fruits and vegetables that are intended for hulling, peeling or washing by the consumer." In other words, ready-to-eat products may include any food item that doesn't require any kind of preparation before consumption and is edible even without any preparation. Numerous food products are being prepared, marketed, sold, and consumed by the individuals all over the country. Baked and fried items seem to be at the top of the ready-to-eat food products available in the market. Ready-to-eat foods containing fats and oils, such as biscuits, samosa, cookies, *matthi*, among others, oxidize slowly during storage.

Various oxidation products cause rancidity and deterioration in the sensory properties of the food products. Oxidation is a nearly ubiquitous chemical reaction involving the transfer of electrons from one compound to another occurring in the food items. One of the most important changes that occur to food is lipid oxidation. The susceptibility of lipid to oxidize is one of the major causes of oxidative stress, resulting in a consequent decrease in nutritional quality and safety, caused by the formation of secondary, potentially toxic compounds, unpleasant tastes and odors, and changes in color (Pezzuto and Park 2002; Suja et al. 2005). Foods containing higher content of polyunsaturated fatty acids are more prone to oxidation (Aardt et al. 2004), resulting into the reversion of taste and finally rancidity. Thus, these food products have a short life span.

Antioxidants are a good solution to this problem of the manufacturers and producers. Antioxidants added to the food may be natural, which are prepared from natural sources such as fruits, vegetables, grains, and meat or synthetic that are prepared in laboratories. Among the synthetic types, the most frequently used to preserve food are butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tert-butyl hydroquinone (TBHQ). Synthetic antioxidants such as BHA and BHT have been used as antioxidants for foods, since centuries (Byrd 2001). The use of these synthetic antioxidants, however, has begun to be restricted because of their toxicity and carcinogenicity (Botterweck et al. 2000; Taghvaei and Jafari 2013). Several long-term studies have demonstrated the ill effects of synthetic antioxidants (Venkatesh and Sood 2011).

Emerging evidence is elucidating that non-nutrient phytochemicals possess protective roles. These phytochemicals are biologically active secondary metabolites that also provide color and flavor. Fruits and vegetables are known to contain significant amounts of phytochemicals with free-radical scavenging capacity toward reactive oxygen species. These phytochemicals are found to be mainly concentrated in the parts that are exposed to the atmosphere such as the peels of fruits and vegetables which help in preserving the fruit and vegetable from decay and are established to be powerful antioxidants. These bioactive components can be of great economic importance once proven to extend the shelf life of foods to be stored for extended period before consumption. Hence, the focus has been shifted toward the natural antioxidants that are cheap, can extend the shelf life of RTE foods, and are safe for human consumption. Peels of several fruits and vegetables have been reported to be potent sources of antioxidants (Kalpna 2011).

Several researches have reported the fact that mango peels are a good source of bioactive compounds, and India being the world's biggest producer of mangoes produces about 19,687 million tons per year (National Mango Database 2017). A major portion of ripe mangoes is relished as such while another major portion (i.e., 20% of the production) enters the processing industry where it is converted in to juices, jellies, nectar, jams, puddings, bakery filling, marmalades, squash, leather, etc. In which ever form the mangoes may be consumed, the peels only form a part of biowaste which accounts for 15–20% of the fruits. Presently, these peels only form a part of waste and are discarded, though studies have proven that they possess the highest values of bioactive compounds and antioxidative properties.

12.2 Proximate Composition of Mango Peels

Desi variety of mangoes from the Udaipur market was procured and analyzed for the moisture content which was found to be 70.91 g per 100 g (Table 12.1). The results are in line with the findings of Ajila et al. (2007), but higher than that reported by Arumugam and Manikandan (2011). The mango peels were dried to form a powder, and then the proximate content of the powder was estimated. The protein content of mango peel powder (MPP) was estimated to be 4.87 g per 100 g.

Table 12.1 Nutrient composition of MPP

Nutrient constituents	(Mean ± SD)
Moisture (g per 100 g)	3.94 ± 0.50
Protein (g per 100 g)	4.87 ± 0.34
Fat (g per 100 g)	0.41 ± 0.27
Fiber (g per 100 g)	9.56 ± 1.15
Ash (g per 100 g)	3.37 ± 0.28
Carbohydrate (g per 100 g)	78.93 ± 1.98
Energy (kcal/100 g)	338.76 ± 9.16
Vitamin C (mg/100 g)	45.31 ± 2.26
Beta carotene (μg/g)	171.38 ± 6.18

Vergara-Valencia et al. (2007) and Arumugam and Manikandan (2011) also observed a similar protein content in mango peel (i.e., 4.28% and 4.27%, respectively).

Hassan et al. (2011) also quantified the mango peels of *bambangan* variety and reported the protein content of 4.60% on dry weight basis. However, Ojokoh (2007) observed slightly higher protein content of 6.16%. Whereas other researchers such as Ashoush and Gadallah (2011) and Ajila et al. (2007) observed a much lower protein content. MPP when quantified for its fat percent was found to be 0.41% which was lower than that reported by other researchers. Vergara-Valencia et al. (2007), Ajila et al. (2007, 2008), Hassan et al. (2011), and Arumugam and Manikandan (2011) have reported a marginally higher content of 2.35%, 2.22%, 2.66%, 2.90%, and 3.20% individually. Ashoush and Gadallah (2011) reported a fat content of 1.23% in the *zebda* variety of mango peel.

About 9.56 g per 100 g of crude fiber was found in MPP which was in accordance with the findings of Ashoush and Gadallah (2011). A slightly lower content of dietary fiber in *raspuri* and *Badami* variety of mango as 5.80 ± 0.01 and 7.40 ± 0.20, respectively, was documented by Ajila et al. (2007). While Ojokoh (2007) reported high fiber content (16.40%) in the strip of mango.

The ash content in the mango peel powder in the present study was observed to be 3.37% which is in line with the findings of Vergara-Valencia et al. (2007), who found the ash content of *Tommy Aktins* to be 2.83% ± 0.0%. Ajila et al. (2008) also found ash content of mango peel as 3.00% ± 0.18%, and Ashoush and Gadallah (2011) who studied on the *zebda* variety of mango peel found ash content to be 3.88% ± 0.59%. However, Arumugam and Manikandan (2011) and Ajila et al. (2007) have reported a still lower ash content in the peels of mango, that is, in the range of 1.16–1.87%. The carbohydrate content of MPP was found to be 78.93%. The results were consistent with the findings of Ajila et al. (2008) and Ashoush and Gadallah (2011), who reported a content of 80.70% and 77.04%, respectively. The energy content of MPP was observed to be 338.76 kcals per 100 g. The vitamin C content of fresh mango peel was found to be 168.15 mg per 100 g which was observed to be lower than the vitamin C content of *raspuri* and *badami* variety of mango, in which Ajila et al. (2007) reported a content of 349 ± 11 and 392 ± 21 mg per 100 g. While on drying the peels, the vitamin C content was observed to decrease drastically to 45.31 ± 2.26 mg per 100 g.

The beta-carotene content of fresh mango peel was found to be 38.12 μg per g. The beta-carotene content in dried samples was 171.38 μg per g. The findings are quite low when compared with the findings of Ajila et al. (2007). The major reason for this difference can be accorded to the fact that the researcher estimated total carotenoid, while in the present study only beta-carotene content was estimated. The variation in nutrient content of the present study to that of the previous reporting might have been due to the difference in the method of quantification and more importantly due to varietal difference (Ajila et al. 2007; Kalpna 2011).

12.3 Acceptability of Chilly Biscuits

Results of the sensory evaluation of the chilly biscuits prepared with 5%, 10%, 15%, and 20% of MPP along with control are presented in Table 12.2 and Fig. 12.1. Control was observed to score the highest for all the sensory characteristics with an overall acceptability of 8.88 ± 0.02, suggesting that the control of chilly biscuits was liked very much by the panel members. Among the treatments, TM1, that is, 5% level of incorporation, scored the highest for appearance when compared with the others. For appearance, a decrease was noted in the scores with the increase in the level of addition of MPP, and the sensory scores ranged between liked moderately to liked very much. Whereas TM3 (15% MPP) obtained the highest score for color (8.34 ± 0.21), flavor (8.87 ± 0.06), taste (8.84 ± 0.12), texture (8.70 ± 0.11), and overall acceptability (8.48 ± 0.04). The sensory scores obtained in case of MPP-incorporated chilly biscuits depicted that on an overall basis, control was the liked very much followed by TM3, TM2, TM1, and then TM4, revealing that addition of MPP in chilly biscuits resulted in an increase in the sensory scores up to 15% incorporation level, but then the sensory scores decreased with 20% addition of MPP. Therefore, TM3 (15% incorporation of MPP) was the most acceptable treatment, and it can be suggested that ready-to-eat products can be prepared by adding 15% of mango peel powder with good consumer acceptability.

Results of the present study regarding the level of incorporation of MPP in chilly biscuits are in line with the finding of Nassar et al. (2008), who found that biscuits prepared by adding orange peel were acceptable up to 15% level of addition. Arogba (1999) and Ajila et al. (2008) found that at levels of 20% of MPP had a slight bitter biscuit taste which may be due to high polyphenol content. The findings of the present study are in accordance with Ashoush and Gadallah (2011) who also reported enzymatic browning to be the reason for rejection of biscuits prepared by adding 20% of MPP.

Table 12.2 Mean acceptability scores of MPP-added chilly biscuits

Quality attributes	Control	TM1 (5%)	TM2 (10%)	TM3 (15%)	TM4 (20%)
Appearance	8.80 ± 0.04	7.70 ± 0.06	7.70 ± 0.10	7.67 ± 0.06	7.20 ± 0.10
Color	8.87 ± 0.06	8.24 ± 0.21	8.30 ± 0.20	8.34 ± 0.21	7.97 ± 0.24
Flavor	8.90 ± 0.06	8.84 ± 0.06	8.85 ± 0.11	8.87 ± 0.06	7.50 ± 0.10
Taste	8.90 ± 0.12	8.74 ± 0.12	8.77 ± 0.07	8.84 ± 0.12	7.70 ± 0.10
Texture	8.90 ± 0.34	8.64 ± 0.06	8.67 ± 0.12	8.70 ± 0.11	7.94 ± 0.12
Overall acceptability	8.88 ± 0.02	8.43 ± 0.08	8.45 ± 0.08	8.48 ± 0.04	7.66 ± 0.02

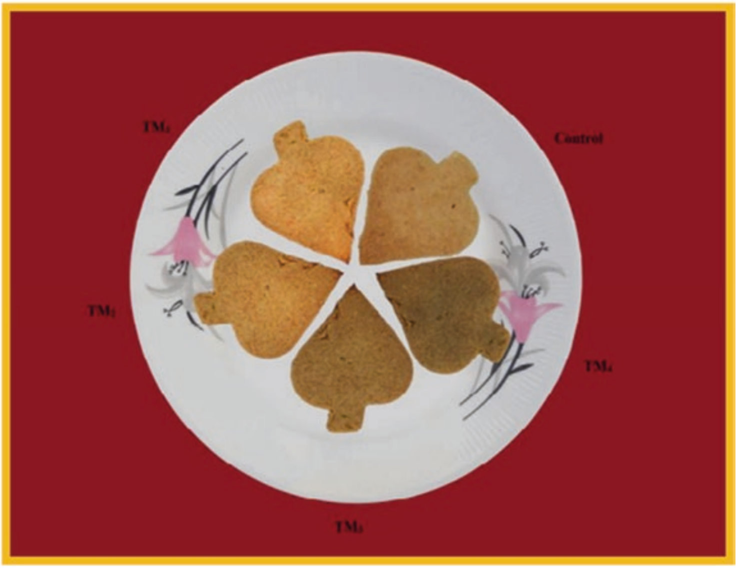

Fig. 12.1 Biscuits prepared by using mango peel powder with different proportion

12.4 Proximate Composition of Chilly Biscuits

According to Manley (2003), biscuits are a significant part of the food industry in most countries of the world. Hosney (1986) feels that biscuit and biscuit-like products have been eaten by man since centuries. They may be either sweet or salty. This serves as the most easy and convenient experimental food. The most preferred treatment (i.e., level of addition) prepared by adding MPP along with their control was analyzed for its proximate composition.

Nutrient analysis of foods provides vital information regarding its quality and is an important part of quality assurance. Chilly biscuits were found to contain 0.58% ± 0.18% of moisture for control and 0.61% ± 0.07% for MPP-added counterparts (Table 12.3). The protein content of chilly biscuits was observed to be 6.72% ± 0.28% for control and 7.98% ± 0.74% for treatment (MPP). Fat content was 20.74% ± 0.21% and 21.95% ± 0.11% for control and MPP-added chilly biscuits, respectively.

Fiber and ash content of control were discerned to be 2.12% ± 0.42% and 2.80% ± 0.03% for control and for 4.65% ± 0.66% and 3.32% ± 0.42%, respectively, MPP-added chilly biscuits. Beta-carotene was 0.47 ± 0.03 μg per g for control, which was noted to have increased to 1.29 ± 0.09 μg per g for MPP-added chilly biscuits. Carbohydrate and energy contents were more in control (67.04% ± 1.27% and 481.71 ± 2.64 kcal, respectively) when compared with MPP-added chilly biscuits (61.49% ± 0.80% and 475.43 ± 1.34 kcal, respectively). Statistically significant difference was noticed between control and treatment for all the nutrients except moisture ($P \leq 0.05$) (Table 12.3).

Table 12.3 Nutrient composition of MPP-added chilly biscuits

Nutrient constituents	Control	Treatment	*t-value*
Moisture (g/100 g)	0.58 ± 0.18	0.61 ± 0.07	*0.09*^{NS}
Protein (g/100 g)	6.72 ± 0.28	7.98 ± 0.74	3.20*
Fat (g/100 g)	20.74 ± 0.21	21.95 ± 0.11	6.92*
Fiber (g/100 g)	2.12 ± 0.42	4.65 ± 0.66	11.08*
Ash (g/100 g)	2.80 ± 0.03	3.32 ± 0.42	3.72*
Carbohydrate (g/100 g)	67.04 ± 1.27	61.49 ± 0.80	5.90*
Energy (kcal/100 g)	481.71 ± 2.64	475.51 ± 1.34	4.59*
Beta carotene (μg/g)	0.47 ± 0.03	1.29 ± 0.09	8.02*

NS nonsignificant at 5% significance level. *Significant at 5% significance level. Values are expressed on dry weight basis. Level of MPP incorporation—15%

The increase in the nutrient content of treatment (MPP added) when compared with its control (except for moisture, carbohydrate, and energy content) was clearly due to the incorporation of the respective powders in the product which enhanced the nutrient composition of chilly biscuits. As dry powders were added to the treatment, it did not affect the moisture content. Carbohydrate content of control was found to be higher when compared with the treatment because a different method was used for its calculation and fiber was observed to be a major factor contributing toward it.

Energy content was assessed based on the calorific fuel value of protein, fat, and carbohydrate content; hence, lower carbohydrate content resulted in lower energy value for the respective treatments when compared with control. Addition of fresh green chilies in the basic recipe might be the probable reason for beta-carotene being found in control. The moisture content of control and MPP-added chilly biscuits were found to be lower than the moisture content reported by AICRP report (1999) for biscuits. Protein, fat, fiber, carbohydrate, and energy content of control of chilly biscuits are in proximity with the results of biscuits prepared by Vaidehi (1994), AICRP report (1999), and Pasricha (2004).

12.5 Conclusion

In the present day mango peels is just treated and thought to be biowaste but it has enormous nutrient potential and preservative potential, and is also rich in bioactive compounds such as flavonoids and phenols. Organoleptically, also it is acceptable quite well by the consumers at a 15% incorporation rate in food products.

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Fatty Acid Composition of Oilseed Crops: A Review

13

Tanu Jain

Abstract

Fatty acids play a very important role in our body. Both essential and nonessential fatty acids are necessary for our body. They help in regulation of membrane structure and function, transcription factor activity, regulation of intracellular signalling pathways, and gene expression. Traditional oilseed crops in India include safflower, sunflower, mustard, soybean, etc. Linseed and garden cress seeds are also being popularized due to its healthy effect on the heart and body. The fatty acids are categorized based on bond present in them, viz., saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA). As per WHO (Interim summary of conclusions and dietary recommendations on total fat and fatty acids. The joint FAO/WHO expert consultation on fats and fatty acids in human nutrition. World Health Organization, Geneva, Switzerland, 2008) specifications, the ratio between sat-, mono-, and polyunsaturated fatty acids should be 1:1.5:1 which is considered ideal for healthy heart. This exact ratio is not present in any oil. Moreover, the oils are lacking in one or more essential fatty acids. Therefore, the present article shows the brief description and comparison of fatty acid composition of seven different oilseeds, viz., mustard, garden cress, sunflower, safflower, groundnut, linseed, and sesame seeds, to find out among the best oil to be consumed.

Keywords

Fatty acids · Saturated and unsaturated fatty acids · Oilseed crops

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13.1 Introduction

Both essential and nonessential fatty acids play an important role in our body. They help in regulation of membrane structure and function, regulation of intracellular signalling pathways, transcription factor activity, and gene expression and regulation of the production of bioactive lipid mediators (Roy 2000). In vegetable kingdom, the main sources of these fatty acids are oilseeds and crops. The traditional oilseed crops in India include safflower, sunflower, mustard, soya bean, etc. Linseed and garden cress seeds are also being popularized due to its healthy effect on the heart and body (Jain and Grover 2016). These oils have different fatty acid compositions. On the basis of single and double bond present in fatty acids, they are divided into three groups, viz., saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA). According to WHO, the ratio between sat-, mono-, and polyunsaturated fatty acids should be 1:1.5:1 which is considered ideal for healthy heart (WHO 2008). In the present scenario, the increased competition between different oils increased the customer curiosity to choose best oil, in terms of nutritional value. In the present article, seven different oil crops are reviewed and compared for their fatty acid composition.

13.2 Oilseed Crops

13.2.1 Garden Cress Seeds

Garden cress (*Lepidium sativum*) is an annual crop belonging to the family Brassicaceae. The plant is related to mustard crop. It has been documented as an important medicinal plant since ancient times in Indian scriptures. Seeds, leaves, and roots are used as medicine. The seeds are antihypertensive, hypoglycemic, anticarcinogenic, antioxidant, anti-cholesterolemic, and diuretic in nature. The seeds contain 21–25% protein and up to 25% fat and provide 474 Kcal (Jain and Grover 2016). The seeds have high iron content (Gopalan et al. 2011) and are used to reduce anemia. Fatty acid composition of seeds is described in Table 13.1.

13.2.2 Mustard Seeds

Mustard seeds (*Brassica nigra*) are one of the common spices used in India. Mustards are winter crops. The plant gains a height of about 4–5 ft. and bears yellow flowers. They are tiny, spherical seeds about 1 mm in diameter which are podded inside a fruit (Harriet et al. 1996). The seeds are usually black in color and about 1–2 mm in diameter. The seeds are a rich source of oil and protein. The seeds contain 40% fat and 19–20% protein content (Gopalan et al. 2011) and are used in Indian homes for cooking purposes. The oil is packed with essential fatty acids, antioxidants, minerals, vitamins, and other phytochemicals. Pungency of mustard seeds is due to the presence of an essential oil, sinalbin (Abul-Fadl et al. 2011).

Table 13.1 Comparison between fatty acid compositions of different oilseeds

S. no..	Fatty acid (%)	Mustard seed	Garden cress seed	Linseed	Sesame seeds/ gingelly seeds (white)	Sunflower seeds	Safflower seeds	Groundnut seeds
1	Palmitic acid (C16:0)	856 ± 29.4	2190 ± 36.2	1503 ± 68.1	3883 ± 17.2	3215 ± 109	1789 ± 132	4520 ± 84.5
2	Stearic acid (C18:0)	389.3 ± 38	730 ± 21.6	1323 ± 65.6	2206 ± 143	2166 ± 179	546 ± 21.4	1303 ± 96.2
3	Arachidic acid (C20:0)	289 ± 27.8	800 ± 24.0	59.74 ± 4.28	256 ± 22.8	175 ± 7.7	90.69 ± 5.27	598 ± 66.3
4	Palmitoleic acid (C16:1)	69.74 ± 7.52	55.48 ± 2.08	25.61 ± 1.29	55.87 ± 7.22	71.56 ± 7.04	17.08 ± 2.37	242 ± 22.6
5	Oleic acid (C18:1n9)	4012 ± 549	5166 ± 261	5049 ± 303	16,001 ± 330	17,649 ± 467	3487 ± 27	17,719 ± 562
6	Linoleic acid (C18:2n6)	4932 ± 112	2839 ± 50.1	3191 ± 144	18,477 ± 495	25,545 ± 308	18,760 ± 227	11,584 ± 426
7	Alpha-linolenic acid (C18:3n3)	3341 ± 379	7484 ± 246	12,956 ± 467	120 ± 14.1	35.6 ± 5.78	21.90 ± 0.73	0.00 ± 0.00
8	Total saturated fatty acid (SFA)	2112 ± 41.7	4101 ± 69.3	2968 ± 48.4	6430 ± 189	6159 ± 310	2548 ± 115	8144 ± 214
9	Total monounsaturated fatty acid (MUFA)	21,032 ± 503	8131 ± 242	5112 ± 303	16,124 ± 329	17,803 ± 471	3589 ± 26.7	18,337 ± 552
10	Total polyunsaturated fatty acid (PUFA)	8910 ± 540	10,464 ± 234	16,147 ± 378	18,597 ± 490	25,580 ± 305	18,781 ± 226	11,584 ± 426

Values are taken from "Indian Food Composition Tables" (Longvah et al. 2017)

Mustard seeds may cause gastric irritation and bleeding from the stomach when consumed in large amount. The erucic acid in mustard has been discovered to have possible carcinogenic effects.

13.2.3 Sunflower Seeds

Sunflower seed (*Helianthus annuus*) plant is a native of North America. It was grown by American Indian as food. Crude sunflower oil contains mainly triglycerides with phospholipids, tocopherols, sterols, and waxes (Oomah and Mazza 1999). The oil consists mainly of linoleic acid, followed by oleic acid. The linolenic acid content is very low (Longvah et al. 2017).

13.2.4 Linseeds

Linseeds (*Linum usitatissimum*) are small, oval shaped, and brown or golden colored in appearance (Harriet et al. 1996). Their skin is very shiny and smooth. Linseeds have a good amount of fiber lignin which helps in improving digestion. The unsaturated fatty acids, especially alpha-linolenic fatty acid, help in decreasing cholesterol. It also helps in reducing sugar craving, balancing hormones, and decreasing obesity and supporting weight loss (Arjmandi et al. 1998). The seeds have anticarcinogenic property. All these qualities make the seeds special from other seeds. It also contains a good amount of protein, vitamin B1, B6, iron, zinc, manganese, magnesium, phosphorus, and fair amount of selenium (Longvah et al. 2017). It also contains a good amount of mucilage gum content which has a gel forming property and helps in digestion (Hallund et al. 2006; Jenkins et al. 1999). The seeds can be taken raw as well as in roasted form.

13.2.5 Groundnut Seeds

Groundnut (*Arachis hypogaea*) is an annual herbaceous legume crop from Fabaceae family which grows 30–50 cm. tall. The plant is grown for its edible seeds. The seeds oil is used for consumption purposes. The seeds comprise a good amount of fat and high-quality protein (Longvah et al. 2017) with essential fatty acids like linoleic acid and essential amino acid like methionine (Jain et al. 2016). The seeds can be taken in roasted and boiled form. Groundnut flour is also available in the market for consumption.

13.2.6 Safflower Seeds

The safflower (*Carthamus tinctorius*) plant is an annual plant belonging to Asteraceae family. The crop is primarily grown for its oil. The seeds are high in linoleic acid. It contains high amount of vitamin E which acts as antioxidant. The seed oil is helpful in reducing respiratory problems, helping proper blood circulation, and strengthening immune system (Singh and Nimbkar 2016).

13.2.7 Sesame Seeds

The sesame (*Sesamum indicum*) is one of the oldest oilseed crops. The plant belongs to the family Pedaliaceae, and seeds are used for consumption or for oil extraction. The seeds are notable source of fat, protein, fiber, iron, calcium, zinc, copper, vitamin E, thiamin, and phytosterols (Wellness 2016). The seeds are also useful for diabetes, osteoarthritis, hypertension, hypercholesterolemia, and oxidative stress.

13.3 Fatty Acid Composition

A total of seven fatty acids were taken for the study out of which three are saturated fatty acids (palmitic, stearic, and arachidic acid), two are monounsaturated fatty acids (palmitoleic and oleic acid), and two are unsaturated fatty acids (linoleic and alpha-linolenic acid). The values are taken from "Indian Food Composition Tables" (Longvah et al. 2017). Seven oilseed crops were compared for their fatty acid composition, and it was found that groundnut seed had the highest amount of palmitic acid, followed by sesame seeds and sunflower seeds (Table 13.1), while the lowest palmitic acid content was found in mustard seeds. Stearic acid was found maximum in sesame seeds followed by sunflower seeds and linseeds. The lowest stearic acid content was found with mustard seeds. Garden cress seeds were found with maximum amount of arachidic acid followed by groundnut and mustard seeds, while linseed contained minimum quantity of arachidic acid. The maximum value of palmitoleic acid was observed with groundnut seeds followed by sunflower seeds and mustard seeds, while lowest amount was found in safflower seeds. Oleic acid was found maximum with groundnut seeds followed by garden cress seeds and linseed. The minimum amount was found with sesame seed. Linoleic acid was found maximum with sunflower seed, followed by safflower and sesame seeds. The lowest amount of linoleic acid was found with garden cress seeds. The maximum amount of alpha-linolenic acid was found with linseed followed by garden cress and mustard seeds, while minimum almost negligible amount was found with groundnut seed oil.

Total saturated fatty acids (SFA) were found maximum with groundnut followed by sesame seeds and sunflower seeds. Minimum SFA was found with mustard seeds. Maximum monounsaturated fatty acids (MUFA) were found with mustard seeds followed by groundnut seeds and sunflower seeds, while minimum MUFA was found with safflower seed oil. Sunflower seed oil contained the highest percentage of polyunsaturated fatty acids (PUFA), followed by safflower and sesame seed oil, while mustard seed oil contained the lowest PUFA.

From the results, no oil is complete in terms of fatty acids. All the fatty acids are required by the body, and to fulfil the requirement, therefore, every oil should be consumed. If we consume only one type of oil for daily routine, chances of occurring deficiency of other fatty acids are possible. The best way to rescue from the deficiency of fatty acids is to blend the different oils in a certain proportion. In present time, many blended oils are marketed to ensure the supply of all fatty acids. The other option for this may be to use two or three types of oil on a weekly basis.

13.4 Conclusion

Instead of comprising maximum amount of palmitic, oleic, and palmitoleic acid, SFA does not make groundnut seed complete oil for consumption because it is lacking in an essential fatty acid, alpha-linolenic acid. Likewise, sunflower seed oil contained maximum linoleic acid with highest percentage of polyunsaturated fatty acids but lacking in alpha-linolenic acid and other fatty acids. Linseed was found with maximum alpha-linolenic acid, and monounsaturated fatty acids were found maximum in mustard. It may be concluded that every oil should be consumed to fulfil daily requirement. Blending of different oils in a certain proportion may be one of the possible options. Using different oils on different days may also be helpful to cope up the deficiency of fatty acids in the body.

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14 Study of Municipal Solid Waste Management and Factors Affecting Its Sustainability in Indian Scenario

Karunendra Singh, Mebal Chaudhary, Animesh Mohanty, A. Rahman, and Irin Dominic

Abstract

The improper handling of solid waste and their segregation and collection from various sources is one of the major challenges. The open dumping areas of the municipal corporation are one of the factors which not only contribute to air pollution but also invite major chronic communicable diseases. The burning of heaps of waste may generate greenhouse gases like carbon dioxide, nitrous oxide, and methane which may contribute to global warming. The government initiative regarding the Swachh Bharat Mission (SBM) in 2014 helps to strengthen the solid waste management by providing basic infrastructure and services especially in rural areas and adopting the scientific methods to collect, process, and dispose of solid waste. It's about a one third of the population lives in urban areas, and it is expected that about 50% of India's population will be living in urban areas by 2050, and waste generation will grow at least by 5% annually. Our objective of the study is to focus on the current challenges about the solid waste management and find out the scientific way in Indian scenario to make them more effective and minimize the financial losses also for the area of solid waste.

Keywords

Solid waste management · Swachh Bharat Mission (SBM) · Sustainability

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14.1 Introduction

Today, we need to emphasize more on solid waste management because of their adverse future impacts on our society. The more solid wastes are dumped into the earth, the more our earth gets polluted, thereby retarding the richness of the soil. Various organizations and countries have come forward to deal with the solid waste and make it safer to live on earth. India is among the continent have showing positive and rapid industrial growth. Rapid urbanization and change of lifestyle have become major contributors in the enhancement of the hazard, risk, and vulnerability to the environment. About one third of the Indian population lives in urban areas, and it is expected that about 50% of India's population will be living in urban areas by 2050, and waste generation will grow at least by 5% annually. As of 2016, the global average municipal waste generation rate was 0.74 kg/capita-day which is expected to be 1.26 kg/capita-day by 2050 (ASSOCHAM 2017). The non-equilibrium between waste generation and absorptive capacity of the earth now culminates into environmental pollution (Lumby 2005). Minimizing future worries about waste management requires not only strong will but also effective management infrastructure and scientific methodologies.

14.2 Waste Incineration in Country

Under the Ministry of Environment and Forests and the pollution control boards, the Central Pollution Control Board and State Pollution Control Boards together form the regulatory and administrative core of the waste management sector in India (EBTC n.d., report). In India around 88 hazardous wasters, as well as more than 200 recycling facilities, exist in the country (Hazardous Waste Issues in India 2018).

There are five waste-to-energy plants underway in order to utilize the MSW in India:

1. *Timarpur-Okhla*: About 1300 TPD of waste received at the landfill daily, an initiative of M/s Jindal ITF Ecopolis. The incineration plant is commissioned since January 2012 and is foreseen to process 450 TPD of RDF and generate 16 MW power. Performance data are not yet in the public domain.
2. *Ghazipur*: About 2000 TPD of waste received at the landfill daily; the facility will process/incinerate 1300 TPD to generate 433 TPD of RDF and 12 MW power. The project is under construction. The PPP operator is M/s ILFS.
3. *Bangalore*: About 8 MW power plant is in the process of being set up in Bangalore. This initiative is carried out under a PPP framework between M/s Srinivasa Gayithri Resources Recovery Ltd. and Bruhat Bengaluru Mahanagara Palike (BBMP). The plant is not yet operational.
4. *Pune*: About 10 MW gasification plant is being set up in Pune with funds from Ministry of New and Renewable Energy (MNRE). The plant will need 700 TPD of waste for production of 10 MW of electricity. The plant is still in the construction stage.

5. *Hyderabad*: About 11 MW power plant, which will utilize 1000 TPD of MSW, is being installed in the Nalgonda district. The plant will produce RDF for in-house incineration and power generation. The plant is currently under construction.

14.3 Major Contribution of Solid Waste

India is in Southern Asia and has a total area of almost 3.3 million km^2 making it the largest peninsula in the world and the seventh largest country. It is bordered in the northwest by Pakistan; in the north by China, Nepal, and Bhutan; and in the northeast by Myanmar and Bangladesh. In the south, some 7600 km of coastline is on the Arabian Sea, Indian Ocean, and Bay of Bengal. The municipal solid waste generally includes household waste, commercial and market area waste, slaughter house waste, institutional waste, horticultural waste, and treated biomedical waste (Table 14.1).

14.4 Swachh Bharat Mission

The objectives of Swachh Bharat mainly include eliminating open defecation through the construction of household-owned and community-owned toilets and establishing an accountable mechanism of monitoring toilet use. To accelerate the efforts to achieve universal sanitation coverage and to put focus on sanitation, the Prime Minister of India launched the Swachh Bharat Mission on 2 October 2014. The mission has two thrusts: Swachh Bharat Abhiyan ("gramin" or "rural"), which operates under the Ministry of Drinking Water and Sanitation, and Swachh Bharat Abhiyan ("urban"), which operates under the Ministry of Housing and Urban Affairs (Swachh Bharat Campaign 2014). The mission aims to achieve Swachh Bharat by 2019, as a fitting tribute to the 150th birth anniversary of Mahatma Gandhi, which shall mean improving the levels of cleanliness in rural areas through solid and liquid waste management activities and making gram panchayats Open Defecation Free (ODF) clean and sanitized. The mission shall strive for this by removing the bottlenecks that were hindering the progress, including partial funding for individual household latrines from MGNREGS (Mahatma Gandhi National Rural Employment Guarantee Act) and focusing on critical issues affecting outcomes (Fig. 14.1).

Table 14.1 Composition of urban solid waste in Indian metropolitan cities

	Major industries contributing solid waste (% by weight)						
Metro city	Paper	Glass	Plastic	Textile	Organics	Metals	Others
Delhi	5.88	0.31	1.46	3.56	22.95	0.59	7.52
Mumbai	3.20	0.52		3.26	15.45	0.13	18.07
Chennai	5.90	0.29	7.48	7.07	16.35	0.70	13.74
Kolkata	0.14	0.24	1.54	0.28	33.58	0.28	16.98

Fig. 14.1 A picture of Swachh Bharat Abhiyan

14.4.1 Major Categories and Composition of Municipal Solid Waste

The solid waste may be classified accordingly based on sources which are as follows:

- Residential waste: The waste generated in dwellings houses and apartments.
- Commercial waste: The waste generated from departmental stores, restaurants, marketplaces, and malls.
- Institutional wastes: The waste generated by government and private institutions, offices, museums, public libraries, and recreation centers like cinema theaters and sports stadiums.
- Civil construction and demolition waste: The waste generated in construction and demolition sites.
- Industrial waste: The waste generated during the processes and manufacturing of products by various industries like automobile, cosmetics, food processing, pharmaceutical, etc.
- Agricultural waste: The waste generated in agricultural activities (Fig. 14.2).

14.5 General Guidelines and Policies in the Country for Solid Waste Management

Waste management in India falls under the purview of the Union Ministry of Environment, Forests and Climate Change. In 2016 this ministry released the Solid Waste Management (SWM) Rules 2016, and these rules replaced the Municipal Solid Wastes (Management and Handling) Rules, 2000. It is mandatory to segregate waste into the following streams like organic, biodegradable waste, dry waste, and domestic hazardous waste. India has over 1.5 million subsistence informal waste pickers, and including them into the formal waste management system represents an opportunity for urban local bodies to streamline their operations while providing the

Fig. 14.2 Picture of color coding and types of containers for specific waste

waste pickers with better income opportunities (Buenrostro et al. 2001; Permana et al. 2015).

14.5.1 Current Challenges of Solid Waste Management

- Lack of awareness among peoples for the segregation of solid waste.
- Lack of effective implementation and characterization of municipal solid waste.
- Lack of appropriate level funding and urbanization.
- Lack of coordination among the center, state, and related agencies.

14.5.2 Sustainable Solid Waste Management

Solid waste management is a challenge for the authorities mainly in segregation, collection, and transportation. Due to increasing of waste day by day, the burden posed on the municipal budget requires a sustainable solid waste management which helps to minimize waste and also minimize the municipal budget (Kaushal et al. 2012). A sustainable solid waste management has the following things (Arsova 2010):

(a) *Collection*: The collection of waste from houses is usually transferred into communal bins that are fabricated from metal, concrete, or in combination of both.
(b) *Segregation*: The segregation takes places under very unsafe and hazardous conditions, and its effectiveness is reasonably low as unorganized sector segregates only valuable discarded constituents from waste stream which can guarantee them comparatively higher economic return in the recycling market.

(c) *Transportation*: This is also an important aspect of sustainable solid waste management practiced in the country, and it includes bullock carts, hand rickshaws, compactors, trucks, tractor, trailers, and dumpers.

14.6 Promotion of 3R System

The promotion of 3Rs can begin from our homes. Internationally recognized waste management hierarchy prescribes that the first priority should be given to waste minimization. Recycling, reusing, recovering, treatment, and disposal in these orders may follow the minimization of all kinds of waste. The 3Rs are meant to be a hierarchy, in order of importance. The waste hierarchy has taken many forms over the past decade, but the basic concept has remained the cornerstone of most waste minimization strategies.

- *Reduce*: Buy only what you need because a better way to reduce waste is by not creating it.
- *Reuse*: If you have to acquire goods, try getting used ones or obtaining substitutes.
- *Recycle*: When discarding your waste, find ways to recycle it instead of letting it go to landfill.

14.7 Conclusion

There is a need for awareness about the adverse effects of waste to the peoples and to focus on the adoption of an integrated approach for disposal of their waste and also try to take initiative individually to make clean and green India. This initiative step by the people not only saves the environment but also ensures a better situation for the future generations.

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Part IV

Emerging Technologies and Innovations

15 New Innovations in Food Packaging in Food Industry

Deepak Khedkar and Renu Khedkar

Abstract

Packaging is an essential and critical requirement for promoting food safety, extended shelf life and thereby promoting food security. The packaging industry is exhibiting a rapid growth owing to the rising demand for processed and packaged food by consumers due to changing lifestyle patterns and eating habits, globalization and affordable income levels. Adoption of new technologies in transportation, logistics and supply chain, post-harvest technology, growth in new retail sector, evolution of e-commerce, need of single-use and single-dose consumer pack, and increasing dependence on appliances such as refrigerators, freezers and microwave ovens has led to a surge in packaging innovations. The recent efforts to meet the needs of the consumer and to ensure product quality during storage and transportation highlight the use of flexible packaging, high-barrier material innovations, improved metal and glass packaging, sustainable plastic packaging, active and intelligent packaging, modified atmosphere packaging (MAP), and other innovations. The future innovations in food packaging and their environmental and societal impact will influence the food industry at large. The present chapter reviews the recent developments in packaging materials and systems that have had impact on the society.

Keywords

Packaging materials · MAP · Aseptic packaging · Active and intelligent packaging · Biodegradable packaging · Connected packaging

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15.1 Introduction

Packaging is an essential and critical component of food safety, extended shelf life, and ensuring food for masses. With the context of globalization, packaging ensures the safety of the final product delivered to the ultimate consumer. Food safety requires an attention to packaging and packaging materials. Packaged foods ensure great advantages to the consumers about the quality of the product; protect against tampering, pilferage, and nonseasonal availability of product; and communicate the information regarding the ingredients and other relevant details.

The packaging industry stands at USD 700 billion globally, whereas the size of food packaging market is USD 277.9 billion and is estimated to be USD 441.3 billion by 2025 registering a CAGR of 5.1% over the period (Food Packaging Market Report 2018). Rising demand for packaged food by consumers due to changing lifestyle and eating habits, globalization, and higher income levels has a major positive impact on the industry. The consumer is shifting toward convenience packs, i.e., single-use and single-dose consumer pack, high-performance packaging materials, and more sustainable packing solutions such as bio-based plastics and thermoplastics, which is further leading to the growth of the industry (Fig. 15.1).

Since the last two centuries, packaging materials have evolved from a mere form of containment to an essential part of complete product design. Packaging has strategic importance in the economy, since it can give a competitive advantage in the industry. Providing a good quality, presentable cost-effective solution has led to increasing the profit margins, enhancing branding, and satisfying the needs of the end user which helps in gaining advantage in the industry.

Cost-effective pack performance is the continual challenge faced by the packaging industry along with reduction in the costs in supply chain, marketing for protection and enhancement of brand image, distinctive communication, aesthetic appearance, enhancing the health, and ensuring food safety. Also, it is necessary to minimize the environmental impact of products and the services needed in their

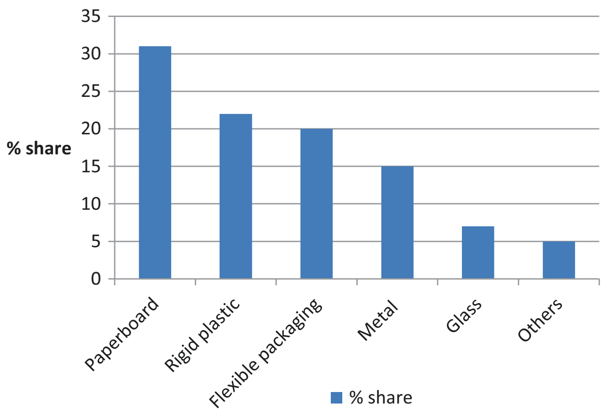

Fig. 15.1 Global share of packaging materials (Source: Packaging: Market and Challenges 2016)

delivery to the ultimate consumer. In recent times, due to technological breakthrough and by adopting best practices in manufacturing of packaging material, the newer options have been developed. New packaging materials are beneficial throughout the life cycle. They are designed to meet improved requirements and cost and are made available using technologies to optimize material and energy uses.

The major forces for innovations in packaging are the changing needs and behavior of the consumers. Few factors responsible for innovations in packaging materials are the following:

- Changing income levels, demography, and lifestyle patterns
- Changing share of different age groups of population
- Evolution of e-commerce and buying pattern of consumers
- Stricter requirements regarding consumer health and safety
- Rise in nuclear families and use of small, single-use, flexible, handy ready-prepared consumer pack with prolonged shelf life
- Change in retail and distribution practices associated with globalization
- Changing distribution channels and infrastructure
- Shelf life extension
- Cost-efficiency
- Environmental issue: reduction, recycling, and biodegradability
- Request for fewer or no food additives/preservatives

Adoption of new technologies in transportation, logistics and supply chain, post-harvest technology, growth in retail sector, and dependence on appliances has led to a surge in packaging innovations. For both commercial and environmental reasons, significant efforts are made by the packaging industry for optimization of the use of packaging material minimizing its impact on the environment through the principle of reduce, reuse, recycle, and recover, land fill, incineration (energy recovery), and disposal.

15.2 Packaging Materials and Systems

The commonly used packaging materials for food products are glass, metals, paper, plastic, and laminates. Before making a right choice for a food product, there is a need to consider the unique advantages and disadvantages of these materials. The different types of packaging materials, systems, and the innovations in food packaging have been discussed below.

15.2.1 Metal Packaging

The global market for metal packaging was $122 billion in 2015 and is estimated to reach $153 billion by 2022, with a CAGR of 3.3% during the forecast period

2016–2022 (Sahu 2017). In the ancient times, metal containers made from silver and gold were in use, which were too valuable for common man. Eventually, there was development and mass production of cheaper metals and stronger alloys with thinner gauges and coatings. Peter Durand is credited for bringing a revolution in canning process when in 1810 he patented the use of tin-coated iron cans instead of bottles. The steel cans were widely used in the food industry, until in the 1950s when the aluminum cans were first manufactured and used. The global market for metal containers is around 410 billion units per annum, where beverage can (both alcoholic and nonalcoholic) market stands at 320 billion and processed food cans at 75 billion (Coles et al. 2003).

Advantages of metal packaging are as follows:

- Excellent barrier properties against moisture and oxygen
- High strength properties
- Protection against external environment conditions
- Excellent display properties
- Easy opening disposal
- Reusable and recyclable

For shelf storage at ambient conditions, heat processing is done to extend the shelf life of the product packaged in cans. The shelf life of the canned food is normally more than a year. Developments are being made in improving the visuals; reducing weight, thereby reducing the material and energy and also the environmental footprint; and recycling the metal packaging. Lightweight aluminum cans have a high recycling rate in trend now. Recent innovations also include the advancements in the design and applications of metal packaging with special features. Examples are self-heating and self-chilling drink cans, peel-able membrane ends for processed food cans, direct heat sealing technology for sealing aluminum foil to the can body, QR codes to improve product traceability, and two-piece DWI (draw and wall ironed) and DRD (draw and redraw) cans made from steel with plastic extrusion coatings. The innovations in metal packaging will ensure that metals will continue to play cost-efficient packaging role in packaging of foods for ambient storage conditions.

15.2.2 Glass Packaging

Glass packaging is the environmentally friendly packaging for foods and beverages. Moreover, glass is unparalleled as a packaging material in its ability to maintain the taste of food and create premium and specialty experiences. Glass is known for its inert nature, recyclability, and reuse. It can be molded into any shape and has excellent barrier properties against gases and moisture. The growth in alcoholic and non-alcoholic beverages is driving the growth of glass packaging industry. The global glass packaging market is estimated to grow at 6% CAGR during the period 2017–2023 (Glass Packaging Market 2018).

Increasing competition from PET bottles has forced the container glass industry to find solutions which appeal the customer. The industry has made a great progress in utilizing an increasing proportion of recycled glass and high energy efficiency in manufacturing processes. British Glass has stated that 60% of recovered glass can be added for clear and amber glass and up to 90% for green glass. Every 1000 tonnes of recycled glass used to make new glass saves 345,000 kwh of energy, 314,000 tonnes of carbon dioxide, and 1200 tonnes of raw material while at the same time reducing the weight of glass waste by 1000 tonnes. Also, these savings can be repeated again and again without any loss in the quality of the glass (King 2008). Current interest about the production and shape of container glass is focusing increasingly on individuality and specific designs. Production quantities and the weight of each bottle are smaller; still the containers are of a high quality while also meeting climate change targets (Table 15.1).

Glass being an inert material, from a health and hygiene viewpoint, offers great safety to the foods and beverages. Compatibility of glass material for liquid and solid foods enables it to enhance the shelf life of the products.

15.2.3 Paper and Paperboard Packaging

Today, paper and paperboard packaging is widely used for food packaging. Around 10% of paper produced is used in packaging. The food industry with more than 50% of paper used for packaging is the largest user industry of paper packaging. Paper and paperboard packaging can be widely seen today in many places, such as supermarkets, fast-food chains, traditional markets and retail stores, dispensing machines, meals in transit, catering, hospitals, etc. Paper packaging is found in the major categories of food shown in Table 15.2.

Paper and paperboard, which account for about 33% of the total packaging market, are found wherever products are produced, distributed, marketed, and used. Various forms of paper and paperboard packaging in use today are shown in Table 15.3.

Paper and paperboard packaging for food/beverage products is used over a wide temperature range. Although it is permeable to water and water vapor, gases, oil and fats, and volatile materials such as flavor and aroma, its barrier properties can be enhanced through coating and lamination with plastics, aluminum foil, wax, and other treatments.

A major advantage of paper and paperboard is that it can be recycled to make new paper and paperboard materials, is non-polluting, and is sustainable. It is recyclable as material, energy, or compost, and, if none of these processes is practical, it is biodegradable.

Table 15.1 Advantages of glass packaging

Transparency	Surface texture	Impermeability	Chemically inert	Design potential	Microwaveable	Resealable
Tamper evident	Ease of opening	Strength	Hygiene	Aesthetic appeal	Product visibility	Environmental benefits

15.2.4 Plastics in Food Packaging

The twenty-first century is known for "plastic packaging." Plastic is the youngest packaging material among other conventional materials. Discovered in the nineteenth century, plastic was derived from natural raw materials, such as coal, oil, and natural gas. Polyethylene, the most widely used plastic, was discovered in 1933 and was commercialized after the 1940s.

It is estimated that the worldwide use of plastics in packaging has increased and stands at 280 metric tonnes (Paine and Paine 2012). Plastic is the most widely used packaging material; more than 90% of flexible packaging is made of plastics, compared to only 17% of rigid packaging. In 2018, the plastic packaging market was valued at USD 334.31 billion and by 2024 is estimated to reach a value of USD 412.17 billion, at a CAGR of 3.47% over the forecast period 2019–2024 (Plastic Packaging Market Report 2019).

There are more than 30 different plastics in packaging; the most common are the following:

- Polyethylene (PE)
- Polypropylene (PP)
- Polyethylene terephthalate (PET)
- Ethylene vinyl acetate (EVA)
- Polyamides (PA) or nylon

Table 15.2 Paper packaging for food products

Category	Examples
Dry food products	Cereals, tea, coffee, spice powders, sugar, bread , biscuits, cake, flour, dry food mixes, etc.
Frozen food	Ice cream
Confectionery	Chocolate and sugar confectionery
Liquid foods and beverages	Juices, milk, and milk products
Fresh produce	Fruits and vegetables, meat, poultry, and fish

Table 15.3 Forms of paper and paperboard packaging

Forms	Examples
Flexible packaging	Paper bags, wrapping, packaging papers and infusible tissues, e.g., tea and coffee bags, sachets, pouches, overwrapping paper, sugar and flour bags, carrier bags, multiwall paper sacks
Rigid packaging	Folding cartons and rigid boxes, corrugated and solid fiberboard boxes, paper-based tubes, tubs, and composite containers, fiber drums, liquid packaging, molded pulp containers
Others	Labels, sealing tapes, cushioning materials, cap liners (sealing wads), and diaphragms (membranes)

Coles et al. (2003)

Table 15.4 Use of plastic in food packaging

Type	Examples
Rigid packaging	Bottles, jars, containers, boxes, trays
Flexible packaging films	Pouches, bags, sachet, stretch films
Cartons	Plastic combined with paper and paperboard
Lids, caps , pouring and dispensing devices	Measuring spoons, plastic straws, droppers
Foamed plastic	Foamed polystyrene trays and accessories
Labels	Pre-printed heat-sensitive shrinkable sleeves

- Polyvinyl chloride (PVC)
- Polyvinylidene chloride (PVDC)
- Polystyrene (PS)
- Ethylene vinyl alcohol (EVOH)

Plastics are used as containers, container components, and flexible packaging. Examples of plastic packaging are shown in Table 15.4.

Plastics are widely used for packaging of food and beverages. The major advantage is their adaptability, versatility, cost-effectiveness, bio-inertness, corrosion resistance, and chemical stability. Plastics also offer strength and toughness and can meet the needs of a wide temperature range, from −40 °C in deep frozen food processing to 121 °C, the temperature of retort sterilization, and 100 °C for microwave processing to 200 °C of conventional ovens. Most packaging plastics are thermoplastic. The major limitation of plastics is their variation in permeability to gases, light, moisture, and low molecular weight molecules. The advancement in plastics includes high-performance barrier films. The strength and the barrier properties of plastic films may be enhanced by combining with other plastics by co-extrusion, blending, lamination, and coating.

Despite plastics' impressive success in the packaging world, it has caused enormous damage to wildlife and human seafood supply chains. Also, it has a poor global recycling record, and 6.9 billion tonnes of plastics waste—including packaging—has been produced since the 1950s of which an estimated 9% was recycled (Packaging Trends 2019).

15.2.5 Flexible Packaging

Any package or part of a package whose shape can be readily changed is flexible packaging. It includes nonrigid structures such as bags, pouches, shrink films, tubes, sleeves, and carded packaging. Flexible packaging, a fastest growing segment, is estimated to grow at a CAGR of 5.9% from 2018 to 2025, owing to its ability to form lighter, thinner, and compact packing. Higher demand has led to the market shifting from rigid to flexible packaging due to superior performance and convenience offered by packages (Singh 2018).

Various examples of flexible packaging are as follows:

- *Pouches*—Provide ease of use, options for reseal ability after purchase and excellent high-quality printability. These pouches with multiple layers of protection have airtight closures and are easy to pack, placeable on shelves (standy pouch), easy to open, and customizable.
- *Flexible films*—Include PVC, PVDC, LDPE, HPDE, PP, nylon, and PS and many more. Used as blister, bagging, and protective wrapping over food in a tray.
- *Foil*—Excellent protection against air, light, moisture, and bacteria, thus increasing a product's shelf life. Also used in multilayered packaging (laminate) to enhance the barrier properties of the packaging material.

15.2.6 Enhanced Barrier Property Material Innovations

To maintain and preserve the quality of food, high-barrier property packaging materials aid in significant reduction in penetration, adsorption, desorption, and diffusion of gases and leakages in liquids. Various techniques are used to improve the barrier properties of packaging materials or packages.

Polymer blending, coating, lamination, or metallization of packaging materials with high-barrier properties improves the protection against moisture, vapor, and gases. It is reported that lamination or coating of high-barrier materials on packaging material decreases the permeability linearly with respect to the square thickness. Also, permeability can be reduced by blending with platelets or droplets of high-barrier materials, but it is less effective than coating or lamination at the same mass as that of high-barrier materials (Lange and Wyser 2003). Some examples are oriented polypropylene (OPP) films with polyvinylidene chloride (PVDC) coating, polyethylene terephthalate (PET) lamination on co-extruded PP/PE, and aluminum metallization on PET. Transparent silica oxide (either vacuum-deposited or plasma-deposited) coating on PET films, epoxy spray on PET bottles, and composites of plastics with nanoparticles are the other innovative technologies adopted for barrier property enhancement (Lange and Wyser 2003; Lopez-Rubio et al. 2004).

15.2.7 Retort Pouch

Packaging influences the shelf life of food products (Rodriguez et al. 2003). Although metal container packaging is still the most common packaging for heat sterilized food, there are other packaging types with many advantages. The retort pouch is a lightweight, rectangular, flexible, laminated plastic which is a four-side hermetically sealed, convenient, and shelf-stable pack in which food is thermally processed. It was developed in the 1960s in the USA and has been successfully used for various foodstuffs all over the world. Food products that have been packed in these pouches include vegetable curries, meat curries, pulao, stews, high-quality meat products, ready meals, gourmet sauces, corn, and green beans.

Compared to traditional metal or glass containers, faster heat transfer is achieved with the retort pouch packaging. It is possible due to their thinner profile, or the higher surface area to volume ratio (Awuah et al. 2007; Rodriguez et al. 2003). There is 30–50% shorter processing time with the same microbial lethality as compared to canning. In case of metal cans, natural convection reduces the processing time. Four-ply lamination of packaging films which can withstand high process temperature and pressure is used in the construction of most of the retort pouches (Jun et al. 2006). The typical retort pouch is a laminate that consists of 12 µm polyester, 15 µm nylon, 9 µm aluminum foils, and 80 µm cast polypropylene. The outer polyester (polyethylene terephthalate) layer offers heat resistance and printability, with an aluminum foil layer protection against oxygen and light, biaxial oriented nylon provides resilience, and an inner layer of cast polypropylene gives the pack sealing (Holdsworth and Simpson 2007). These are inert, heat sealable, dimensionally stable, and heat resistant to at least 121 °C for typical process times. They have low oxygen and water vapor permeability, are physically strong, and have good aging properties. For barrier property enhancement, either aluminum foil or silicon oxide may be used in pouch materials (Holdsworth and Simpson 2007).

15.2.8 Aseptic Packaging

Heat sterilization is a common preservation technique of food in which foods are heated at a high temperature for sufficiently long time for destroying microorganisms and arresting enzymatic activities. Canning is the most common method of in-container sterilization of solid and viscous food products. However, the process has some disadvantages, such as (1) long process time for achieving sterility, (2) high processing temperatures resulting in high energy costs, and (3) loss of nutritional and sensory characteristics of the product. To overcome the limitations of canning, high temperature and short time processing prior to filling in the pre-sterilized containers under sterile conditions can be adopted. Aseptic packaging is the filling of a sterile product in a sterile container under aseptic conditions and then hermetically sealing the containers to prevent reinfection. The meaning of the word “aseptic,” derived from the Greek word *septicos*, is the absence or exclusion of pathogenic microorganisms. The process is successfully adopted for milk and other dairy products, fruits and vegetable juices, soups, sauces, and fermented dairy product like yoghurt.

The major advantages for the use of aseptic packaging are as follows:

- The use of thermally efficient high-temperature short-time (HTST) sterilization processes
- The use of containers that are unsuitable for in-package sterilization
- To extend the shelf life of products at shelf-stable conditions
- Lower cost of distribution channels since cold chain is not the requirement
- No use of preservatives

The three main sterilization processes for packaging material are in common use, either individually or in combination: irradiation, heat, and chemical treatments. Irradiation involves gamma ray radiation from cobalt-60 or cesium-137. Gamma rays have deep penetrating power and have been used to sterilize the packaging materials used for aseptic packaging of acid or acidified food. Other radiations include UV radiation between 248 and 280 nm (UV-C range), with an optimum effectiveness at 253.7 nm, which is effective in decontaminating food contact surfaces. However, UV-C irradiation is generally used along with hydrogen peroxide (H_2O_2).

Heat sterilization processes include steam (moist heat), hot water, or dry heat; these processes may damage the packaging materials and therefore have limited applications. Molded polystyrene cups and foils are sterilized with saturated steam at 165 °C and 600 kPa, whereas dry heated air at a temperature of 315 °C is used to sterilize paperboard laminate cartons.

Chemicals such as ethylene oxide, hydrogen peroxide, peracetic acid, beta-propiolactone, alcohol, chlorine and its oxide, and ozone have been used for sterilizing aseptic packaging materials. Hydrogen peroxide followed by hot dry air treatment is the preferred mode of sterilization of packaging materials for aseptic packaging. Peracetic acid (PAA), a sporicide, is used for sterilization of filling machine surfaces and PET bottles before aseptic filling. Tetra Pak, a paperboard/foil/polyethylene laminate, is the most widely used packaging material for aseptic packaging. It consists of layers of paperboard coated internally and externally with polyethylene and a thin (6.3 μm) barrier layer of aluminum foil.

PET has been increasingly used for packaging in recent years. Sachet and pouch systems made of laminate of LLDPE with EVOH copolymer as the barrier layer and carbon black give the pouch the required shelf life. Other laminates consisting of PVDC, PE, PS, or metallized polyester consisting of vinyl ethyl acetate, nylon, aluminum foil, and PE can also be used. Aseptic bag-in-box systems ranging in size from 1.5 to 1400 L are used for packaging UHT products. The bags are made of EVOH and metallized PET as barrier layers and sterilized using gamma radiation (Robertson 2014).

15.2.9 Biodegradable Packaging

Since the beginning of the twenty-first century, great importance is given to environmentally friendly technologies and products made from renewable resources. Accumulation of plastic in the environment and the serious problems such as leaching in the soil or water streams and limited petroleum resources have led to the developments in biodegradable packaging (Mohatney et al. 2005). There are three categories of biodegradable packaging based on their source and production method: (1) polymers extracted/isolated directly from biomass, (2) polymers produced by classical chemical synthesis and bio-monomers, and (3) polymers obtained directly from natural or genetically modified organisms (Chiellini 2008).

- Polymers extracted/isolated directly from biomass: This category includes biopolymers obtained from plants, marine, and domestic animals. Examples are polysaccharides, such as cellulose and its derivatives, pectin, carrageenan, chitin and starch, whey protein, casein, collagen, soy protein, myofibrillar proteins of animal muscle, etc., which can be used alone or as a mixture with synthetic polyesters such as polylactic acid (PLA).
- Polymers produced by classical chemical synthesis and bio-monomers: The most famous of these groups is polylactic acid (PLA). The properties of PLA are similar to the thermoplastic polystyrene. The raw material for obtaining the lactic acid is obtained by fermentation of glucose or starch from another source. The source of carbohydrate may be corn and wheat or whey and molasses may also be used (Wackett 2008).
- Polymers obtained directly from natural or genetically modified organisms: These biopolymers are synthesized by microbes and are biodegradable and can be used for packaging purposes. Under imbalanced growth conditions, some bacteria like *Bacillus*, *Azotobacter*, *Clostridium, Thiothrix*, etc. deviate from their original physiological pathways and synthesize different compounds such as PHA (poly-*b*-hydroxyalkanoates) and PHB (poly-*b*-hydroxybutyrate), which can become very good substitute for synthetic polymers. Depending on the bacteria and the carbon source, the polyhydroxyalkanoate (PHA) may be manufactured from rigid brittle to plastic to rubberlike polymer and can have similar properties such as propylene and polyethylene, elastic, and thermoplastic (Zivkovic 2009).

15.2.10 Modified Atmosphere Packaging

Modified atmosphere packaging (MAP) technology has been commercialized since the 1970s. MAP products are widely seen on the shelves of supermarkets worldwide. MAP is extensively used as a preservation technique to increase the shelf life of horticultural produce, but is also increasingly used to extend the shelf life of minimally processed fresh fruit and vegetables. In modified atmosphere packaging (MAP), the products are packaged in a package of known permeability in an atmosphere different from that of air, which usually contains 78.08% nitrogen, 20.96% oxygen, and 0.03% carbon dioxide. An inert gas, nitrogen, typically is used as a filler to dilute the concentration of oxygen and carbon dioxide in the package, while carbon dioxide has antimicrobial effect inhibiting the growth of microorganisms. MAP helps to delay the degradation of product, by reducing the amount of oxygen exposed to the product during its shelf life. Various properties to be considered in relation to food distribution though MAP may include gas or water vapour permeability, mechanical properties, sealing capability, thermoforming properties, resistance (toward water, grease, acid, UV, light, etc.), machinability (on the packaging line), transparency, antifogging capacity, printability, availability, and of course cost.

Although many packaging materials are available for MAP, due to their range of permeability to gases and water vapor together with the necessary package integrity needed for MAP, most packages are constructed from polyvinyl chloride (PVC), polyethylene terephthalate (PET), polypropylene (PP), and polyethylene (PE), for packaging of fruits and vegetables (Kader and Watkins 2001; Ahvenainen 2003a, b; Marsh and Bugusu 2007; Mangaraj et al. 2009). Therefore, in these cases the plastic packaging films combined with one another or with other materials such as paper or aluminum through coating, lamination, co-extrusion, and metallization processes are highly beneficial (Mangaraj et al. 2009). Other innovations include active MAP with differentially permeable films, films that incorporate antimicrobial properties, edible coatings in which antimicrobial compounds are incorporated directly onto the product, and the use of nontraditional gases to modify respiration. Intelligent packaging using integrated sensor technologies that can indicate maturity, ripeness, respiration rate, and spoilage is also appearing.

15.2.11 Active and Intelligent Packaging

The most important role of food packaging is to protect and preserve the food product from any external contamination. Food packaging also maintains the quality of food, prolonging the shelf life, and delays the onset of decomposition by protecting against adverse chemical and biological changes, physical damage, and tampering. Among the different techniques for food packaging, the most popular technique is the active and intelligent food packaging. Active and intelligent food packaging plays important functions of packaging, including convenience, marketing, communication, and containment.

Active packaging is referred to as the incorporation of certain additives into packaging systems (whether loose within the pack, attached to the inside of packaging materials, or incorporated within the packaging materials themselves) with the goal of either maintaining or extending product quality and shelf life. Packaging may be termed active when it performs some desired role in food preservation other than the passive role of providing an inert barrier to external conditions (Hutton 2003).

Active packaging helps to increase shelf life, improve safety, or expand sensory properties of food products.

Active packaging involves several functions such as (Table 15.5):

- Delay of oxidation
- Controlling respiration rate
- Controlling moisture migration
- Preventing microbial growth
- Absorbing odor and other gases
- Removing ethylene
- Emitting aroma

Reduction in shelf life due to microbial contamination and the foodborne illnesses is a major factor in development of innovative packaging solutions. Food traceability is also a necessary requirement in developed as well as developing countries. Consequently, there is a great interest among food industry and the

Table 15.5 Active packaging systems

Active packaging system	Mechanisms	Food applications
Oxygen scavengers	Oxidation of iron and ferrous salts (e.g., ferrous oxide)	Grated cheese, cooked meat and fish, coffee, snack foods, nuts, oils, dried foods, and fruit juices
	Oxidation of acid (e.g., ascorbic acid)	
	Oxidation of unsaturated fatty acids (e.g., oleic, linoleic)	
	Metal (e.g., platinum) Catalyst	
	Enzyme oxidation	
	Sulfites	
	Catechol	
Carbon dioxide scavengers/emitters	Iron oxide/calcium hydroxide	Coffee, fresh meats and fish, poultry, cheese, nuts
	Ferrous carbonate	
	calcium oxide/activated charcoal	
	Mixture of ascorbic acid and sodium bicarbonate	
Ethylene scavengers	Activated alumina , silica gel with potassium permanganate	Climacteric fruits and vegetables
	Activated carbon, bentonite,	
	activated clays/zeolites	
Antimicrobials	Organic acids	Cereals, fatty meat and fish, nuts, fat-containing instant mixes, snack foods, dairy products
	Silver zeolite	
	Spice and herb extracts	
	BHA/BHT antioxidants	
	Vitamin E antioxidant	
	Volatile chlorine dioxide	
	Sulfur dioxide	
	Allyl isothiocyanate	
	Nisin	
Ethanol emitters	Alcohol spray	Cakes, bread, biscuits, fish, and bakery products
	Encapsulated ethanol	
	Ethanol-emitting sachets	
Moisture absorbers	Activated clays and minerals	Mushrooms, strawberries, tomatoes, grains, fish, meats, poultry, fruit and vegetables, snack foods, dried foods
	Silica gel	
	Calcium oxide	

(continued)

Table 15.5 (continued)

Active packaging system	Mechanisms	Food applications
Flavor/odor absorbers	Cellulose triacetate	Fruit juices, fried snack foods, fish, cereals, poultry, dairy products, and fruit
	Acetylated paper	
	Citric acid	
	Ferrous salt/ascorbate	
	Activated arbon/clays/ zeolites	
Temperature control	Nonwoven plastics	Ready meals, meats, fish, Poultry, and beverages
packaging	Double-walled containers	
	Hydrofluorocarbon gas	
	Lime/water	
	ammonium nitrate/water	

Source: (Day 1989, 2003; Rooney 2005; Yildrim et al. 2017)

regulatory bodies to develop accurate, rapid, and noninvasive methods to provide real-time information about the freshness of the product.

Intelligent or smart packaging is another popular method of food packaging. It is designed to detect the environment changes and convey information to the user. Intelligent packaging has been defined as "packaging systems which monitor the condition of packaged foods to give information about the quality of the packaged food during transport and storage" (Ahvenainen 2003a, b). It helps to monitor and communicate information about food quality. Such packaging has gained prominence for tracking and tracing perishable food commodities.

Various features in intelligent food packaging are given below:

- Radio-frequency identification and QR codes: for traceability
- Ripeness/microbial spoilage indicators: for example, Toxin Guard, polyethylene-based packaging material containing immobilized antibodies for detection of *Salmonella* and *Escherichia coli* and pH dyes to monitor formation of carbon dioxide due to microbial growth
- Freshness indicators: for example, COX Technologies "Fresh Tag" for storage of fish and other seafoods; "electronic nose" for detection of aroma compounds for ripeness, maturity levels of fruits, and off-flavors
- Time-temperature indicators: for example, diffusion-based TTI, enzyme-based TTI, bacteria-based TTI, and photochrome-based TTI
- Gas concentration indicators: oxygen and carbon dioxide concentration in MAP and active packaging
- Biosensors
- Microbial growth indicators
- Physical shock indicators: for example, ShockWatch indicators
- Leakage indicators, etc.

15.2.12 Applications of Nanomaterials in Food Packaging

Nanotechnology is a newly emerging technique, which involves the characterization, fabrication, and manipulation of structures, devices, or materials that have at least one dimension having 1–100 nm in length (Duncan 2011). The nanomaterials are classified into three classes, namely, nanoparticles, nanofibers, and nanoplates. Nanocomposites are mixture of polymers of organic and inorganic additives having certain geometrics. The applications of nanomaterials in food packaging are:

- Enhancement of gas and moisture barrier properties along with temperature resistance through the incorporation of nano-fillers (e.g., nano-clay)
- Controlled release of active substances such as antibacterial (e.g., nanosilver) in "active packaging" to improve shelf life of food
- Improvement in the mechanical properties of the packaging materials (e.g., nano-titanium dioxide, titanium nitride)
- Use of nanoparticle-based sensors in intelligent packaging to detect the presence of pathogens

The health risks of nanomaterials from food contact materials are determined by the toxicity of the nanomaterial, the rate of migration, and the consumption rate of the particular food (Cushen et al. 2012). Migration studies have shown that migration increases with storage duration and content of the nanomaterial in the packaging (Cushen et al. 2013, Song et al. 2011).

15.2.13 Connected Packaging

Connected packaging is a technique, which influences and drives the purchase by bringing the engagement and interaction of the online world to the consumer. Many recent technologies are enabling to connect physical packaging with the virtual world. With growth in ownership of connected devices throughout the world and advancement in technologies that can link packaging to the online world, brands are connecting virtually with packaging through various options, such as QR codes, near field communication (NFC), radio-frequency identification (RFID), Bluetooth, and augmented reality (AR). QR codes are digital markers, printed patterns, that can activate an action, such as opening a web page on a smartphone. Near field communication (NFC) is a simple tag that can be incorporated into packaging. By tapping the tag on smartphone, the consumer can be directed to product information. Each NFC-enabled tag integrated into product packaging has a unique ID which enables product tracking and authentication and allows interactions with a single consumer. Augmented reality is an enhanced reality where live direct or indirect views of physical real-world environments are augmented with superimposed images over a user's view of the real world, thus enhancing one's current perception of reality. The use of packaging-directed augmented reality (AR) allows brands to position the pack directly within a consumer's real-world experience. AR has the potential to provide instructional guidance that can provide a way to compare products for the shopper and assists in the purchase decision (Mintel 2019).

15.3 Safety Assessment of Packaging Materials

Packaging is a means of ensuring safe delivery of products to consumer. Packaging ensures safety of food from biological contamination, retention of nutritional and sensory characteristics, tamper evidence, and the display of product information, as well as reuse or recycling features. Materials that come into contact with food must be safe as it interacts with food during processing, storage, and transportation. Food contact materials may be plastic, paper, paperboard, glass, metal and alloys, wood, ceramics, waxes, paraffin, lacquer, varnish, ink, etc. Direct food contact materials are bottles, pouches, cans, plastic films, caps, closures, etc., whereas the indirect food contact materials are paperboards, varnishes, and printing ink. When in contact with food, food contact materials (FCM) behave differently and may transfer some constituents to food. Such food, if consumed in large quantities, might affect the health or change the food. With the increasing use of packaging materials, awareness regarding the concerns also became evident. Responsible authorities started developing regulations for consumer protection. The three pillars of safety of food and packaging materials are the toxicity of a substance, migration level of the substance to the food, and the level of exposure. For determination of safety of food product, toxicological evaluation of food ingredients and packaging materials and the migration testing is necessary. The major factors that affect migration include concentration of the additives, type of plastic material, nature of food product and ingredients added, period and temperature of contact, thickness of the material, volume of solvents used and type of exposure, preservation of product over stipulated time, protection of organoleptic properties, and convenience in dispensing, resealing, avoiding pilferage, and holding vacuum and pressure. It is necessary to ensure that FCM and articles must not endanger human health, bring about an unacceptable change in the composition of food, or deteriorate the organoleptic characteristics thereof. There is a need to also ensure that materials and articles are manufactured in compliance with good manufacturing practice (GMP). Choice of the right packaging should comply with:

- Overall migration limit (OML)
- Specific migration limits (SML)
- Maximum legitimate residual content of the substance in the finished food contact material (quantity of material in article QMA)

Regulations for direct and indirect contact materials in different countries are listed below:

- European Framework Regulations (EC) 1935/2004

- Indian regulations: Food Safety and Standards Act 2006
- USA: FDA 21 CFR
- Germany: BfR (Bundesinstitut fur Risikobewertung)
- Italy: Decreto del Presidente della Repubblica no. 777 of 23/8/82 (DPR 777) and the Decreto Legislativo no. 108 of 25/1/92 (DL 108)
- South America: MERCOSUR regulations
- Japan: Food Sanitation Law
- Singapore: Food Regulations 1988

15.4 Printing Ink

The printing ink system may be safe for use on food packaging or unsuitable depending on the packaging material it is printed on, the printing conditions, the food that is packed with the printed packaging, and the conditions during the packaging manufacturing and filling. New developments in printing are aimed at reducing VOC emissions. Fast curing water-based flexo inks compatible with reverse printing offer high color density and high lamination strength running at high press speeds and offer a wide choice for food products (Advances in Ink Technology for Flexible packages 2017). Innovative patented low-migration UV-curable inkjet inks for printing directly on food packaging have been developed (Mondt and Graindourze 2015*)*. There is significant growth in inks and coatings used in digital print processes.

15.5 Life Cycle Analysis

Food packaging has a fundamental role in today's society since it protects and preserves food during the entire shelf life of the product. Due to its widespread use, the amount of packaging material manufactured and disposed of is increasing, leading to serious concerns about the environmental impact. Life cycle analysis (LCA) takes into consideration various aspects of environmental impacts and provides tools and techniques to decide the appropriate product format and packaging system. Life cycle methods can be used as a tool in the package design process and in assessing the sustainability of finished food packaging. LCA is acknowledged as a a science-based method which addresses the environmental impacts of the product or service throughout the life cycle. The methods are based on ISO14040 and ISO14044 for the conduct of LCA. Life cycle assessment consists of four phases: the goal and scope definition phase, the inventory analysis phase, the impact assessment phase, and the interpretation phase (SFS-EN ISO 14040 2006; SFS-EN ISO 14044 2006).

In the last two decades, the LCA approach in the assessment of environmental impact and its role in designing new sustainable packaging materials and systems have received considerable attention.

15.6 Conclusion

Packaging is an integral part of food processing and logistical system and plays an important role in prevention and reduction of wastage in food supply chain. The last century has seen tremendous growth of food industry. The growth owes to a large extent to the advancements in packaging. Growth of global population and consumer demand for prepackaged food is the driving force for the developments and growth of the processed and packaged food industry.

The innovations in packaging have ensured high product quality, safety, and integrity. Most of these advancements have been driven by changes in lifestyle, food safety awareness, industrial developments, awareness in health and environmental consciousness, more healthier and safer options in food consumption, development of smaller pack (single use and single dose), rising income levels, globalization, development of e-commerce, growing use of the Internet, adoption of new technologies in transportation infrastructure, and new retail formats.

High-barrier materials, sustainable packaging, active and intelligent packaging, and other innovations in food packaging have enhanced the food quality and safety and brought convenience to the consumer. Thus, environmental concerns, needs, and requirements of consumers and policy makers will drive further the innovations in food packaging for a better future.

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16 Vacuum Impregnation: A Novel Nondestructive Technique for the Development of Functional Foods

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Abstract

Increased consumer awareness for health-positive foods has accompanied the faster pace development of functional foods. Meeting the objectives, various innovative methods are there in food industry to customize the functional qualities of food. Vacuum impregnation (VI), an osmotic treatment, is a novel and nonthermal method of introducing porous matrices of fruit and vegetables with desirable fortificant solution without affecting organoleptic properties. With the unique convenience of incorporating both the process of osmosis and diffusion during VI application, it has a wide application in fruit and vegetable processing industries. Current chapter provides process details of the vacuum impregnation in comparison with osmotic dehydration and their application in food industries. Furthermore, the importance of VI technique with future gaps has also been delved into so that the same technology can further be explored commercially with resolved technical constraints.

Keywords

Vacuum impregnation · Minerals · Fortification · Functional foods

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16.1 Introduction

Consumers nowadays believe that foods contribute directly to their health. Therefore, expectations are increasing for the food products that can fulfil the healthy and active lifestyle of consumer interest (Menard et al. 2000). Possible reasons for increasing demand of such foods are increasing cost of healthcare, the steady increase in life expectancy, and the desire of older people for improved quality of their later years (Kotilainen et al. 2006; Roberfroid 2000a, b). In this regard, functional foods fit into a continuum that can cater the special health needs of a specific group of consumers. Functional foods are described as "Food similar in appearance to conventional food that is designed to be consumed as part of a normal diet but has been modified to fulfil various physiological roles beyond the provision of simple nutrient requirement" (Bech-Larsen and Grunert 2003). Currently, various modified techniques have been identified to modify normal diet in order to have high health promoting values with desirable sensory attributes. The most commonly used technologies in the development of functional foods are infusing traditional foods with physiological active compounds. Vacuum impregnation (VI) has been identified as one of the innovative techniques to acquaint liquids into the porous structure of some foods (Chiralt et al. 1999), thereby fulfilling the demand of health-conscious consumers for healthy and nutritious food. VI, fundamentally, consists of inverting the internal gas or liquid occluded in open pores to a desirable solute due to the action of hydrodynamic mechanisms (HDM) promoted by pressure changes (Fito 1994; Fito and Pastor 1994). In this way, the product design as well as its physical and chemical properties may be changed in order to enhance some food characteristics (Fito and Chiralt 2000). It is an effective procedure to take benefit of the original fresh food structure to incorporate PAC and thereby obtain fresh functional foods (FFF). Therefore, VI treatments not only enrich food with nutritional and functional components with innovative sensorial properties but also restrict the significant degradation reactions (Derossi et al. 2010). Moreover, VI has been reported to improve the quality of final product and reduce cost operations by removing native liquid (water) from the pores and hence can be used as pretreatment before drying or freezing as it improves (Zhao and Xie 2004).

16.2 Importance of Vacuum Impregnation

VI is an innovative food processing technique with the motive of providing food with immense health—promoting value and uncompromised sensory attributes (Elzbieta et al. 2014). Lgual et al. (2008) stated that VI is an osmotic treatment (OT) based on the process of diffusion. An OT, a nonthermal treatment, intends to customize the composition of food material by partly removing water and in turn impregnating it with desired solute solution while maintaining the materials structural integrity (Spiess and Behsnilian 1998). Vacuum impregnation (VI), an OT, involves the introduction of a desirable solute/fortificant solution after putting the food under vacuum. With this, within a few seconds, it is possible to recover the occluded air formerly contained in the fruit or vegetable pores by the impregnation/fortificant solution, through positive pressure differential, which results when the atmospheric pressure conditions are restored (Tiwari and Thakur 2016).

Thus, it has binary leverages in a sense that it not only partially dehydrates the product's sample but also facilitates to infuse restrained amount of desirable fortificant solution to the food particles. With this the quality of the food product can be improved as has been reported in earlier study (Torreggiani and Bertolo 2001).

16.3 Osmotic Treatments and Vacuum Impregnation

Based on pressure applied on the system, OD (osmotic dehydration at atmospheric pressure), VOD (osmotic dehydration at vacuum pressure), and PVOD (pulsed vacuum osmotic dehydration) (Fito et al. 1994) are the three kinds of osmotic treatments defined. PVOD designing was done after noticing that the effect of crucial HDM is very rapid and appeared just when atmospheric pressure is restored. Fundamentally in PVOD, by the action of a vacuum pulse, VI with the osmotic solution takes place during the first 5–10 min of process and thus causes a fast compositional change in the product that in turn alters the osmotic driving force and mass transfer kinetics (Fito and Chiralt 2000). However, OD is the most recognizable osmotic treatment. Newly developed vacuum impregnation (VI) is the result of further development of OD. Further differences between VI and other osmotic treatments are described in Table 16.1.

Additionally, VI is very often confused with osmotic dehydration (OD) since both belong to the osmotic treatment technique. Hence, it is necessary to clarify the difference between the two technologies before discussing about VI.

Table 16.1 Differences between Vaccum Impregnantion and different Osmotic treatments

Difference points	Process Vacuum impregnation	Osmotic dehydration	PVOD
Time	Minutes	Hours	Days/week
Propulsive force	Pressure gradient and capillary action	Capillary action and chemical potential of components (mainly water)	Mechanical force and pressure gradient
Predominant mechanism	HDM	PDM and CMD	Gas release and pore filling
Equilibrium condition	$\Delta P_{\text{int-ext}} = 0$	$\Delta a_w = 0$	$P_{\text{DRP}} = 0$ $\Delta M = 0$
Water loss rate	High	MiddleΔ	Low
Solid gain	Low	Middle	High

HDM hydrodynamic mechanism, *DRP* deformation relaxation phenomena, *CMD* cell matrix deformation. $\Delta P_{\text{int-ext}}$ pressure difference between the exterior and interior of the product (N/m^2), Δa_W water activity difference between the solution and product, ΔP_{DRP} pressure difference associated with the DRP of the cell matrix (N/m^2), ΔM weight loss referred to the initial mass sample (kg/kg) (Fito et al. 2000)

OD is the conventional process which comprises substantial water removal from a product while adding minimal solids, to downturn product water activity in minimally processed fruits and vegetables or in some deeply processed fruits, such as candied fruits or jam. However, osmotic process effectiveness relies upon a high osmotic rate, which is mainly determined by the type, concentration, and temperature of osmotic solutions, and treatment time. Nowadays infusion technology has engrossed researcher nationally and internationally and has been applied commercially in comparison with traditional food processing, i.e., OD. Infusion comprises maximizing osmotic movement in both directions so that the solutes move into the food, i.e., two counterflows—removal of water from an infusion of solutes into the food, rather than merely causing water efflux (Kuntz 1996). This results in a different set of characteristics in the finished product. Impregnation oftentimes is used reciprocally with infusion and infiltration where the term impregnation means being filled, saturated, or the process of permeating.

VI is the result of further development in osmotic dehydration of foods. In favor of the findings, it had already been reported that with the application of vacuum pressures to the system, depending on the product porosity and mechanical properties, OD and other solid-liquid operations can farther be enhanced with a significant decrease in the processing time (Fito et al. (2001). Thus, VI is a food

Table 16.2 Difference on the basis of processing conditions in VI and OD

Difference points	Process	
	Vacuum impregnation	Osmotic dehydration
Mass transfer	Mass transfer takes place as a result of mechanically induced difference in pressures	Mass transfer depends on the variation in concentration between the intercellular liquid in the food material and the solution
Aim	Current method involves the injection of the external solution into the material which has been the main goal	OD involves the partial water removal from the material, which moves in the direction of concentration gradient
Type of solution used	Since the application of vacuum is the only necessity, hence VI requires isotonic solution	For OD hypertonic solutions are required and the process occurs at atmospheric pressure
Duration	VI is a fast process (get completed in few minutes) and needs low energy cost	OD is reported to be a long duration process
Nutrient loss	No leaching of nutrients has been reported	Leaching of nutrients from tissues has been reported
Nutritional value	No taste alteration and reduction in nutritional value have been observed	The most common compounds of osmotic solution—salt or sugar—have been reported to change the taste significantly and reduction in the nutritional value of food
External solution usage	External solutions may be reused many times and it can be performed at low temperature	External solution can be used single time only

fortification technique that involves the mass transfer between an external impregnation solution and the food matrix as a result of the exposure to vacuum (Bhattacharya 2014). Hence it is evident that besides being nonthermal OT, VI is a novel technique in comparison to OD (Tiwari et al. 2018). The difference between VI, OD, and PVOD, in terms of processing conditions, driving force, controlling mechanisms, and equilibrium is explained in Table 16.2 (Tiwari and Thakur 2016).

16.4 Mechanism Difference Between OD and VI

16.4.1 Osmotic Dehydration Mechanism

Figure 16.1 highlights a typical pathway in a long-term osmotic dehydration process, where two main steps have been discussed (Barat et al. 2001).

16.4.1.1 Dehydration Step

During the first few hours of dehydration step, loss of water evokes strong deformations (mass and volume losses and shrinking) and sometimes case hardening, till the activities of water and solutes reach values equal to those of the osmotic solution. Subsequently in pseudo-equilibrium situation, the mass and volume of the sample rise again. The mechanical stress hoarded in the food matrix during drying due to the shrinking is released as sample swelling.

16.4.1.2 Relaxation Step

Under this phenomenon, pressure gradients in the food matrix are produced thereby promoting the flow of the external liquid into the structure. This bulk mass transport proceeds by HDM throughout the intercellular spaces and sometimes throughout the cell wall. Using Peleg's equation, kinetics of this HDM mass flow in long-term osmotic processes after compositional equilibrium has been attained and modelled by relating mass fluxes to the pressure drop in the structural elements (Fito et al. 2000).

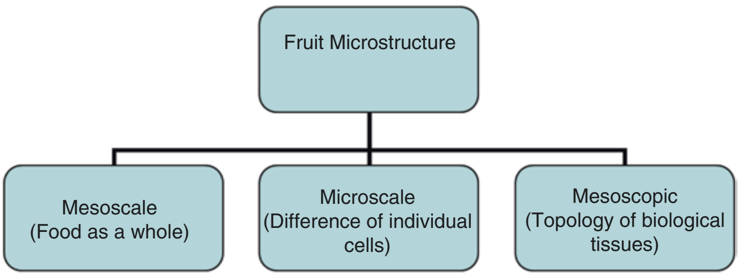

Fig. 16.1 Microscopic classification of fruit (Tiwari and Thakur 2016)

16.5 VI Mechanism

VI process comprises filling of the free spaces and capillaries with the desired material due to a mechanically induced difference in pressure. Hydrodynamic mechanism (HDM) and deformation-relaxation phenomena (DRP) are the two important phenomena responsible for the desired liquid impregnation process. The process consists of two stages: the phase of reduced pressure and the phase of atmospheric pressure. When the material gets immersed in solution (t_0), the pressure inside (p_i) and outside (p_e) the capillary is equal to atmospheric pressure ($p_i = p_e = p_{at}$) and they equalize. The initial volume of the capillary (V_{g0}) is filled with gas.

16.5.1 Vacuum Step/Reduced Pressure Step

In the vacuum step at first the pressure is reduced ($p_1 < p_{at}$), and as a result of the pressure difference, the gas is removed from the capillary. Consequently, due to the action of reduced pressure from the outside, deformation and expansion of the capillary occurs that is the first part of the deformation-relaxation phenomenon (DRP). As a result, the volume of the capillary is incremented ($V_{g1A} = V_{g0} + X_{c1}$), and this stage recurred till pressure equilibrium ($p_i = p_e$) is achieved.

Later, as a result of the HDM, the capillary starts to be partially filled with liquid, and the pressure inside the capillary increases marginally, while the free volume inside it decremented to the value $V_{g1B} = V_{g0} + X_{c1} - X_{v1}$.

16.5.2 Atmospheric Step

In the second phase of the VI process, the pressure returns to the atmospheric value, and the samples are kept into the solution for a relaxation time as per design (t_2). This accounts for the shift of the DRP phase to the relaxation phase. As a result, the capillary shrinks to an even greater extent than before the start of the process. Concurrently, because of the action of capillary pressure and decompression, an exhaustive invasion of liquid from the outside to the inside of the capillary happens, and the final volume of gas inside it decreases to $V_{g2} = V_{g0} - X_c - X_v$. From the practical point of view, the relaxation phase is particularly important because at this stage, only tissue impregnation takes place. Vacuum removal should not be very rapid, since the excessively fast pressure equalization may bring about closure of the capillary vessels and inhibition of the hydrodynamic mechanism (Fito 1994).

16.6 Food Modification by VI

From the earlier findings, it has been inferred that the main changes induced by osmotic treatment are loss of cell turgor; cell debonding; alterations in cell wall resistance; density of cell packaging, sample size, and shape (Martínez-Monzó et al.

1998; Cháfer et al. 2003); temperature (Vincent 1994; Pitt 1992); changes in water and solute concentration profiles (Salvatori et al. 1999); and changes in air and liquid volumetric fraction in the sample (Fito 1994). From the abovedescribed phenomena for both VI and OD, it has been clear that both concepts have various significant differences in terms of timescale, driving force, controlling mechanism, and many other points as described and summarized in Table 16.2.

16.7 Industrial Application of VI in the Food Sector

Energy saving: By reducing volume of the products, VI saves the cost of food processing, storage, and transport. Also, as VI removes most of the water from the product, energy consumption has also been found to be decreased by pretreatment of fruits and vegetables with VI (Zhao and Xie 2004). Dehydrated fruits and vegetables can also be applied as a food ingredient in many products and have also been added to cereals, granola bars, and baked goods and mixes and can even be eaten out of hand.

Value addition: VI has been reported to be the best tool for food fortification process. Calcium can be infused into the cellular structure of the pineapple snacks using vacuum pulsed osmotic dehydration (Marla Mateus de Lima et al. 2016). The dehydration of samples implies a decrease in the cellular respiration rate and, consequently, an increase in the shelf life of the processed fruit, both of which are much evident if calcium is added to the sample (Moraga et al. 2008). Even iron content of VI potatoes increased with vacuum time and restoration time as has been reported by Erihemu et al. (2015). Additionally, VI can also be used as a tool in order to produce probiotic enriched fruit products. Various other examples of value addition to the foods are cited herewith (Table 16.3).

Food salting: Chiralt and Fito (1997) discussed that in order to reduce brining time, a brine VI process has been developed by taking advantage of the salt uptake by hydrodynamic mechanisms (HDM) that takes place in capillary pores by the action of pressure gradients. Moreover, rapid salting kinetics can be also be achieved with a more even salt distribution in the product and with elevated process yields by using VI techniques in salting processes of porous food (Chiralt et al. 1999).

Product quality: Quality of frozen fruits and vegetables has also been reported to be improved with VI pretreatment, mainly by reducing drip loss and improving texture quality, as well as saving energy consumption during freezing (Torreggiani and Bertolo 2001; Xie and Zhao 2004). In comparison with conventional soaking of the fruit, VI is much more effective in minimal processing of fruits or vegetables (Tamer and Çopur 2010) (Table 16.4).

Table 16.3 Application of vacuum impregnation in the food sector

Raw material	Solution used for vacuum impregnation	Effect	References
Whole potatoes	Zinc gluconate solution (9 g/100 g zinc)	VI potatoes (peeled or unpeeled), due to vacuum and restoration time application, had 69–70 times higher zinc content	Erihemu et al. (2015)
Whole potatoes	Ascorbic acid solution (10%)	VI potatoes had high ascorbic acid concentration (50 mg/100 g fr.wt.)	Hironaka et al. (2011)
Apple slices cv. Granny Smith	Isotonic aqueous solution containing sucrose and calcium lactate	From 0% to 40% increase in calcium of the recommended daily intake for an adult per 200 g of apples was noticed	Barrera et al. (2009)
Fresh cut apples cv. Fuji	20% diluted high-fructose corn syrup (HFCS) or 1% calcium caseinate aqueous solution with an addition of 0.4% α-tocopherol acetate, 7.5% Gluconal Calcium, and 0.04 zinc lactate	In 100 g fresh-cut apples, the vitamin E content increased more than 100 times, and calcium and zinc contents incremented about 20 times in comparison with unfortified samples	Park et al. (2005)
Iceberg lettuce leaves	Sucrose aqueous solution of the same water activity as lettuce leaves used for vacuum impregnation	Total content of 169 mg caper and 250 g of impregnated iceberg lettuce leaves	Gras et al. (2011)
Apple cylinders	Apple juice with an addition of microorganism *Saccharomyces cerevisiae,* milk with an addition of *Saccharomyces cerevisiae* and *Lactobacillus casei*	Over 10^6 CFU/g *Lactobacillus casei* in air-dried (40 °C) product	Derossi et al. (2010)
Pieces of guava and papaya	Papaya and guava juice with an infusion of *Lactobacillus casei* microorganism	After impregnation 10^8–10^9 CFU/g *Lactobacillus casei* was observed	Krasaekoopt and Suthanwong (2008)

16.8 Future Challenges

VI processing technique has been studied to alter product formulation, enhance product quality, and restore energy in some fruit and vegetable product. VI application can further be regulated and optimized by choosing appropriate process conditions. However, to take full advantage of its unique features and large-scale industrial operation applications, comprehensive studies are still required. Some of the technical challenges and future research needs are mentioned herewith.

From the perspective of development of food product, it is well established that the operation model not only affects final product quality but also the drying kinetics and power consumption. The improved food quality features have been associated with the modification in composition, color, flavor, texture, volume, size, and

Table 16.4 Application for VI

Raw material	Solution used for vacuum impregnation	Effect	References
Apples cv. Granny Smith	Rectified grape must and 3% high methoxyl pectin solution	Improvement of mechanical and structural properties of tissues, noticeable decrease in freezable water which in turn improves fruit resistance to freezing damage	Martínez-Monzó et al. (1998)
Strawberry (10 mm slices)	50% high-fructose corn syrup	Improvement in textural properties and decreased drip loss of frozen thawed strawberries	Xie and Zhao (2004)
Zucchini (slices 0.5 cm thick)	Maltodextrin solution and $CaCl_2$	Improvement of solute and water gain and restrained textural and microstructural changes	Occhino et al. (2011)
Pineapple	Chitosan film forming emulsion	Extension of shelf life for caseinate-based coating pineapple-cereal system	Talens et al. (2012)
Truffles	Antifreezing solution	Because of low ice crystal formation, improved texture for truffles was observed	Derossi et al. (2015)
Wheat grain	Various gluten concentrations	Meaningful difference in morphological structure was observed which in turn leads to the acceleration of the long-term process of wheat preparation to many production processes (e.g., milling of flour, hulling, etc.)	Leszek and Dariusz (2008)
Peaches	Pectin methylesterase together with $CaCl_2$	Increase of firmness in canned peaches	Javeri et al. (1991)
Papayas (cut into 4 × 2.5 × 0.5 cm pieces), strawberry	55% and 65% (w/w) sucrose solution, 65% (w/w) sucrose solution	Decrease of water activity	Moreno et al. (2000, 2004)

shape in line with the dehydration-hydration processes. Due to its unique characteristics, VI has been reported to be the first food processing technique based on the exploitation of three-dimensional food microstructure. The extensive challenge involves the structural and functional complexity of cellular tissues and the least available knowledge of their role in the coupling of heat and mass transfer mechanisms with deformation-relaxation phenomena at microscopic (cellular) level. These microscopic coupled mechanisms, in sync with phase transition phenomena, will result in product shrinking or swelling at macroscopic level. But this relationship is yet not very well understood. As a matter of fact, it is well known that in fruit microstructure there are three different spatial scales (mesoscale, microscale, and mesoscopic) (Mebatson et al. 2008) as depicted in Fig. 16.1.

- Therefore, the precise characterization of the three-dimensional architecture of foods, its changes during food processing, and its relationship with safety and quality would be one of the important future challenges (Datta 2007a, b; Halder et al. 2007). In-depth study of above-described three-dimensional changes in fruit microstructure comes under the concept of food matrix engineering (FME). FME is a food engineering branch in which the knowledge about food matrix composition, structure, and properties is applied with the intention to promote and control adequate changes and hence improve some sensorial/functional properties in the food products as well as their stability.
- The lack of information for industries on the advantages of these techniques may be the reason for its reduced applicability at industrial level.
- Another analytical aspect that needs to be examined is the microbial safety of VI solutions and processed product as it can hinder the successful application of VI technique. Product contamination could commence from the farm. If raw materials are contaminated, consequently VI solutions may also get contaminated during VI processing. Further contamination would take place if contaminated solutions are to be reused. Very little study has been described about this aspect, thus requiring a substantial research effort.
- In the large-scale industrial application of VI and any other osmotic processing, management of the residual/leftover solution at the end of the process is one of the major issues. From the engineering standpoint, it is advantageous to reuse the solution at least 20 cycles of the same recycled solutions. In favor of the findings, discussed that water loss, solid gain, and color of dehydrated apple cubes obtained in osmotic dehydration process with reused osmotic solution remained the same with those obtained with fresh osmotic solution. Unfortunately, the recycle of osmotic solution is yet one of the main shortcomings and challenges. One of the possible causes is that due to simultaneous leaching of color, acids, and fragments from the product and the solutes in the solutions penetrating the product, some of the characteristics of the solutions become changed at the end of the process. Secondly, in the case of mixed solutes, the reuse becomes even more complicated since the proportion of each solute must be tested and adjusted. Therefore, techniques to treat the waste concentrated solutions, especially for the mixture solution, are very important and need further intensive study.
- Another important challenge is the complete immersion of the products under the solution, while maintaining good contact throughout the process is essential for the VI processing. Generally, products tend to float on the external solution (osmotic solution) because of the comparative lower density than that of solution. To overcome the problem, stirring or compressing is used for current industry operation, but it also adds more cost and may also damage the products. Therefore, other cost-effective approaches need to be investigated.
- Furthermore, in order to increase its application at industrial scale, information should be made available on the applications and advantages of these techniques.

16.9 Conclusion

VI, newest development in OD, seems to be the most feasible technology for exploitation of fruit and vegetable tissues as new matrices into which successful incorporation of functional ingredients can be achieved, without affecting organoleptic properties. It has a wide number of food processing industrial applications such as for dehydration, pretreatment methods, embittering processes, pH reduction in vegetables, causing antimicrobial effect, changing microstructure of the products, probiotic food production, food salting, etc. Nevertheless, the applications of VI at industrial scale are still poor because of various technical constraints such as controlled mass transfer rate, characterization of the three-dimensional architecture of foods, its changes during food processing and its relation with safety and quality, complete immersion of the products under the solution while maintaining good contact throughout the process, management of the remained solution at the end of the process, and microbial safety of VI solution and processed product. Further studies need to be done on FME and its exploration, preventing VI solution from contamination, effective management of residual solution, study of other cost-effective technique for complete immersion of the product under VI solution, and making the information more available on application of VI in order to minimize the technical issues in VI applicability.

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17

Effect of High-Pressure Processing on Starch Modification: A Review

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Abstract

High-pressure processing (HPP) is a nonthermal technology widely used to inactivate certain enzymes and microorganisms in foods to enhance food quality and safety. HPP at low, ambient and moderate temperatures leads to the destruction of spoilage and pathogenic microorganisms with few changes in colour, flavour and texture when compared to conventional technologies. Moreover, this technology constitutes the efficient tool to alter food biopolymers such as proteins and starches. There have been increasing interests in recent years among researchers on processing of starch using nonthermal technique to study its characteristics. As several native structure and properties of starch restricts their function in food industry, thereby requiring modification. This paper will aim to discuss about basic principles underlying high-pressure processing followed by its mechanism of gelatinization on starches. Also, the paper will focus on different high-pressure treatments and their effect on gelatinization, granule morphology and crystallinity on different starches. HPP also induces the resistant starch formation, thereby helpful for treatment of diabetes and some cancers.

Keywords

High-pressure processing · Starch gelatinization · Granule morphology · Crystallinity

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17.1 Introduction

The inactivation of enzymes and microorganisms in food enhances its shelf life, food safety and quality. High-pressure processing (HPP) is a nonthermal technique widely used for the purpose of extension of shelf life by inactivating enzymes and microbes (Porretta et al. 1995; Tangwongchai et al. 2000; Rodrigo et al. 2007). HPP leads to spoilage of pathogenic microorganisms with fewer changes in colour, flavour and texture when compared to other conventional technologies (Cheftel 1995). For years, this technique has been employed for production of composite materials, ceramics, carbon graphite and plastics. All these technological developments gradually penetrated the application of HPP in the food sector (Smelt 1998). The basic principles underlying the effects of high pressure include Le chatelier's principle and isostatic principle. Le Chatelier's principle states that any phenomenon like phase transition, change in molecular configuration and chemical reaction is followed by reduction in volume, increased by pressure. Isostatic principle states that the pressure is distributed throughout the sample in uniform and quasi-instantaneous manner. The competence of high pressures to dormant the microorganisms as well as to modify the food biopolymers was studied about a 100 years ago. Moreover, high-pressure technology constitutes the efficient tool to alter food biopolymers such as starches and proteins (Knorr et al. 2006). Starch is a biopolymer consisting of linear amylose and branched amylopectin. The native granule of starch is partially amorphous and partially crystalline, with these areas alternating. Starch is being widely used as colloids, stabilizer, thickener, bulking agent, gelling agent, etc. Unmodified native starches generally lack in stability under shear, temperature, pH and refrigeration conditions exhibiting very limited application in the food industry. High-pressure processing could induce certain modification which could alter their physical and chemical properties. The aim of this paper is to review the alterations in starch high-pressure processing.

17.2 Types of High-Pressure Treatment

High-pressure applications on starch could employ a wide range of pressure from 200 to 1000 MPa to achieve different objectives. The following are three objectives of HPP according to Liu and Zhou (2016):

1. High-pressure gelatinization—When a starch suspension with excess water of 30–99% is subjected to static pressure of 200–800 MPa, it would result in starch gelatinization similar to thermal gelatinization.
2. High-pressure homogenization—When a starch water suspension is subjected to dynamic pressure of 20–100 MPa, then pressure-induced phenomenon like cavitations, shearing, turbulence and temperature rise takes place simultaneously causing modification in starch.

3. High-pressure compression—When a low moisture starch/solid starch is subjected to static pressure of 200–1100 MPa, it could modify the physicochemical properties by modifying the external and internal structure of starch molecule.

17.3 Effect of High Pressure on Water Absorption

Water absorption of rice grains is essential to initiate starch gelatinization. It could be achieved either by soaking at ambient temperature or high temperature or high pressure. There are a number of hydrothermal soaking-related studies on rice, but there are only few studies on water uptake characteristics on rice under high pressure. Pressure treatment of Japonica rice at 500 MPa for 20 min has increased the moisture content around 50% whereas the moisture content was 35–40% in case of rice pre-soaked for 30 min (Huang et al. 2009). Hence, high-pressure treatment leads to rapid hydration of rice grain required for gelatinization. Rapid water absorption has taken place for the first 40 min of pressure treatment of Japonica rice followed by slower rate at later stages, and similar trend was observed in Thai glutinous rice (Ahromrit et al. 2006). This rapid water uptake at initial stages occurs even when the rice is soaked at ambient temperatures.

Water uptake characteristics of Thai glutinous rice under various high temperature and pressure conditions during soaking were studied (Ahromrit et al. 2006). They found that moisture content is not being influenced up to 300 MPa and increased at higher pressures because the hydrogen bonding between water and starch at high pressures increases, thereby promoting water uptake (Douzals et al. 1996). For HPP treatment at 600 MPa for 120 min, the maximum moisture contents attained at 20 °C, 50 °C, 60 °C and 70 °C were 1.7, 3.0, 3.2 and 3.3 g water per g dry solids.

17.4 Effect of High Pressure on Starch Gelatinization

Gelatinization is the disruption of molecular orders within the starch granule which in turn causes irreversible changes in starch properties like granular swelling, crystallite melting, viscosity development, starch solubilization and loss of birefringence (Bor and Robert 1991). Knorr et al. (2006) defined gelatinization as disruption of native crystalline structure, at characteristic temperature known as gelatinization temperature in the presence of excess water which is characterized by crystallinity loss and solubilization of amylose and irreversible swelling of granules. Gelatinization can be achieved either by thermal treatment or pressure treatment, but the degradation mechanism varies. In pressure gelatinization, different starches gelatinize at different gelatinization range of pressures, and degree of gelatinization can change depending upon treatment pressure, pressurization temperature and treatment duration (Bauer and Knorr 2005).

17.4.1 Mechanism of High Pressure-Induced Gelatinization

When the starch suspension was heated at pressure of 200 MPa, the gelatinization will occur at lower temperature than heating at an ambient pressure. So, if high pressure, it is possible to gelatinize starch at room temperature (Thevelein et al. 1981; Muhr and Blanshard 1982). In case of hydrothermal treatment, gelatinization was found to initiate at any point between 55 °C and 80 °C depending on the rice variety (Bhattacharya 1979).

The mechanism of starch gelatinization varies from thermal treatment and pressure treatment. In case of thermal gelatinization in the presence of excess water, amorphous growth rings get hydrated and melting of crystalline regions occurs; this melting structure is disintegrated by means of helix-helix dissociation and helix-coil transition, leading to re-association of solubilized amylose resulting in increased viscosity and gel formation (Stolt et al. 2000). Whereas in pressure gelatinization, starch granules remain intact or partially disintegrated so solubilization of amylose is poor, leading to stabilizing of amylopectin which prevents the melting of crystalline regions too. This incomplete disintegration is due to pressure stabilization of Van der waals and hydrogen bonds that favour helix conformation which seems to be the reason behind the conversion of pressure gelatinized starch from A-type to B-type crystallinity (Knorr et al. 2006).

17.4.2 Gelatinization of Pressure-Treated Whole Grains

Kinetics of starch gelatinization in Thai glutinous rice under combined effect of high pressure (100–600 MPa) and temperature (20–70 °C) was studied (Ahromrit et al. 2007). They investigated the effect of pressure on gelatinization and found that no gelatinization was seen when pressurized below 300 MPa at 20 °C and 50 °C after soaking for 20 min and degree of gelatinization increased with pressure, whereas rate of gelatinization increased with temperature. Table 17.1 signifies the effect of pressure on gelatinization of different starches. Preparation of quick cooking rice (QCR) by high-pressure treatment of Jasmine rice was investigated by Boluda-Aguilar and Taboada-Rodríguez (2013). They studied the effect of pre-soaking and HPP on degree of gelatinization (DG), and the results indicated that pre-soaked rice treated at 300 and 400 MPa reached 14 and 27% DG, and double HPP (400 MPa/4 min and 570 MPa/20 min) treatment showed little higher DG around 30%. Whereas in Japonica rice no gelatinization occurred up to 300 MPa, and higher DG was 73% when treated at 500 MPa at 50 °C for 120 min (Huang et al. 2009).

Table 17.1 Studies on the effect of High pressure on gelatinization of various starches

Materials	Treatment pressure range (MPa)	Temperature (°C)	Time (min)	Gelatinization (%)	References
Raw rice (Jasmine)	300 400 400 and 570	25 25 25	4 4 4 and 20	14 27 30	Boluda-Aguilar and Taboada-Rodríguez (2013)
Thai glutinous rice	500 600	20 20	45 45	15 17	Ahromrit et al. (2007)
Japonica rice	500	50	120	73	Huang et al. (2009)
Japonica rice starch	200–300 400–600 300–600	20 and 40 20 and 40 50	15 15	Gelatinization Initiates 33–100 47–100	Tan et al. (2009)
Basmati rice flour slurry	350	22–25	15	47.8	Ahmed et al. (2007)
Basmati isolated pure starch	550	22–25	15	100	
	650	22–25	15	100	
Waxy rice starch, waxy corn starch, tapioca starch,	600	20	30	100	Oh et al. (2008a, b)
normal rice and normal corn starch,	600	20	30	Partial Gelatinization	
potato starch	600	20	30	No gelatinization	
Waxy rice starch	500	10–60	30	100	Oh et al. (2008a, b)
Native barley starch	550	30	0	100	Stolt et al. (2000)
Potato starch	1000	40	66 h	100	Kawai et al. (2007)
Sorghum starch	600	20	15	100	Vallons and Arendt (2009)
Maize starch	100 140	12 17	0	12.9 26.8	Wang et al. (2008)
Normal and waxy rice starch	600	30	30	100	Hu et al. (2011)
Wheat, tapioca and potato	400 550 700	29 29 29	15 15 15	100 75 60	Bauer and Knorr (2005)

17.4.3 Gelatinization of Pressure-Treated Isolated Starches

Isolated pure starches which are devoid of proteins and lipids show higher DG than native starches, and this was observed in Basmati rice flour slurry when treated at 650 MPa which showed complete gelatinization, whereas isolated starch attained complete gelatinization at 550 MPa (Ahmed et al. 2007). Similarly, the Japonica rice starch showed complete gelatinization at 600 MPa for 20 °C, 40 °C and 50 °C (Tan et al. 2009). The effect of high pressure on various normal and waxy starches was examined by Oh et al. (2008a, b); they have divided the starch suspensions into three types based on their pressure gelatinization behaviour:

1. Waxy starches (e.g. waxy rice, waxy corn)—completely gelatinize at high pressure (>400 MPa).
2. Normal starches (e.g. normal rice, normal corn)—partially gelatinize under high pressure (600 MPa).
3. Pressure-resistant starches (e.g. potato)—not affected by high pressure (600 MPa).

17.5 Effect of High Pressure on Crystallinity of Starches

Based on characteristic x-ray diffraction pattern, starches can be categorized as A-type, B-type and C-type starch. Examples of A-type starches include starches of normal rice, waxy rice, normal corn and waxy corn. Potato and tapioca come in the category of B- and C-type starches. The diffraction pattern for pressurized starches reveals that there is conversion of A-type into B-type pattern, whereas B-type keeps their original pattern without any change indicating to be pressure resistant (Stute et al. 1996; Rubens et al. 1999; Katopo et al. 2002). A-type crystalline structure has more compressibility than B-type crystallites, therefore staying to be pressure resistant (Yoshiko et al. 1993). High-pressure-treated normal corn, wheat, waxy corn, tapioca and potato native starches did not show any alteration in x-ray diffraction pattern indicating that crystalline pattern is not altered (Liu et al. 2008), but pressure-treated starch in water suspension showed alterations in their crystal structure. Slow digestible properties of HPP-treated (600 MPa/30 °C/30 min) gelatinized waxy and non-waxy rice starches during retrogradation and its mechanism were examined by Tian et al. (2014); they found that B-type crystallites are formed in the course of retrogradation (Hibi et al. 1990), and treatment decreased the perfect crystallites and increased imperfect crystallites of slow digestible starches. No change in crystaline pattern was observed in high pressure-homogenized cassava starch, and it indicates that crystalline struture is highly resistant to highpressure homogenization (Che et al. 2007).

The effect of ultrahigh pressure treatment (690 MPa/5 min and 1 h) on crystalline structure conversion and physical properties of starch (normal maize, tapioca, high amylose maize, rice and potato starch) was studied by Katopo et al. (2002). They found that starches in ethanol suspension are most stable to pressure treatment and help in preserving the crystallinity of starch. In case of high-pressure treatment of normal maize and rice starch, transformation to weak B-pattern and V-pattern was seen, but high amylose maize kept their original pattern without change.

Changes in crystalline structure of starch granules due to pressure treatment were investigated by Kawai et al. (2012). They found that x-ray peaks of normal corn starch were dull indicating that crystalline structure was destroyed by pressure but the peak was sharp for potato indicating no damage. Moreover, crystalline pattern of normal, defatted, waxy corn and rice starch showed only few changes when subjected to 200 MPa for 20 min, but after subjecting to 500 MPa for 20 or 60 min, A-type crystalline structure gets damages and tends to shift into faint B-type pattern. But crystalline structure of potato starch was not affected at any stage of pressure treatment since they are B-type. In order to study the role of water in change of crystalline structure of starches, hexane was used, and the results showed that even after treatment of 500 MPa for 60 min, there were no changes in A- and B-type patterns of untreated samples. This proves that crystalline structure of starches could not be changed without water under high pressure. Similar kind of crystalline transformations was seen in case of wheat starch (Douzals and Perrier cornet 1998).

17.6 Effect of High Pressure on Birefringence

When viewed under polarized light, the crystallites get radically oriented and native starch granules show “Maltese cross”. This is referred to as birefringence. High-pressure-treated starches might have alterations in their crystalline structure due to compression, so it can cause changes in birefringence. Loss of birefringence is the indication of gelatinization of starch (Thomas and Atwell 1999; Oh et al. 2008a, b). After pressure treatment at 600 MPa, the birefringence of normal rice, waxy rice, normal corn, waxy corn and tapioca starches was lost, but birefringence is still observed in potato starch granules (Oh et al. 2008a, b); this is in agreement with Stute et al. (1996) and Knorr et al. (2006), whereas contradictory results were observed by Kudta and Omasik (1992). A critical pressure level of 450 MPa for waxy corn starch and 600 MPa for tapioca starch leads to loss of birefringence (Pei-Ling et al. 2012). The number of Maltese cross reduced higher increasing pressure and temperature in case of sorghum starch when treated above 300 MPa and 60 °C. At 600 MPa or 75 °C, Maltese cross is completely lost indicating complete gelatinization (Vallons and Arendt 2009). When compared to other starches, rice starch shows loss of birefringence when treated at 500 MPa (Oh et al. 2008a, b).

17.7 Effect of High Pressure on Starch Granule Morphology

Granular integrity of starches was determined using scanning electron microscope. When pressurized the 1:1 (v/w) water/starch suspension of waxy maize at 690 MPa for 5 min, the starch granules have partially lost its granular integrity. However, at same conditions, the normal maize starch retained its granular integrity (Katopo et al. 2002). Starches suspended in pH 7 buffer with two different ionic forces were examined during HP treatment at 500 MPa, and both the waxy rice and corn starch showed no swelling, but the granules lost their structure to form a gel during the treatment and some form granule ghosts (Atkin et al. 1998). Similarly barley starch has maintained its granular structure even at HP treatment of 600 MPa (Stolt et al. 2000). When compared to waxy rice, waxy corn starch granules maintained their original shape, whereas others swell and form ghosts (Simonin et al. 2011). Moreover, normal rice starch treated by high pressure maintained its integrity, but waxy rice starch lost its integrity (Hu et al. 2011).

The effect of high pressure on modified noncrystalline granular starch of waxy corn and tapioca starch was studied by Pei-Ling et al. (2012). They found that both starches have maintained their granular shapes even after complete loss of birefringence, but the original smoothness of granules became rough with small cracks particularly in case of tapioca starch. Changes in structure of high-pressure-treated potato starch were studied by Błaszczak et al. (2005), and even though potato is a pressure-resistant type of starch, they found that prolonged treatment at 600 MPa leads to greater destruction of granular integrity. Vallons and Arendt (2009) studied the structural changes of sorghum starches. Their SEM images revealed that native sorghum starch occurs as water-insoluble granules ranging from 2 to 30 μm. During thermal gelatinization, their granule structure gets altered. But in case of pressure treatment, even after subjecting the sorghum starch to 600 MPa (100% degree of gelatinization) their granular integrity was retained. Several recent studies in high-pressure treatment of starches and its major findings are discussed in Table 17.2.

17.8 Conclusion

HPP is effective in altering the physicochemical properties of starch biopolymers. It restricts the swelling power of the granules, so its viscosity is lower when compared to granules treated with temperature. It can produce starch gelatinization at room temperature or even low. HPP treatment produces resistant starches, which have a similar role as soluble fibres and are beneficial to human health.

Table 17.2 Recent studies on high-pressure treatment of starches

Researcher	Starch	Treatment conditions	Responses studied	Major findings
Katopo et al. (2002)	Normal maize, waxy maize, high amylose maize, tapioca, potato and rice starches	600 MPa/5 min and 1 h	Changes in morphology, crystallinity, gelatinization and pasting properties	– Same results are seen for starches treated at 690 MPa/1 h and 5 min – Starch suspension turned to cake or gel form – HP treatment of waxy maize changed them to C-type pattern, tapioca to B-type pattern, normal maize and rice starch to B-pattern and V-pattern – B-type starches are pressure-resistant type – Starches treated in 2:1 (v/w) water starch suspension have higher DG than 1:1(v/w) suspension – No change in molecular weight distributions after UHP treatment
Hu et al. (2011)	Normal rice, waxy rice	600 MPa/30 °C 30 min	Gelatinization behaviour, retrogradation behaviour, morphology and amylose leaching	– Complete gelatinization at 600 MPa – After treatment for normal rice, the degree of retrogradation was lower and granule structure was not affected – For waxy rice degree of retrogradation is not affected and there is loss of granular integrity – Amylose leaching was less in normal rice and unaffected in waxy rice
Bauer and Knorr (2005)	Wheat, potato, tapioca	100–700 MPa/ 10–70 °C/15 min	Degree of gelatinization and loss of birefringence	– At constant temperature, gelatinization increased with increasing pressure and vice versa – Wheat and tapioca starch show sigmoidal gelatinization curve – Potato starch showing rudimentary curve (i.e. resistant to pressure) – Increase in gelatinization was high at first hour of treatment

(continued)

Table 17.2 (continued)

Researcher	Starch	Treatment conditions	Responses studied	Major findings
Oh et al. (2008a, b)	Normal rice, waxy rice	100–700 MPa/ 10–60 °C/0–30 min	Pasting behaviour, initial apparent viscosity, degree of swelling, loss of birefringence and leaching of starch and amylose	– Waxy rice starch showed noticeable changes in initial viscosity than normal rice – Increase in initial viscosity was correlated with degree of swelling and degree of gelatinization – Normal rice showed 50% swelling whereas waxy rice had 100% – Relation between initial viscosity and pressure follows sigmoidal curve – Complete loss of birefringence was at 500 MPa – Amylose leaching was increasing with pressure treatment
Ahmed et al. (2007)	Basmati rice flour and its isolated pure starch	350, 450, 550, 650 MPa/7.5 and 15 min	Effect of pressure on mechanical strength, effect of holding time on viscosity, effect of concentration, degree of gelatinization	– As pressure increased, the degree of gelatinization increased, and enthalpy decreased – Complete gelatinization of isolated starch was at 550 MPa – Complete gelatinization of rice flour slurry is at 650 MPa, and this slower gelatinization is due to presence of proteins in it – Pressure treatment increased mechanical strength – Increase in elasticity of rice gel with holding time – Slurry less than 1:3 (flour to water ratio) resulted in incomplete gelatinization due to insufficient water – Isothermally heated gel has higher mechanical strength than pressure-treated gel

Liu et al. (2008)	Normal corn, waxy corn, wheat, potato	HPT1-740 to 880 MPa/5 min–2 h, HPT2-960-1100 MPa/24 h, HPT3-1500 MPa/24 h	Starch gelatinization, structural changes	– Gelatinization onset temperature and enthalpies are lowered after HP treatment – There was significant difference between HPT1-treated and HPT3-treated starches and also influence on gelatinization – High-pressure treatment caused no changes in internal structure and x-ray diffraction pattern – Starch granules have changed their shape from smooth to rough surface
Oh et al. (2008a, b)	Normal rice, waxy rice, normal corn, waxy corn, tapioca, potato	400 and 600 MPa/20 °C/30 min	Degree of swelling, pasting curve, birefringence	– Complete gelatinization and 100% swelling occurred in waxy rice, waxy corn and tapioca – Partial gelatinization and 50% swelling seen in normal rice and normal corn – No gelatinization and 20% swelling seen in potato starch – Loss of birefringence was seen when normal rice and waxy rice were treated at 400 MPa – Other starches except potato lost their birefringence at 600 MPa

(continued)

Table 17.2 (continued)

Researcher	Starch	Treatment conditions	Responses studied	Major findings
Tan et al. (2009)	Japonica rice	HP treatment: 100–600 MPa, 20–50 °C/15 min Heat treatment for 20–85 °C	Swelling index, degree of gelatinization, rheology	– When compared to heat gelatinization, complete gelatinization occurs under pressure along with less hydration – Maximum swelling index was 12 g at 85 °C and 600 MPa resulted in 7 g of swelling index – Subjecting to pressure range of 300–600 MPa induced higher starch gelatinization – Pressure treatments of 400–600 MPa increased the DG to 33–100% and 300–600 MPa at 50 °C caused 47–100% of gelatinization – Complete gelatinization occurred at 600 MPa for 20 °C, 40 °C or 50 °C – Pasting properties of pressure-treated samples significantly differ from heat-treated samples with high G' values – Viscosity increases with increase in swelling index and DG
Tian et al. (2014)	Waxy rice and non-waxy rice	600 MPa/30 °C/30 min	In vitro digestibility and crystalline of SDS products, thermal properties of retrograded starch gels, freezable water analysis	– SDS percentage of pressure gelatinized rice was higher than heat gelatinized one – HPP inhibited retrogradation of both the rice starch and does not associate with percentage of SDS – During retrogradation, ice melting enthalpy change was higher for starch gel indicating presence of less quantity of unfreezable water in it – Complete gelatinization was observed – HP treatment decreased the perfect crystallites and increased imperfect crystallites

Simonin et al. (2011)	Waxy rice and waxy corn	Solutions with pH ranging from 5.0 to 9.0 (5.0, 5.6, 7.0, 8.4, 9.0) and with different salt osmolarities between 69 and 333 mosmol 500 MPa for 30 min	Degree of gelatinization, gel swelling power, rheology	– The higher gel swelling capacity was observed in waxy rice than waxy corn starch, but pH has no influence on gel swelling power – Negative effect of osmolarity was seen for both the starch – Irrespective of ionic force and pH, rice starch gelatinizes quicker than corn starch – At acidic conditions (pH 5), starch gelatinization was found to be enhanced – Gelatinization was found to occur during first 15 min of HP treatment – As osmolarity increases, the rate of gelatinization and maximal level of gelatinized starch were found to decrease – Increasing concentration of salts reduced the gelatinization speed – Rheological properties and gel strength of both starches were not influenced
Yoshiko et al. (1993)	Potato, normal corn, waxy corn, normal rice, waxy rice	50–500 MPa 17–23 °C for 20–60 min	Birefringence, crystalline structures, acid hydrolysis, specific gravity, moisture content	– Except potato starch, birefringence was lost in all other starches and crystal structure was damaged after treatment – HP treatment at 500 MPa for 20 or 60 min transformed A-type crystallites to B-type pattern for normal and waxy rice and corn starches – The higher the crysta and moisture content of starches, the smaller the specific gravity – Destroying the crystalline structure of starch granule increases its density

(continued)

Table 17.2 (continued)

Researcher	Starch	Treatment conditions	Responses studied	Major findings
Stolt et al. (2000)	Barley	400–550 MPa for 30 °C	Rheology, microstructure, loss of birefringence, melting of amylopectin crystals	– Viscosity increases with pressure and holding time – When the applied pressure levels are less, then structural changes are minimum – A smooth thick paste was formed during pressurization when starch concentration is raised from 10% to 25% – 10% starch suspension when exposed to 450 MPa for 30 min and 600 MPa for 0 min has lost its birefringence completely – Subjecting 25% suspension to pressure level of 550 MPa, loss of birefringence occurs – Heat treatment of 25% starch suspension shows higher degree of swelling – There was no leaching of amylose after high-pressure treatment
Błaszczak et al. (2005)	Potato	600 MPa for 2 and 3 min at 20 °C	Degree of gelatinization and microstructure	– High pressure at 600 MPa causes decrease in gelatinization temperature, increase in amorphic conformations and alteration of granule structure – Gelatinization enthalpy also decreased with time – Majority of starch granules retained their granular shape – The abundance of amorphous and crystalline part is affected due to high pressure in potato starch structure – Inner parts of starch are more susceptible to pressure than its surface

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18

Determining the Change in Fatty Acid Profile of Saturated Cooking Oils After Repeated Heating

Neha Rawat and Jyoti Chaudhary

Abstract

In the present study, an approach is made to determine the change in fatty acid profile of selected saturated cooking oils after repeated heating. A total number of six samples were taken for the study, including coconut oil, vanaspati, and desi ghee. Out of these, three different samples were heated for one time, and the remaining three of the same type were heated for five times each. The prepared samples were tested by spectrophotometry method. Further the comparison was made to note the difference between the fatty acid profile of one-time heated and five-times heated edible saturated oils. The results revealed that among all the oils tested, coconut oil when heated five times showed decrease in total fat, saturated fat, PUFA, and MUFA by 3.6 g, 6 g, 0.72 g, and 1.2 g, respectively, as compared to the one-time heated coconut oil. Nil amount of trans fat and cholesterol was found in coconut oil. Similarly, every cooking oil showed variation in fatty acid profile after reheating.

Keywords

Edible oils · Saturated fat · Fatty acid profile · Heating the edible oils

18.1 Introduction

Cooking oils contribute as an important component of food in Indian households. It is plant, animal, or synthetic fat used in frying, baking, and other types of cooking and preparation. Oils are majorly composed of fatty acids, triglycerides, and cholesterol, in addition with some other nutrients. The type of fatty acid present in oil determines its various physical and other chemical properties. Fatty acids are of two

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Table 18.1 Changes in fat composition of saturated cooking oils ($n = 6$)

S. no.	Parameters	Coconut oil		Ghee		Vanaspati	
		Amount (one time heated)	Amount (five times heated)	Amount (one time heated)	Amount (five times heated)	Amount (one time heated)	Amount (five times heated)
1.	Total fat	98.89 g	95.29 g	99.30 g	94.30 g	99.33 g	97.31 g
2.	Saturated fat	85.35 g	79.35 g	60.35 g	58.39 g	56.29 g	52.29 g
3.	Trans fat	0.0 g	0.0 g	1.5 g	1.0 g	2.30 g	2.19 g
4.	PUFA	1.5 g	0.78 g	37.80 g	31.21 g	13.78 g	12.75 g
5.	MUFA	5.30 g	4.10 g	27.47 g	23.65 g	24.66 g	25.62 g
6.	Cholesterol	0.0 mg	0.0 mg	240 mg	180 mg	290 mg	280 mg

types, namely, saturated and unsaturated. Unsaturated fatty acids have one or more double bonds between carbon atoms, while saturated fatty acids have no double bonds. When oils are heated to their smoke point, their chemical composition begins to change as the oils break down. Thus, it is important to choose them wisely according to their properties.

18.2 Methodology

Laboratory testing of the edible oil samples was done to compare the changes in the fatty acid profile of oils after heating. Acid value and free fatty acid were determined by using the reagents ethyl alcohol and indicator solution.

18.3 Results and Discussion

Table 18.1 reveals the fatty acid profile of saturated cooking oils which are heated one time and five times. When compared, it was found that there is notable variation in the amount of total fat, saturated fat, trans fat, PUFA, MUFA, and cholesterol in five-times heated saturated oils and one-time heated saturated oils (Figs. 18.1, 18.2, and 18.3).

18.4 Conclusion

From the above findings, it can be said that there is always a notable change in the fatty acid composition of the cooking oils after repeated heating exposure. This alters the overall composition of the oil, and thus it is avoidable to reheat the oils for several times. It is important to develop healthy habits in reference to cooking oils as they form a major component of the diet. Majority of the recipes are prepared with a little or more quantity of oil. Thus, it is important to choose the right oil for maintaining a good health status and also using it in a right manner.

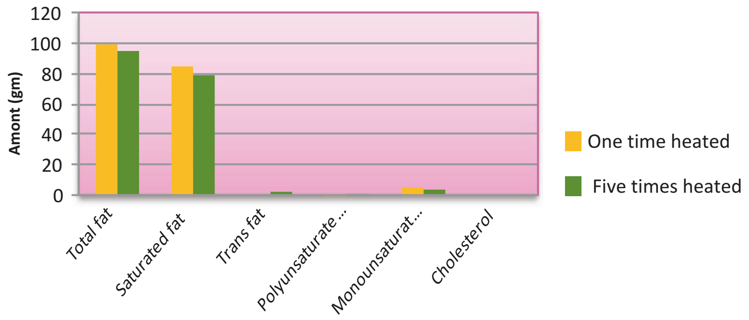

Fig. 18.1 Fatty acid profile of coconut oil

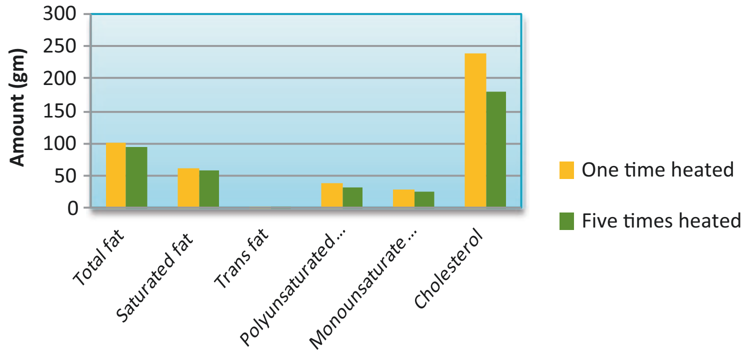

Fig. 18.2 Fatty acid profile of ghee

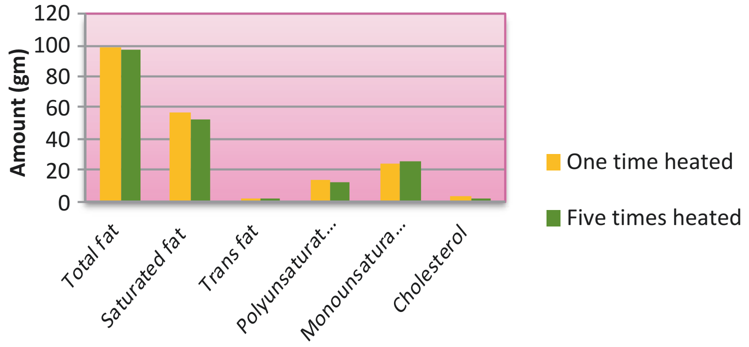

Fig. 18.3 Fatty acid profile of vanaspati

19 Effect on Broiling on Phytochemicals and Nutritional Values in Sweet Corns

Divya Verma and Navita Pareek

Abstract

Sweet corn is one of the staple foods in many nations across the world. It has high-quality phyto-nutrition profile comprising of dietary fiber, vitamins, and antioxidants in addition to minerals in moderate proportions. The aim of this study is to investigate the effect of broiling on the proximate composition, antioxidant activity, and phytochemical content in sweet corn. Broiling and drying were done for the preparation of dry powder and aqueous extract of sweet corn. Proximate composition, phytochemical content, and antioxidant activity of the sample were determined through standard procedures. The results indicated that moisture, protein, carbohydrate, fat, iron, calcium, and vitamin C content decreases and fiber and ash content increases after broiling of sweet corn. There were no qualitative changes that have been seen in phytochemical and antioxidant content (tannin, phytic acid, flavonoids, and phenols) after broiling of sweet corn.

Keywords

Sweet corn · Broiling · Proximate composition · Antioxidants · Phytochemicals

19.1 Introduction

Sweet corn is one of the staple foods in many nations across the world. There are many varieties of corn which are used for human's food and are processed to make food ingredients, like corn syrup, corn starch, etc. (Temple 2000). Sweet corn is a gluten-free cereal and may be used safely in celiac disease. It contains healthy amounts of some important minerals like zinc, magnesium, copper, iron, and manganese (Bernhardt and Schlich 2006). Cooking methods affect both physical and chemical changes resulting in an increase or decrease in proximate composition and

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phytochemical contents, particularly antioxidants present in sweet corn. Fresh sweet corn has been consumed broadly by broiling since past times (Rhoads 2008). Cereals when subjected to heat result in many changes as there is some destruction of protein, lipid, and vitamin which is detrimental to the nutritional value of cereals. Many studies have shown that diet rich in cereals is protective against diseases and populations that consume such diets have the higher plasma antioxidant status and exhibit a lower risk of cancer and cardiovascular diseases. Grilling brings about many changes in sweet corn (Sood et al. 2002). Therefore the main objective of the present study was to determine the effects of broiling on the proximate composition, phytochemical content, and antioxidant activity of sweet corn, with the hope that the findings would guide future practice of suitable cooking methods in order to minimize the degradation of nutrients in sweet corns.

19.2 Materials and Methods

1. **Collection and preparation of sample:** Sweet corn was collected from the Department of Agriculture in Banasthali Vidyapith (Rajasthan). It was broiled at 64 °C and then powdered it after sun drying. Aqueous extract was also prepared for phytochemical testing.
2. **Proximate and mineral composition of raw and broiled sweet corn:** Raw and broiled sweet corn powders were subjected to the determination of the moisture, ash, crude fiber, protein, CHO, fat, and minerals like calcium and iron through standard technique.

   Moisture content in the sweet corn samples was estimated according to the method described in AOAC (2000). Drying, cooling, and weighing were done until the weight of the sample becomes constant. Mineral ash content was estimated according to the method described in Raghuramulu et al. (2003), and it was basically done for the estimation of minerals like calcium and iron. Crude fiber content in the sweet corn samples was estimated by the method described in the AOAC (2000). Hydrogen chloride and sodium hydroxide were used as a reagent for the estimation of crude fiber. Fat content was estimated in a dry sample following the removal of moisture, and petroleum ether was use as a reagent for its estimation. It is estimated by the method given in the Sharma (2007). Protein content of the sweet corn samples was estimated by Kjeldahl method given in AOAC (2000), and in this method, digestion, distillation, and titration were done on the sample for the protein estimation. Carbohydrate content is calculated by the sum of moisture, protein, ash, fat, and crude fiber and was subtracted from 100 to get the carbohydrate content of the sample. The calcium content in sweet corn was determined using titrimetric method given in Raghuramulu et al. (2003). The iron content was estimated following the Wong's method described in Raghuramulu et al. (2003).
3. **Estimation of antioxidants and phytochemical content:** Ascorbic acid content in sweet corn was estimated by the method given in AOAC (2000). For the estimation of vitamin "C," the sample was titrated against 2,6-dichlorophenol indo-

Table 19.1 Proximate analysis of raw and broiled sweet corn on dry weight basis

Constituents	R\Raw sweet corn	BB Broiled sweet corn
Moisture (g/100 g)	75.1 ± 0.17	62.1 ± 0.34*
Ash (g/100 g)	8.96 ± 0.5	10.16 ± 0.11*
Crude fat (g/100 g)	10.3 ± 0.17	9.9 ± 0.17*
Crude fiber (g/100 g)	1.43 ± 0.23	1.96 ± 0.11^NS
Protein (g/100 g)	0.13 ± 0.020	0.07 ± 0.005^NS
Carbohydrate (g/100 g)	12.99 ± 0.15	12.03 ± 0.15*
Iron (mg/100 g)	3.80 ± 0.01	3.72 ± 0.03^NS
Calcium (mg/100 g)	10.01 ± 0.01	9.01 ± 0.01^NS

Values are means of three replicates ± SD and expressed on g/100 g sample. (∗) indicates significant difference at $P > 0.05$ levels, *NS* non-significant

phenol solution. Phytochemical content in raw and broiled sweet corn was determined by the qualitative method. Total flavonoids were estimated by the method of Luximon-Ramma et al. (2002). The total polyphenol contents were determined according to the method of Folin and Denis (1915). The method of Schanderl (1970) was employed for determination of tannins in the sample of sweet corn. And phytic acid content was estimated by the method of Wheeler and Ferrel (1970).

Statistical Analysis
Descriptive statistics was used to analyze the data. The Student's *t*-test was applied to evaluate the effect of cooking treatments (broiling) on the studied parameters of sweet corn. The values of the cooked samples were compared with the fresh sweet corn sample.

19.3 Observation and Discussion

Proximate nutrients in raw and broiled sweet corn have been shown in Table 19.1. It indicates the percentage loss and percentage gain in proximate composition in the sample during broiling.

19.3.1 Proximate and Mineral Composition

Proximate compositions of raw and broiled sweet corn are presented in Table 19.1. Ash and crude fiber contents were increased, whereas moisture, crude fat, protein, and calcium were decreased after broiling. There was no significant ($P > 0.05$) difference in crude fiber and protein contents of raw and broiled sweet corn. The same value of crude fiber and protein was reported in the other studies (Norwood 2001;

Table 19.2 Qualitative assessment of antioxidants and phytochemical constituents in sweet corn

Antioxidants/phytochemicals	Raw sweet corn	Broiled sweet corn
Vitamin C (mg/100 g)	5.67 ± 0.06	4.26 ± 0.05^{NS}
Polyphenols (mg GAE/100 g)	Positive	Positive
Flavonoids (mg QU/100 g)	Positive	Positive
Tannins (mg/100 g)	Positive	Positive
Phytic acid (mg/100 g)	Positive	Positive

Rehman et al. 2001). Broiling significantly ($P < 0.05$) decreases the moisture, fat, and carbohydrate contents. The same value was found in the other studies (Walker et al. 2013; Norwood 2001; Rehman et al. 2001). Ash content was significantly ($P < 0.05$) increased by broiling, and the same value was found in the other study (Walker et al. 2013). There was no significantly ($P < 0.05$) reduction in the iron and calcium content of sweet corn after broiling. And the same value for iron and calcium was found in the other study (Rehman et al. 2001).

19.4 Antioxidants and Phytochemicals

Vitamin "C" content in the sweet corn was nonsignificantly ($P < 0.05$) reduced after the broiling of sweet corn, and it is presented in Table 19.1. Similar result was found in the other study (Sood et al. 2002). Antioxidant and phytochemical contents in raw and broiled sweet corn have been shown in Table 19.2, and they were assessed by the qualitative method. Results indicate that the antioxidants (polyphenols and flavonoids) were present in both raw and broiled sweet corn, and phytochemicals (tannins and phytic acid) were also present in both raw and broiled sweet corn.

19.5 Conclusion

Being healthy requires physical and mental fitness and therefore to be healthy one needs to be optimally nourished, but as the population increases day by day, their nutritional requirements are not met with the recommended allowances due to excess or imbalance of nutrients. Moisture, fat, and carbohydrate were significantly decreased, and protein, iron, calcium, and vitamin C contents were nonsignificantly decreased after the broiling of sweet corn. Ash content was significantly increased, and crude fiber content was nonsignificantly increased after the broiling of sweet corn. Among the phytochemical contents, phytic acid and tannins and in antioxidant factors phenols and flavonoids were presented qualitatively in raw as well as broiled sweet corn. Thus it is important to choose the right method of cooking for maintaining a good health status and also using it in a right manner.

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Effect of Garden Cress (*Lepidium sativum* L.) Seeds Supplementation on the Sensory and Nutritive Quality of *Laddu*

20

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Abstract

Laddu is one of the traditional sweet snacks which is not only popular among children but also liked by every age group and every section of population. It can be supplemented with garden cress seeds (*Lepidium sativum* L.) to make it nutritious. Therefore, a trial has been conducted to develop and evaluate nutritious garden cress *laddu*. Garden cress seeds were supplemented in *laddu* at different levels (5%, 10% and 15%) and tested on nine-point hedonic scale by trained and untrained panellists to observe acceptability. The most acceptable trial (10%) was analysed for nutritive value against control. Mean scores were found highest (7.6) for overall acceptability at 10% garden cress seed supplementation after control. The acceptable supplemented *laddu* contained higher percentage of protein (6.52%), fat (27.47%), ash (1%), fibre (1.17%) and energy (528.67 kcal/100 g). Significant ($p \geq 0.01$) improvement was also observed in the case of calcium (44.51 mg/100 g), iron (3.53 mg/100 g) and zinc (1.82 mg/100 g) content of *laddu*. Lysine (4.31 g/100 g protein) and tryptophan (0.93 g/100 g protein) were also increased with supplementation. Significant ($p \geq 0.01$) increase in MUFA and PUFA content was also observed with supplementation. Roasted garden cress-supplemented *laddu* was found to be rich in macro- and micronutrients as compared to control *laddu*. It has potential to be a part of diet of poor and malnourished children through various supplementary feeding programmes.

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Keywords
Laddu · *Lepidium sativum* · Malnourishment · Feeding programmes

20.1 Introduction

Laddu is one of the traditional sweet snacks which is not only popular among children but also liked by every age group and every section of population. It can be supplemented with garden cress seeds (*Lepidium sativum* Linn.) to make it nutritious. Garden cress seeds are rich in macro- as well as micronutrients. Garden cress is an important medicinal and nutritional plant. Seeds, leaves, roots and the whole plant are used for medicinal purpose (Jain and Grover 2016). The garden cress seeds constitute a good amount of protein (25.3 g/100 g), iron (100 mg/100 g) and other micronutrients like thiamine (0.59 mg/100 g), riboflavin (0.61 mg/100 g) and niacin (14.3 mg/100 g) (Gopalan et al. 2011). These nutrients can reduce malnutrition with other micronutrient deficiencies like anaemia (Jain et al. 2017). It provides 454 kcal/100 g calories and 24.5% fat. It contains good amount of calcium (377 mg/100 g) and magnesium (430 mg/100 g). The seeds are packed with essential amino acid (lysine) and fatty acid (linolenic acid) (Jain et al. 2016). The common name of the plant is "Common cress", "Halim", "Aliv", "Chandrashoor", etc. (Gokavi et al. 2004). Due to its nutritional properties, it may become a part of daily food. Since it is cost-effective, it may be a part of government supplementary programmes and feeding scheme. So, a trial has been conducted to develop and evaluate nutrient dense garden cress *laddu*.

20.2 Material and Methods

20.2.1 Procurement of Raw Material

Raw materials like whole wheat flour, Bengal gram flour, powdered sugar and *desi ghee* and garden cress seeds were bought from local market. Seeds were roasted in an iron vessel at 150 °C until a pleasant flavour of garden cress seeds comes. The seeds were stored at ambient conditions (20 °C, 60% RH) in the airtight plastic container after cooling.

20.2.2 Preparation of *Laddu*

Laddu was prepared in the Department of Food and Nutrition, College of Home Science, PAU, Ludhiana. Whole wheat flour (75 g), Bengal gram flour (25 g), powdered sugar (100 g) and *desi* ghee (60 g) were used for the preparation of control *laddu*. Whole wheat flour and Bengal gram flour were roasted separately with ghee till the flour became light golden brown in colour. It was then cooled and mixed together with sugar. The mixture was further divided into equal portions by weight, and small balls were prepared (Pant 2011). In garden cress *laddu,* garden cress seeds were supplemented at 5%, 10% and 15%.

20.2.3 Sensory Evaluation

The sensory characteristics of biscuits were assessed by using a panel of ten untrained and semi-trained judges. The panellists evaluated the products for different attributes, viz. appearance, colour, texture, flavour and overall acceptability. Guidelines were followed for presentation of samples. They were presented in identical containers, coded with different numbers and served simultaneously. A nine-point hedonic scale (Watts et al. 1989) was used for rating. The test was performed in the Department of Food and Nutrition, College of Home Science, Punjab Agricultural University, Ludhiana, Punjab.

20.2.4 Nutritional Analysis

20.2.4.1 Proximate Principles

Proximate principles were analysed using methods of AOAC (2000).

20.2.4.2 Total Minerals

The samples were employed for wet digestion with nitric and per chloric acid mixture in 5:1 ratio (v/v) on hot plate. Digested samples were further analysed by atomic absorption spectrophotometry (Lindsey and Norwell 1969) for the determination of calcium, iron and zinc content.

20.2.5 In Vitro Digestibility of Starch and Protein

In vitro digestibility of starch was estimated by Bernfeld (1954) method. Sample starch was digested with pancreatic alpha-amylase and incubated at 37 °C for 2 h. Quantity of released maltose was depicted in percentage. For in vitro digestibility of protein, Akeson and Stahman (1964) method was employed. Pepsin and pancreatin solutions were used to digest the sample and incubated at 37 °C for 1 day. Nitrogen content was analysed by Marco Kjeldahl method. The digestibility coefficient was determined by subtracting residual protein from initial protein based on 100 g of sample.

20.2.6 In Vitro Iron

In vitro iron and percent bioavailability were estimated by Rao and Prabhavathi (1978) method.

20.2.7 Estimation of Selected Amino Acids and Fatty Acid Composition

Extraction of sulphur amino acids was done by hydrolysis. Hydrolyzed samples were employed to determine methionine (Horn et al. 1946) and cystine (Liddell and Saville 1959) content. Carpenter (1960) modified by Booth (1971) was used to assess lysine and tryptophan was estimated by Concon (1975).

For fatty acid estimation, oil from samples was extracted through Soxhlet extraction method, and the same was analysed using gas chromatography. Fatty acid methyl esters (FAME) were synthesized by Appleqvist Method (1968) and analysed on gas chromatography (Varian CP 3800, USA). Saturated (C 16:0 and C 18:0), monounsaturated (C 18:1 and C 20:1) and polyunsaturated fatty acids (C 18:2 and C 18:3) were analysed.

20.2.8 Anti-nutritional Components

Oxalic acid and phytin phosphorus were determined by Abeza et al. (1968) and Haug and Lantzsch (1983) method, respectively.

20.2.9 Statistical Analysis

Values were taken in triplicate and data were analysed statistically using Statistical Package for the Social Sciences (SPSS) version 16.0. Differences between mean scores were obtained using Tukey test for sensory evaluation. “T” test was applied to check significant difference for nutritional evaluation. Level of significance was accepted at $p < 0.05$.

20.3 Results and Discussion

20.3.1 Sensory Evaluation

A decrease value was analysed in the score of sensory attributes with increase in garden cress seed in *laddu* (Table 20.1). Control *laddu* was most liked by panel members as compared to treatments. Values for appearance and colour of *laddu* decreased from extremely liked (for control) to very good (for developed *laddu* with 5% and 10%). Levels of supplementation at 5% and 10% were found statistically nonsignificant. Nonsignificant difference was computed among treatments for texture. For flavour, treatments with 5% and 10% supplementation of garden cress were found to be different slightly in their mean scores (7.4 vs. 7.5). In case of overall acceptability, mean scores were found to be highest (8.06) for control followed by 10% (7.6) and 5% level (7.35) with statistically significant difference.

Table 20.1 Sensory evaluation of *laddu*

Sensory attributes*					
Level of supplementation	Appearance	Colour	Texture	Flavour	Overall acceptability
Control	$8.3^{a} \pm 0.48$	$8.1^{a} \pm 0.74$	$7.9^{a} \pm 0.74$	$8.0^{a} \pm 0.67$	$8.06^{a} \pm 0.55$
Experimental 5%	$7.3^{bc} \pm 0.48$	$7.2^{b} \pm 0.63$	$7.5^{a} \pm 0.53$	$7.4^{ab} \pm 0.53$	$7.35^{bc} \pm 0.24$
10%	$7.8^{ab} \pm 0.42$	$7.5^{ab} \pm 0.53$	$7.6^{a} \pm 0.70$	$7.5^{a} \pm 0.52$	$7.6^{b} \pm 0.39$
15%	$6.8^{c} \pm 0.63$	$6.9^{b} \pm 0.57$	$7.4^{a} \pm 0.52$	$6.8^{b} \pm 0.42$	$6.98^{c} \pm 0.28$

Values are in mean ± SD; alphabets with different superscripts show difference at 5% level of significance

*9 Excellent, 8 Extremely good, 7 Very good, 6 Moderately good, 5 Good, 4 Fair, 3 Very fair, 2 Poor, 1 Very poor

15% level for supplementation obtained least scores (6.98). A specific flavour of garden cress seeds may be accountable for the acceptability of garden cress *laddu,* but it gave a bitter taste to product on addition of seeds at more than 10% level. This may be the reason of least acceptability of *laddu* at 15% level of supplementation. Verma et al. (2014) reported that incorporation of sesame seeds enhanced colour, taste and other parameters with overall acceptability of *laddu.* Likewise, soy blend *laddu* was also found equally acceptable (Singh and Singh 2009).

20.4 Nutritional Evaluation

20.4.1 Proximate Principles

Proximate principles of control and developed supplemented *laddu* are described in Table 20.2. The data revealed that moisture content of supplemented *laddu* was less (0.81%) than that of control (0.93%). The protein content of control *laddu* was estimated as 5.89%, while supplemented *laddu* was found with significantly ($p \leq 0.01$) higher (10.57%) protein content (6.52%). The fat content of supplemented *laddu* (27.47%) was found significantly ($p \leq 0.01$) higher with supplementation of seeds in comparison with control (26.21%). In the same manner, fibre content also raised with significant difference ($p \leq 0.01$) in supplemented *laddu* (1.17%) as compared to control (0.64%). The ash content of control *laddu* was found to be 0.80% which increased (25%) significantly ($p \leq 0.05$) to 1.0% in developed *laddu*. The available carbohydrate content of control and developed supplemented *laddu* was computed as 66.45% and 63.83%. The energy value of control and developed supplemented *laddu* was estimated at 525.32 and 528.67 kcal per 100 g. Angel and Devi (2015) developed garden cress seeds *laddu* (5 g) which consisted rice flakes, bajra, Bengal gram, jaggery and *samai*. 50 g of *laddu* provided 376 kcal of energy and 12.8 g of protein. The results are in agreement with the reported values, mentioned in the results of Verma et al. (2014), Nailwal (2013) and Kaur (2011) who also prepared *laddu* incorporating different flours, sweet potato flour and Bengal gram leaf powder, respectively.

Table 20.2 Proximate composition of *laddu* (DM basis)

Treatment (*laddu*)	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)	Energy[a] (kcal)
Control	0.93 ± 0.12	5.89 ± 0.17	26.21 ± 0.26	0.64 ± 0.04	0.80 ± 0.10	66.45	525.32
Experimental	0.81 ± 0.07	6.52 ± 0.13	27.47 ± 0.17	1.17 ± 0.03	1.0 ± 0.18	63.83	528.67
***t* value**	1.96	6.07**	8.48**	18.29**	2.28*		

[a]Energy = (protein × 4) + (carbohydrate × 4) + (fat × 9)

Experimental (acceptable level of supplementation at 10%); Values are in mean ± SD; *Significant at 5% and **Significant at 1% level

20.4.2 Amino Acid Content and Fatty Acid Composition

The results showed that lysine content (4.31 g/100 g protein) increased after addition of cress seeds in supplemented *laddu* (Table 20.3). It also showed decreased methionine (152.42 g/100 g of protein) and cystine (1.15 g/100 g protein) as compared to control (2.60 and 1.20 g/100 g protein). Tryptophan (0.93 g/100 g protein) was also found to be improved by 8.14% in supplemented *laddu* as compared to control (0.86 g/100 g protein). Increase in lysine and methionine but decrease in cystine content of *laddu*, developed by using Bengal gram leaves, was also reported by Kaur (2011).

The results showed that control *laddu* was found with 34.7% palmitic acid, while supplemented *laddu* contained 33.17% palmitic acid with supplementation of garden cress seeds (Table 20.4). The stearic (10.90%) and oleic acid (26.87%) were also found to be slightly decreased in supplemented *laddu* (11.43% and 30.83%), while linoleic acid increased from 5.00% to 5.23%. The linolenic (1.13%) and ecosanoic (2.40%) acids were significantly ($p \leq 0.05$) increased with addition of seeds in supplemented *laddu* in comparison with control (0.53% and 0.90%).

20.4.3 Total Iron, Percent Ionizable Iron and Percent Iron Bioavailability, Calcium and Zinc Content

The iron content of control and supplemented *laddu* was found to be 2.43 and 3.53 mg per 100 g with 45.21% significant ($p \leq 0.01$) increase (Table 20.5). The percent ionizable iron of supplemented *laddu* (14.99%) was found to be slightly higher with 7.30% iron bioavailability than that of control which was 14.4% with 7.26%. Iron content was found increased in *laddu* incorporating Bengal gram leave powder with increase in ionizable iron and % bioavailability (Kaur 2011).

Kaur (2011) and Angel and Devi (2015) reported iron content of garden cress *laddu* (at 10% incorporation) as 20 g with 4% iron bioavailability. The value for control and supplemented *laddu* was found to be 31.35 and 44.51 mg per 100 g with 45.21% rise in calcium content of supplemented *laddu* with significant ($p \leq 0.01$) difference (Table 20.6). Zinc content was found to be 1.11 ± 0.01 and 1.82 ± 0.02 mg per 100 g for control and supplemented *laddu*, respectively. Calcium and zinc content increased significantly with the addition of garden cress seeds.

Table 20.3 Amino acid content of *laddu* in g/100 g of protein (DM basis)

Treatment (*laddu*)	Lysine	Methionine	Cystine	Tryptophan
Control	4.12 ± 0.02	2.60 ± 0.11	1.20 ± 0.06	0.86 ± 0.08
Experimental	4.31 ± 0.05	2.42 ± 0.06	1.15 ± 0.02	0.93 ± 0.03
***t* value**	0.82	1.87	1.07	0.45

Experimental (acceptable level of supplementation at 10%), Values are in mean ± SD; *Significant at 5% and **Significant at 1% level

Table 20.4 Fatty acid composition of *laddu*

Treatment (*laddu*)	C16:0 (%)	C18:0 (%)	C18:1 (%)	C18:2 (%)	C18:3 (%)	C20:1 (%)
Control	34.70 ± 2.91	11.43 ± 0.96	30.83 ± 2.57	5.00 ± 0.46	0.53 ± 0.06	0.90 ± 0.10
Experimental	33.17 ± 2.71	10.90 ± 0.90	26.87 ± 2.24	5.23 ± 0.40	1.13 ± 0.35	2.40 ± 0.89
***t* value**	1.28	1.31	2.65*	1.27	3.66*	3.64*

Experimental (acceptable level of supplementation at 10%); values are in mean ± SD; *Significant at 5% and **Significant at 1% level

Table 20.5 Total iron, % ionizable iron and % iron bioavailability of *laddu* (DM basis)

Treatment (*laddu*)	Iron (mg/100 g)	% Ionizable iron	% Iron bioavailability
Control	2.43 ± 0.21	14.4	7.26
Experimental	3.53 ± 0.33	14.49	7.30
***t* value**	5.89**		

Experimental (acceptable level of supplementation at 10%); Values are in mean ± SD; *Significant at 5% and **Significant at 1% level

Table 20.6 Calcium and zinc content of *laddu* (DM basis)

Treatment (*laddu*)	Calcium (mg/100 g)	Zinc (mg/100 g)
Control	31.35 ± 0.01	1.11 ± 0.01
Experimental	44.51 ± 0.55	1.82 ± 0.02
***t* value**	48.82**	6.41**

Experimental (acceptable level of supplementation at 10%); Values are in mean ± SD; *Significant at 5% and **Significant at 1% level

20.4.4 In Vitro Digestibility of Starch and Protein

In vitro starch digestibility of *laddu* was analysed as 82.46, but in supplemented *laddu*, it was found to be significantly ($p \leq 0.01$) decreased with 80.71% (Table 20.7). Similarly, in vitro protein digestibility of control *laddu* (78.57%) was also found to be decreased significantly ($p \leq 0.01$) after supplementation of seeds (77.07%). In contradiction, other studies reported significant increase in in vitro protein digestibility of *laddu*, developed using Bengal gram flour (Kaur 2014) and potato, soy and corn flour (Gahlawat and Sehgal 1998) which may be due to less fibre content of potato, soy and corn which increased the digestibility of product. Due to high fibre content of garden cress seeds, in vitro digestibility of macronutrients like protein and starch was found to be decreased.

20.4.5 Anti-nutritional Components (Oxalate, Phytin Phosphorus)

Anti-nutritional components of *laddu* like oxalate and phytin phosphorus are showed in Table 20.8. Results explained that anti-nutritional components were found to be raised in supplemented *laddu*. Seeds have good amount of oxalate and phytate, responsible for increase in anti-nutrients in food products. Oxalate content of *laddu* was found to be 3.81 mg per 100 g, while it was significantly increased to 4.21 mg per 100 g in supplemented biscuits. Phytin phosphorus content of control *laddu* (102.75 mg/100 g) was also found to be increased to 104.55 mg per 100 g after supplementation with significant difference ($p \leq 0.01$). Similar results were reported by Nailwal (2013) and Kaur (2011) who developed *laddu* using sweet potato flour and Bengal gram leave powder.

Table 20.7 In vitro digestibility of *laddu* (DM basis)

Treatment (*laddu*)	In vitro starch digestibility (%)	In vitro protein digestibility (%)
Control	82.46 ± 0.50	78.57 ± 0.55
Experimental	81.71 ± 0.65	77.07 ± 0.21
***t* value**	4.54**	5.38**

Experimental (acceptable level of supplementation at 10%); Values are in mean ± SD; *Significant at 5% and **Significant at 1% level

Table 20.8 Anti-nutritional components of *laddu* (DM basis)

Treatment (*laddu*)	Oxalates (mg/100 g)	Phytin phosphorus (mg/100 g)
Control	3.81 ± 0.33	102.75 ± 1.84
Experimental	4.21 ± 0.55	104.55 ± 1.99
***t* value**	1.15	5.04**

Experimental (acceptable level of supplementation at 10%); Values are in mean ± SD; *Significant at 5% and **Significant at 1% level

It may be inferred that increase in oxalate and phytin phosphorus content of *laddu* may be attributable to the addition of seeds which have sufficient quantity of these anti-nutritional components even if it is used at low percentage.

20.5 Conclusion

It may be concluded that *laddu* supplemented with garden cress seeds was rich in energy; protein; fat; minerals especially iron, calcium and zinc; amino acids; and fatty acids. In vitro digestibility of starch and protein was found to be decreased due to increased content of anti-nutritional components. Further trials may be conducted to increase the digestibility by decreasing anti-nutritional components. Garden cress *laddu* has potential to be a part of diet of poor and malnourished children through various supplementary feeding programmes.

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21 Screening of Bioactive Compounds of *Pleurotus sajor-caju* Extracted Using Supercritical CO_2 Fluid Extraction Technique

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Abstract

Pleurotus species have been explored for untapped metabolites that have applications for developing new life-saving drugs. The screening, extraction, and production of the bioactive compounds using appropriate techniques are still a challenge. Various novel techniques, viz., ultrasound and microwave assisted, supercritical fluid, and accelerated solvent methods for the extraction of nutraceutical compounds/elements, have been evolved to shorten the extraction time, minimize the solvent utilization, escalate the extraction yield, and enhance the trait and number of compounds present. Current study was an attempt to compare the supercritical CO_2 extraction technique with the conventional extraction method for obtaining important bioactive compounds from the *Pleurotus sajor-caju* fruit bodies. The mushroom fruit body extracts were examined for the yield and their chemical composition using GC-MS. It was observed that although the yield obtained with the supercritical extraction was found to be less (0.8%) as compared to the methanolic ones (1.86%), the number of compounds identified were more in the same. The major chemical groups identified were fatty acid esters, fatty acids, ergosterol, terpenoids (triterpenes and diterpenes), alcohols, and phytols. The present study indicated that the extract obtained with supercritical method, although gave low yield, produced quality extract with more number of organic compounds superior over extract obtained by conventional extraction method and could be successfully used in pharmaceutical applications.

Keywords

Bioactive compounds · Mushrooms · Nutraceutical · *Pleurotus* · Supercritical extraction

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21.1 Introduction

Mushroom fruiting bodies have been used as food and medicines for centuries due to their unique flavor and numerous therapeutic properties. Their utilization as nutraceutical drugs and health food has been established and proven both *in vivo* and *in vitro* (Prasad et al. 2015). Mushroom's consumption as a vegetable and as nutraceuticals in the form of capsules, formulations, concentrated extracts/powder and dietary supplements, etc. is increasing day by day and its leading brand industries gaining pace in the entire world (Rathore et al. 2017). Among the most acceptable mushroom species, *Pleurotus* spp. are the second most cultivated and acceptable spp. which are known to be rich in quality protein, essential amino acids, dietary fibers, and B-complex vitamins and important minerals such as potassium, iron, and selenium (Correa et al. 2016). The fruit bodies have been reported to have therapeutic actions (Prasad et al. 2018) such as antibacterial (Schillaci et al. 2013), antiviral (Fakharany et al. 2010), antidiabetic (Ng et al. 2015), anti-oxidative (Li et al. 2017), anti-hypercholesterolemic (Anandhi et al. 2013), anticancer, and antitumor (Deepalakshmi and Mirunalini 2013). These marvelous health characteristics are due to the presence of diverse secondary metabolites and bioactive compounds. But these active compounds are usually present in very less amount; hence, the extraction of such bioactive molecules remains as a challenge for the pharmaceutical companies. Till now, many extraction cost-effective techniques such as with solvents (methanol and ethanol) are being utilized for the purpose of extracting high yield crude extracts in lesser time (Askin et al. 2007), which are considered to be hazardous for both human health and environment (Prasad et al. 2017). Supercritical carbon dioxide (SC-CO_2) has come up as a powerful extraction technique using organic solvents for the extraction, i.e., CO_2. This technology has been extensively used for the extraction of essentials oils (Kamali et al. 2015) and for making purees, juices, etc. from vegetables and fruits (Rawson et al. 2012). In our previous study, we have also tried to extract the concentrated extracts from the medicinal mushroom shiitake (Prasad et al. 2017), and the extract obtained was superior and efficient in quality as compared to the methanolic extracts. In overview of the above facts, the current study was designed to extract and compare the yield of the mushroom spp. *Pleurotus sajor-caju* (*P. sajor-caju*) with the conventionally extracted extracts.

21.1.1 Preparation of Spawn and Cultivation of *P. sajor-caju* Mushroom

Culture of *P. sajor-caju* was procured from collection bank of Directorate of Mushroom Research (DMR), Solan. The cultures were routinely maintained on potato dextrose agar (PDA) slants; the fungus was inoculated into the wheat grains to be used as spawn. The spawn was incubated at 25 °C till the substrate is completely colonized. The cultivation technology was followed as prescribed by Gothwal et al. (2012).

21.1.2 Extraction of Biomolecules from *P. sajor-caju*

Supercritical CO_2 extraction (*SCE*): The SCE elicitation was carried out as per the method developed by Prasad et al. (2017). It was done using a supercritical fluid extraction arrangement (Thar Technology, USA) in which CO_2 was constricted to the desired pressure involving a diaphragm compressor. Heating jacket was used to heat the extraction vessel while the thermostat was deployed to control the pressure (±1 °C). Pressure was restrained by a backpressure regulator. *P. sajor-caju* powder (120 g) was put into a 400 mL vessel capped by glass wool and extracted with CO_2 at a flow rate of 40 g/min. The temperature was maintained at 50 °C, and the extractions were executed at a pressure of 30 MPa. The extracts were pooled in an additional vessel adhered to the depressurization valve, which were held in a rotating refrigerated bath at 0 °C. The crude extracts were gathered and stored in a refrigerator (4 °C) for further investigations.

Solvent extraction: Soxhlet apparatus was used for the extraction, and it was carried out correspondingly to the 920.39 °C method of AOAC (2005). 150 mL of methanol solvent was taken to extract 5 g of dried sample, in a Soxhlet apparatus for 6 h at the boiling temperature. The solvents of the resulting extracts were evaporated under reduced pressure in a rotary evaporator to obtain the crude extracts. Extracts obtained were stored in sealed amber glass bottles at 4 °C.

21.1.3 GC-MS Analysis

Supercritical CO_2 fluid and solvent extracted extracts were analyzed using GCMS-QP2010 Plus, Shimadzu, Japan, equipped with programmable head space self-regulating sampler and auto-injector. The capillary column used was DB-1/RTX-MS (30 m) with helium as a carrier gas, at a flow rate of 3 mL/min with 1 μL injection volume. The constituent compounds were identified by correlating their retention times and mass weights with those of legitimate samples acquired by GC and with the mass spectra from the Wiley libraries and the database of National Institute of Standards and Technology (NIST).

21.1.4 Statistical Analysis

Mean and standard deviation of the data obtained was analyzed using software SPSS, version 17.

21.2 Results and Discussion

21.2.1 Yield of Mushroom Extract Obtained After Supercritical and Solvent Extraction

In the results pertaining to *P. sajor-caju* extract yield, comparing both the techniques is illustrated in Fig. 21.1.

The yield obtained with the supercritical extraction was found to be less (0.8%) as compared to the methanolic ones (1.86%). Results indicated that the amount of extract was related to the solvent power, and the greater yield in conventional method using organic solvents might be due to the solvent solute interaction that contributes to the higher solubilization of components from the sample. Our results are in agreement with the findings of Rodríguez-Solana et al. (2014) and Prasad et al. (2017). Reporting the same results, i.e., yield in Soxhlet, was more in comparison to supercritical fluid extracts. However, in contrast Ozcan and Ozcan (2004) concluded that both the techniques (Soxhlet and SCF) utilized yielded similar weight of plant extracts, but they stated that hydrocarbon recovery was more in supercritical carbon dioxide extracts, i.e., 0.6 mg/g. Although, the yield obtained in the current study was less in case of SCE, that can be overcome by using the combinations of the solvents such as 5% or 10% of methanol (Prasad et al. 2017). It was observed that despite not achieving the high extract yields, supercritical extraction method was superior in order to obtain a large number of compounds/molecules. The active principle molecular weight, concentration (%), molecular formula, molecular structure, and retention time are presented in Table 21.1. The major bioactive compounds having therapeutic importance detected in the SCE extracts in terms of % area peak were linoleic acid (19.23%), palmitic acid (15.20%), and ergosterol (16.23%). Linoleic acid has tremendous therapeutic properties, and studies have reported that inclusion of dietary linoleic acid reduces the risk of coronary heart diseases (Farvid et al. 2014), breast cancer (Zhou et al. 2016), and diabetes (Henderson et al. 2018). Similarly, palmitic acid is also known to possess important health healing properties such as controlling diabetes, cardiovascular diseases, and various types of cancer (Mancini et al. 2015). The terpenoid group of volatile

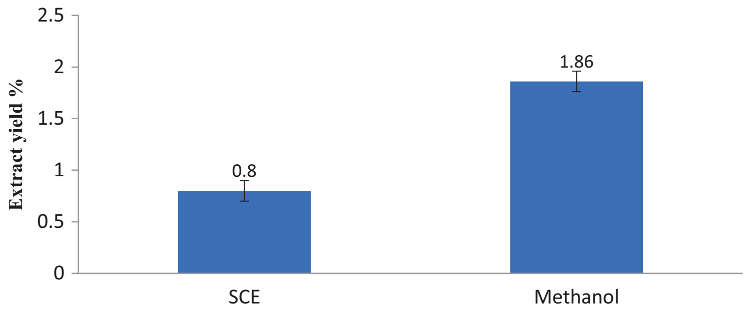

Fig. 21.1 Yield % of extracts using different techniques

Table 21.1 Relative composition profile, in % peak area, of *P. sajor-caju* extracts obtained by conventional method (methanol) and supercritical fluid extraction (SCE)

S. no.	Compound name	Molecular formula	RT	Peak area (%) of SCE extract	Peak area (%) of methanolic extract	Molecular weight	Therapeuticproperties
1	n Hexadecanoic acid (palmitic acid)	$C_{16}H_{32}O_2$	16.578	15.20	1.72	256.42	Anti-inflammatory
2	E, Z-1, 3, 12-nonadecatriene (linoleic acid)	$C_{18}H_{32}O_2$	22.667	19.23	18.53	280.44	Analgesic,anti-inflammatory
3	9-Octadecenoic acid, 1,2,3 propanetriyl ester (E,E,E)	$C_{57}H_{104}O_6$	20.872	8.63	8.03	282.46	Anti-inflammatory andantitumoral effects
4	Ergosta-5,7,22-trien3ol, (3.beta, 22E)-(ergosterol)	$C_{28}H_{44}O$	29.737	16.12	13.18	438.68	Precursor of vitamin D synthesis
5	1-(1,5-Dimethyl-4-hexenyl)-4 methylbenzene (2-haptane)	C_7H_{14}	10.924	5.29	–	98.19	Immunomodulatoryeffects
6	9-Octadecen-1-ol, (Z) (oleyl alcohol)	$C_{18}H_{36}O$	18.470	4.20	–		–
7	Beta-Bisabolene	$C_{15}H_{24}$	11.261	3.65	–	204.35	Cytotoxic effectsagainst cancers
8	Beta-Sesquiphellandrene (terpenoids)	.	2.43	5.46	–	204	Anti-inflammatory properties
9	n-Propyl 9, 12-octadecadienoate (propyl linoleate)	$C_{21}H_{38}O_2$	18.274	3.29	–	322.5	–
10	Gamma-Ergostenol	$C_{28}H_{48}O$	31.357	1.87	–	400	–

unsaturated hydrocarbons extracted from the *P. sajor-caju* has also been reported for its anti-inflammatory activities and is widely used by the pharmaceutical companies to develop drugs responsible for antimalarial, anti-cholinesterase, antiviral, antibacterial, and anti-inflammatory actions (Rathore et al. 2017).

Mazzutti et al. (2012) also carried out the supercritical extraction of *Agaricus brasiliensis* and reported 44.24% of linoleic acid in the extract obtained from SCE + 5% ethanol. Similarly, extracts *of A. blazei* mushroom obtained by SCE with CO_2 at 40 MPa and 243.15 K have been reported to be rich in palmitic acid and oleic acid (Coelho et al. 2009). Our previous data on *L. edodes* also showed that SCE extracts were rich in therapeutically active components along with the goodness of antioxidants including phenolics and radical scavenging effects (Prasad et al. 2017). The density is much greater than those of typical gases and slightly less than those of organic liquids, and supercritical CO_2 can easily penetrate the interior structure of the samples, helping to retrain more bioactive compounds. Also, low critical temperature of CO_2 allowed to extract thermobile and hydrolyzed components also, which cannot be extracted using solvents, such as terpenoids.

Further, *P. sajor-caju* was found to contain high quantity of ergosterol (Table 21.1), which is a precursor for the conversion of vitamin D. It has been reported that on exposure to UV, ergosterol start converting into vitamin D_2, via a photochemical reaction (Rathore et al. 2017). It has been also reported by Shu and Lin (2011) that the ergosterol isolated from the fungi exhibits pharmacological activities, anti-oxidative capacity, and antitumor activity. As evident from the results, the conventional extraction process has low ability to extract functional compounds.

21.3 Conclusion

The findings of the present study revealed that supercritical fluid extraction technique was superior as compared to the Soxhlet, as it was found suitable for characterizing the complete chemical profiling of the medicinal mushroom *P. sajor-caju*. More number of therapeutically stable bioactive compounds such as terpenoids, ergosterol, and essential fatty acids were recorded. SCE could prove to be a beneficial technique for obtaining important biologically active compounds that can help in developing various novel nutraceuticals. This would strengthen the existing sector of convenience functional food production for the benefit of mankind.

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22

Optimization of Process Parameters for Osmotic Dehydration of Apple Slices

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Abstract

Osmotic dehydration of apple slices by using dry sugar method was done along with the use of various additives for enhancing the flavor. The degree Brix was checked and maintained for 3 consecutive days. After 3 days, the osmotically pre-treated apple slices were further dehydrated in a cabinet dryer at 60 °C and were analyzed with sensory score texture, flavor, color, and overall acceptability.

Keywords

Osmotic dehydration · Apples · Preservation · Osmosis · Drying

22.1 Introduction

Fruits are healthy and tasty food products, consumed either fresh or processed, as a snack or as an ingredient. Apples are consumed as a fresh fruit as well as in desserts, ice creams, and puddings. Apples have a shelf life of approximately 6–8 weeks in refrigeration but, if kept at normal temperatures, ripen very quickly due to enzymes; hence they keep for a week or two.

Dried fruits have a prolonged shelf life and can be used in different products. Different drying techniques enhance the quality of dried products. The technological challenge is primarily difficult since very low moisture levels for maximum product

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stability are not simply obtained with minimum change to food materials. Osmotic dehydration is getting wide admission as an effective and possible alternative to enhance the quality of dried food products. Osmotic dehydration is a process used for the partial removal of water from the product by immersing it in a hypertonic (osmotic) solution. Water removal is based on the phenomenon of osmosis. The driving force for the diffusion of water from the tissue into the solution is provided by the higher osmotic pressure of the hypertonic solution. The aim of the present study was to optimize the process parameters for osmotic dehydration of apple slices by using sugar in combination with various additives such as honey, lemon juice, salt, etc. for enhancing on the whole quality of the final product. Various combinations of osmotic agents were used, and the degree Brix was checked and maintained for 3 consecutive days. After 3 days, the osmotically pre-treated apple slices were further dehydrated in a cabinet dryer at 60 °C and were analyzed for shrinkage, texture, flavor, color, and overall acceptability based on a five-point hedonic testing.

22.1.1 Review of Literature

Bahadur Singh et al. (2007) found that if osmotic dehydration process is optimized by RSM (response surface methodology), then it will acquire maximum water loss, rehydration ratio, retention of color, sensory score, and minimum solute gain. It was observed that in the osmotic dehydration of carrot cubes in aqueous sucrose solution at 45–55° Brix, temperature of 35–55 °C, and process duration of 120–240 min, RSE is very effective to optimize above parameters. It was concluded that for maximization of above parameters, by numerical optimization, the °Brix obtained was 52.5 and temperature was 49 °C and duration was 150 min.

The outcome of agitation and structural attributes on osmotic dehydration was studied by Nikolaos E. Mavroudis et al. (1998). An agitated vessel at 20 °C using 50% sucrose solution as the osmotic medium was used for the osmotic dehydration. The impeller Reynolds number was used for agitation quantification. Separation of the sample was done into inner and outer apple parenchymatic tissue, the intercellular space interconnectivity, and aspect ratio (length to width ratio) being higher in inner than outer tissue. Structural differentiation revealed a strong effect on process responses. Independent of agitation level, solid gain (kg/kg i.m.) was higher in inner than in outer apple parenchymatic tissue. Water loss (kg/kg i.m.) was lower in inner than outer apple parenchyma at the same Reynolds number. Water loss was higher in the turbulent flow region than in the laminar flow region. Through this study, the external mass conditions were studied.

Apoorva Behari Lal et al. (2012) concluded that osmo air-dried apples can be prepared by subjecting the slides to optimum osmotic concentration and then the osmosed slices are dried. In this study, they have subjected the osmosed slices at temperature of 65.16 °C, drying time of 3.16, and at an air velocity of 1.5 m/s. By such process, a shelf-stable product can be achieved. The product is acceptable, and it has good sensory, textural attributes, and rehydration ratio. It is a very economic and energy efficient process and can be useful at village and farm levels. Yadav and Singh (2014) reviewed distinct methods, treatments, optimization, and effects of osmotic dehydration and finally came to the conclusion that osmotic dehydration is the best method to increase the shelf life, and it is chosen over other methods because of its retention property of vitamins, color, minerals, and taste. They also concluded that combinations of osmotic agents are better apart from sucrose alone as it adds up the property of the solutes added. Chavan and Amarowicz (2012) assessed the methods and advantages in the process of osmotic dehydration of vegetable and fruits. Osmotic dehydration is a simple process and being less energy extensive can be used to enhance the organoleptic properties of fruits like banana, sapota, fig, pineapple, guava, apple, mango, grapes, carrots, pumpkins, etc. It has possible merits for the processing industry to maintain the food quality and to preserve the wholesomeness of the food.

22.1.2 Materials

Apples of delicious variety and lemons were purchased from the local market of Vasundhara Enclave East Delhi. Honey, sugar, and salt were brought from residential grocery shop of Vasundhara Enclave.

22.1.3 Methodology

The apples were washed in running water and then manually cored and cut into slices of thickness 8.0–10.0 mm. For osmotic concentration the apple slices and sugar of known weight were kept in alternate layers in the ratio of 1:1 along with different additives.

For sample 1, 195 g of apple slices were sprayed upon by sugar of 195 g, i.e., in the ratio 1:1 in alternative layers. 22 mL of lemon juice, extracted from two lemons, was added as an additive. For sample 2, 199 g of apple slices were sprayed upon by sugar of 199 g, i.e., in the ratio 1:1 in alternative layers. 180 g of honey was added as an additive. For sample 3, 212 g of apple slices were sprayed upon by sugar of 212 g, i.e., ratio 1:1 in alternative layers. 20 g of salt was added as an additive. For sample 4, 192 g of apple slices were sprayed upon by sugar of 192 g, i.e., ratio 1:1 in alternative layers. Five percent of citric acid, i.e., 1 g in 20 mL of distilled water, was added as additive (Table 22.1).

All the prepared samples were covered with an aluminum foil and were labeled. The containers were then kept in a tray halfway filled with water to keep it safe from

Table 22.1 Different additives used in samples

S. no.	Name of the sample	Weight of the sample (g)	Additive used	Osmotic solution ratio
01	Sample 1	195	Lemon juice	1:1
02	Sample 2	199	Honey	1:1
03	Sample 3	212	Salt	1:1
04	Sample 4	192	Citric acid	1:1

ants and other insects. The containers were kept at room temperature (31–33 °C). All the samples were kept for 3 days with regular checking and maintained of the degree Brix each day. On the third day, the apple slices were taken out from their respective containers and were drained off from their syrups for half an hour. Apple slices were spread on plastic sheets, labeled, and then were kept in laboratory cabinet tray drier. The temperature maintained in the drier was 60 °C and apple slices were dried for duration of 4 h. Then the apple slices were taken out from the drier and were kept at normal room temperature for an hour. Later, they were packed and labeled accordingly. Sensory evaluation was carried out by 20 panelists on a five-point hedonic scale (Tables 22.2, 22.3, and 22.4).

22.2 Results and Discussion

22.2.1 On the First Day

22.2.1.1 Sample 1: (Sugar + Lemon Juice)

There was no change in the color of apples (fresh like color). The color of the syrup was slight pinkish, i.e., the leaching of the color from peels occurred. A small amount of sugar was present in crystallized form at the bottom of the container; a distinctive odor of lemon (sour) was predominant in the sample. The observed degree Brix was 54°. The syrup was then heated (after separating out the slices in a plate), and the degree Brix was then increased up to 70°. After cooling, the slices were again kept in the syrup and were covered and kept in water tray.

22.2.1.2 Sample 2: (Sugar + Honey)

The color of the syrup was light honey colored (dull yellow). The apples were of creamish white color. A significant amount of sugar crystallized at the bottom of the container. A sweet odor of honey was predominant. The syrup was comparatively viscous than the other sample. The degree Brix was observed to be 62°. The syrup's degree Brix was increased up to 70°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.1.3 Sample 3: (Sugar + Salt)

The colors of apples were much similar to that of fresh sample. The syrup color was slightly pinkish. A very small amount of crystalline sugar was present at the bottom of the container. Characteristic odors of apples were perceived. The observed degree

Table 22.2 Degree Brix maintained for Day 1

S. no.	Sample	Additive	Observed degree Brix	Final degree Brix
01	Sample 1	Lemon juice	54°	70°
02	Sample 2	Honey	62°	70°
03	Sample 3	Salt	54°	70°
04	Sample 4	Citric acid	48°	60°

Table 22.3 Degree Brix maintained for Day 2

S. no.	Sample	Additive	Observed degree Brix	Final degree Brix
01	Sample 1	Lemon juice	59°	75°
02	Sample 2	Honey	64°	76°
03	Sample 3	Salt	54°	77°
04	Sample 4	Citric acid	53°	75°

Table 22.4 Degree Brix maintained for Day 3

S. no.	Sample	Additive	Observed degree Brix	Final degree Brix
01	Sample 1	Lemon juice	65°	65°
02	Sample 2	Honey	66°	66°
03	Sample 3	Salt	67°	67°
04	Sample 4	Citric acid	62°	62°

Brix was 54°. The syrup's degree Brix was increased to degree Brix 70°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.1.4 Sample 4: (Sugar + Citric Acid)

The color of the apples was much similar to fresh ones. The syrup color was very slight pinkish. A very small amount of crystallization of sugar was present at the bottom of the container. The characteristics odors of apples were preserved. The observed degree Brix was 48° which was increased up to 60°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.2 On Second Day

22.2.2.1 Sample 1: (Sugar + Lemon Juice)

Slight browning of the apples present at the top had occurred. Syrup was slight pinkish in color. No crystalline sugar was present in the container. The sour odor of lemon juice was perceived. The observed degree Brix was 59°. The degree Brix was made to 75°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.2.2 Sample 2: (Sugar + Honey)

The apples which were at surface turned brown. The sugar syrup was light honey colored. Very slight crystallization and sticking of sugar at the bottom was observed. The odor was same as that of previous day. The syrup was more viscous comparatively. The observed degree Brix was 64° and was made up to 76°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.2.3 Sample 3: (Sugar + Salt)

No browning had occurred and the color of the apples turned more appealing white (same as the first day; odor and color of the syrup). No crystallization at the bottom of vessel was observed. The observed degree Brix was 59° and made up to 77°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.2.4 Sample 4: (Sugar + Citric Acid)

There was no significant change in the color. The color of the syrup was slightly pinkish. A very small amount of crystallization of sugar had taken place at the bottom of the container. The observed degree Brix was 53° and was made up to 75°, and after cooling the slices were again kept in the syrup and were covered and kept in water tray.

22.2.3 On Third Day

22.2.3.1 Sample 1: (Sugar + Lemon Juice)

Slight browning of the apples present at the top had occurred. Syrup was slight pinkish in color and had turned more viscous. No crystalline sugar was present in the container. The sour odor of lemon juice was perceived. The observed degree Brix was 65°.

22.2.3.2 Sample 2: (Sugar + Honey)

The apples which were at surface turned brown. The sugar syrup was light honey colored. Very slight crystallization and sticking of sugar at the bottom was observed. The odor was same as that of previous day. The syrup had turned more viscous comparatively. The observed degree Brix was 66°.

22.2.3.3 Sample 3: (Sugar + Salt)

No browning had occurred and the color of the apples turned more appealing white (same as the first day; odor and color of the syrup). No crystallization at the bottom of vessel was observed. The observed degree Brix was 67°.

22.2.3.4 Sample 4: (Sugar + Citric Acid)

There was no significant change in the color. The color of the syrup was slightly pinkish. A very small amount of crystallization of sugar had taken place at the bottom of the container. The observed degree Brix was 62°.

Sensory evaluation was performed on the various samples and the general results were that all the sample were satisfactory. In terms of appearance, sample 3 was the best, with minimal browning and textural losses. Sample 1 was very chewy in texture and had good flavor but browning had occurred. Sample 2 was very sweet in flavor and odor was pleasant. Sample 4 had good and balanced flavor.

Sample 1: The first sample had additive lemon juice and was sourer than desired levels. Browning due to drying had occurred but the sample had good palatability. Hence, it was a satisfactory sample. The average scores for color, texture, and flavor were 3.57, 2.71, and 3.71, respectively.

Sample 2: The second sample had honey as an additive and was having adequate sweetness of sugar and honey. Browning did occur due to improper drying of the samples. It was a bit of too sweet, but it had characteristic sweetness of honey. The average scores for color, texture, and flavor were 3.14, 4, and 3.85, respectively.

Sample 3: The third sample had salt as an additive. The natural color was retained quite well. The sample was a bit too salty, but it balanced out with sweetness of sugar. Texture was firm. The average scores for color, texture, and flavor were 4.71, 4.42, and 3.42, respectively. Sample 3 received the best scores.

Sample 4: The fourth sample had citric acid as additive. The sample had a good flavor, and browning did occur with leaching off color in sugar syrup. The average scores for color, texture, and flavor were 3.85, 4, and 3.57, respectively.

Based on sensory scores obtained for the various samples, the following graphs were plotted (Figs. 22.1, 22.2, 22.3, and 22.4).

After performing the sensory evaluation of all the samples, all were acceptable. Panel members found sample 2 to be good in flavor and sample 3 to be extremely salty. Sample 3 had good appearance and quality. The color was all good in almost all the samples. By decreasing the concentration of the salt in sample 3, the product

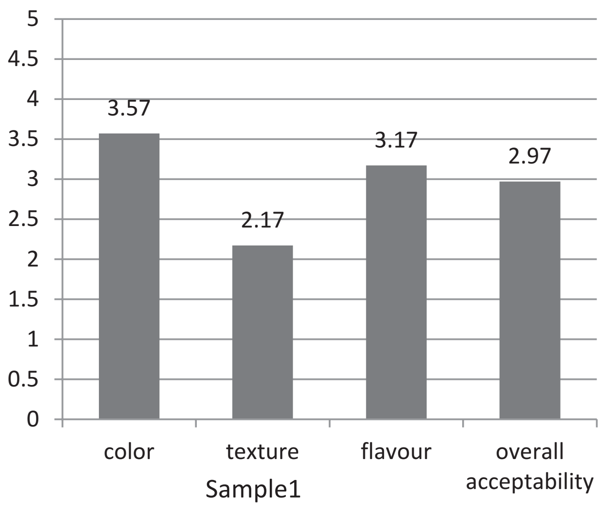

Fig. 22.1 Sensory score for Sample 1

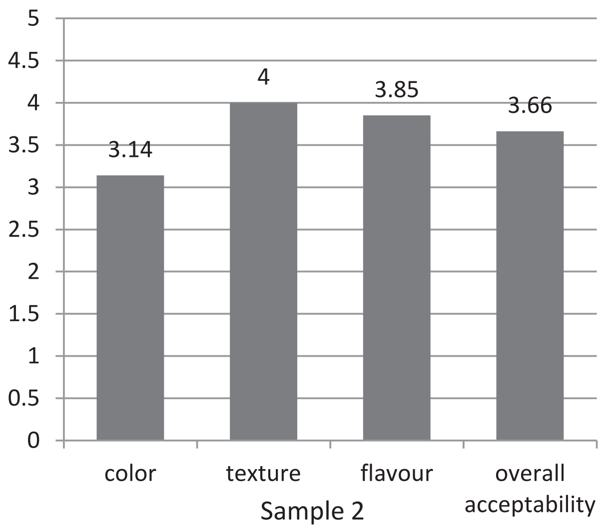

Fig. 22.2 Sensory score for Sample 2

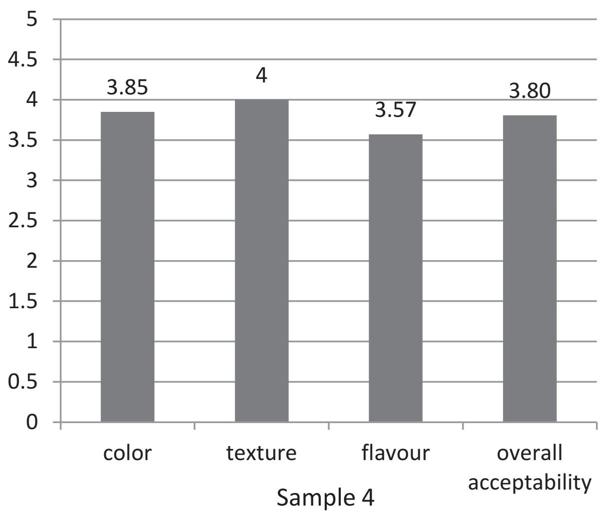

Fig. 22.3 Sensory score for Sample 3

may had been of better quality. Same in the case sugar + lemon juice, by decreasing the content of lemon juice, the product can be enhanced.

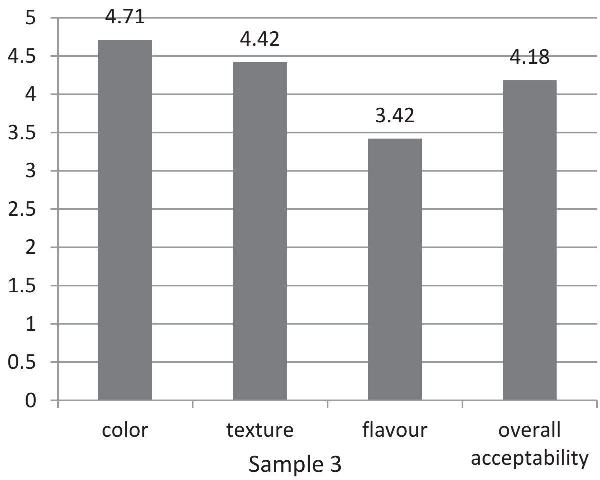

Fig. 22.4 Sensory score for Sample 4

22.3 Conclusion

The estimated price of the packet of 100 g of osmotically dehydrated apples was found to be Rs. 74 approximately. Further work may be done to analyze the physicochemical properties of the samples. Various other fruits and combinations of additives may also be tried in the future.

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Exploitation of Unmarketable Potatoes for the Preparation of Instant Custard Powder with Different Flavours and Their Sensory Evaluation

23

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Abstract

Ready to use instant custard powder (ICP) was prepared by mixing potato starch and flour with powdered milk, sugar and dry fruits (cashews, almonds and resins). A total of four flavours, viz. butterscotch, cardamom, vanilla and orange, were tried, out of which orange was inferred to be the best. Grade D potatoes were procured from the market. The potato starch was prepared by crushing the potato slices in excess of water to make slurry which was sieved so that the settled starch can be obtained which was washed and dried in oven at 45° centigrade and ground into fine powder. The potato flour was prepared by drying the slices of potatoes in oven to bring down its moisture level to 3–4%. This was followed by the grinding of the dried slices. The custard was prepared by mixing the potato starch and potato flour in a given amount of milk and hot water, and dry fruits were added. The sensory evaluation was done with a panel of 20 members, and orange flavour was judged the best of all the four samples. The cost analysis was done, and it came out to be Rs 7/per packet.

Keywords

Potatoes · Instant custard powder · Quality · Economics

23.1 Introduction

Potato (*Solanum tuberosum* L.) is one the pioneer tuber crops of the world, especially in Europe and America, and the most important commercial vegetable crop harvested in India. Production of potato has achieved greater heights in recent years.

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In India, the growth has expanded over an area of 1.91 million hectares with a total yearly production of 41.5 million tonnes comprising 5–10% of D-grade potatoes. It is rich in good quality protein and carbohydrates and is available in India throughout the year and is a good supplement of the cereal diets. However, 10% of the total produced is used as seed, and 10–15% is wasted during harvest and post-harvest operations due to absence of sufficient cold storage facilities. At farm level total produce includes grade A (tuber size 50–75 mm) and D-grade (tuber <25 mm) potatoes. Unmarketable potatoes die to their small size (<25 cm) and are difficult to handle and fetch low price to the growers which can be processed to get better remunerative advantage. The current research work focuses on how unmarketable potatoes can be utilized more beneficially for the preparation of instant custard powder (ICP) after preparation of potato flour and starch.

This research work has its basis in one most extensively researched field in food industry which is to find the ways to utilize the methods, approaches and processes to prepare food products in an efficient way, which take into account the following objectives:

- Renewability of by products
- Reducing the wastage during production
- Reutilization of unused or unconsumed produce

Our research work primarily focuses on the third point of the above-mentioned objectives, i.e., reutilization of in-used or unconsumed produces.

Awoyale et al. (2015) worked on evaluation of the nutritive value of custard powder prepared from high-quality yellow cassava starch enriched with partially defatted soya bean flour of varying propositions of 5%, 10%, 20% and 30%. Their approximate composition, pigment (carotenoid) content and pasting (sticking) property were observed. Okoye et al. (2008) did a research in which they prepared soya fortified custard and checked for its nutrient composition and sensory acceptability. The incorporation of soya protein isolates in custard powder was done to increase its protein content and its nutrient composition with study of its sensory quality. It was observed that fortifying custard powder with protein from some economical source like soya bean increases its nutritional value but alters sensory and functional property. Increase in the content of isolate leads to increase in dispensability, packed bulk density, swelling power, viscosity and solubility index.

Alimi et al. (2016) studied the engineering properties of composite corn-banana custard flour products developed by involving and further utilizing native, heat moisture-treated or annealed banana starch as a percentage (15%, 25% or 35%) of the composite was determined. Big oval granules of banana starch lead to occupying empty spaces in the matrix resulting in more compact composite of the corn flour structure and, in turn, higher bulk density with increasing level of inclusion. It led to significant reduction in the swelling capacity of the corn flour samples with gelling and boiling points getting diversified.

Awoyale et al. (2015) studied the effect of storage on the chemical composition and microbiological activity followed by sensory properties of cassava starch-based custard powder. The use of yellow-fleshed cassava root starch was implied in this study. The production of custard powder had poor nutritional value especially protein. Therefore, fortification with high-quality animal protein product like whole egg powder might improve its protein quality and quantity. The interaction of these constituents formulated some changes in the product during storage, and one or more food characteristics reached an undesirable state. After storage, the moisture content and microbiological load also increased. All the sensory attributes were accepted at the end of storage, except taste and colour, with carotene contents decreasing significantly.

23.2 Material and Methods

23.2.1 Requirements

1. Potatoes
2. 3% NaCl solution and 0.05% ascorbic acid solution
3. 0.2% KMS solution
4. Distilled water
5. Milk powder
6. Milk
7. Dry fruits
8. Powdered sugar

23.2.2 Methodology

1. **Raw material:** Grade D potatoes were procured from the market. All the potatoes were washed thoroughly and peeled with the help of stainless steel peeler. The potatoes were then cut into small pieces of sizes 1–2 mm thick using hand-operated stainless steel slicer.
2. **For preparation of potato flour:**
    - The cut slices were put into 3% NaCl and 0.05% ascorbic acid solution to prevent browning caused by polyphenol oxidase.
    - These slices were then blanched at 80–85 °C for 3 min for flour preparation.
    - The blanched slices were cooled under tap water and then treated with 0.2% KMS for 15 min to prevent non-enzymatic browning.
    - Slices were then dried in mechanical drier at three stages, viz. 70 °C for 2 h, 65 °C for 4 h and finally 60 °C, and brought down moisture content to 3–4%.
    - The dried slices were cured for equalization of moisture in tin container followed by grinding to a fine powder to make potato flour.
3. **For extraction of potato starch:**
    - Slices were blanched at 80–85°for 1 min and then crushed in excess water (5 times) in a grinder (4–6 min) to make fine slurry.

- Slurry was sieved through muslin cloth and filtrate was allowed to settle in tub.
- Supernatant was discarded and settled starch was washed with fresh water 2–3 times to remove all impurities and to get clear starch.
- Starch was dried in oven at 40–45 °C. Before complete drying, it was made into fine powder and then packed in polythene bag and labelled.

4. **For preparation of instant custard powder:**
   - Starch and flour obtained were used for instant custard powder preparation.
   - Recipe for the formulation of ready to use custard powder was worked out by mixing potato starch and flour with powdered milk and dry fruits, and different flavours were obtained by mixing ICP with different flavouring powders.
   - The best recipe was selected on the basis of the higher sensory score on 5-point hedonic scale.

A. Methodology pertaining to preparation of custard from powder is given below:

Instant Custard Powder (100grams)

Make a paste with 50mL water

Add paste to 60mL milk

Stir for 2–3 min while heating and add all the flavouring agents. Cooling of custard is done by refrigerating it for few hours which is followed by serving it chilled in plates.

Composition of the Raw Material Used:

Potato flour—5 g (per sample)
Potato starch—2 g (per sample)
Milk powder—1 g (per sample)
Flavour—0.75 g (per sample)
Sugar—2.5 g (per sample)

23.2.3 Sensory Evaluation

- The prepared four samples of different flavours were evaluated for sensory qualities on the basis of colour, consistency, flavour and overall acceptability by a panel of 20 judges on a five-point hedonic scale.
- Finally, the best sample was obtained on the basis of sensory evaluation score.
- Costing of ICP was calculated by taking into consideration various inputs like raw material, labour, electricity, processing cost, packaging and other changes.

For calculating the sale price of the product, 10% profit margin was added to the cost of instant powder.

23.3 Results and Discussion

A total of four flavours of instant potato custard was prepared, out of which orange was best as mentioned below:

Sample A (Cardamom):

A. The colour was judged best in the case of cardamom flavour. Average score was 4.11.
B. Flavour was a bit more in the sample but was acceptable. Average score was 3.55.
C. Consistency was fine but could have been thicker, which can be done by addition of more starch. Average score was 3.61.
D. The sample's overall acceptability was fair. Average score was 3.55.

Sample B (Butterscotch):

A. The colour was widely accepted by most of the judges and was scored very well. Average score was 4.22.
B. Flavour was poor as the quantity of flavouring agent was more; hence it left an aftertaste. Average score was 2.88.
C. Consistency was rated the best out of the all samples. Average score was 3.77.
D. Overall acceptability was good in the butterscotch sample. Average score was 3.77.

Sample C (Vanilla):

A. Colour was very good and creamier white. Average score was 3.77.
B. Flavour was overcooked and hence was rated fair. Average score was 3.66.
C. Consistency was not up to the mark and could have been thicker by addition of thickening agent. Average score was 3.55.
D. Overall acceptance was good. Average score was 3.77.

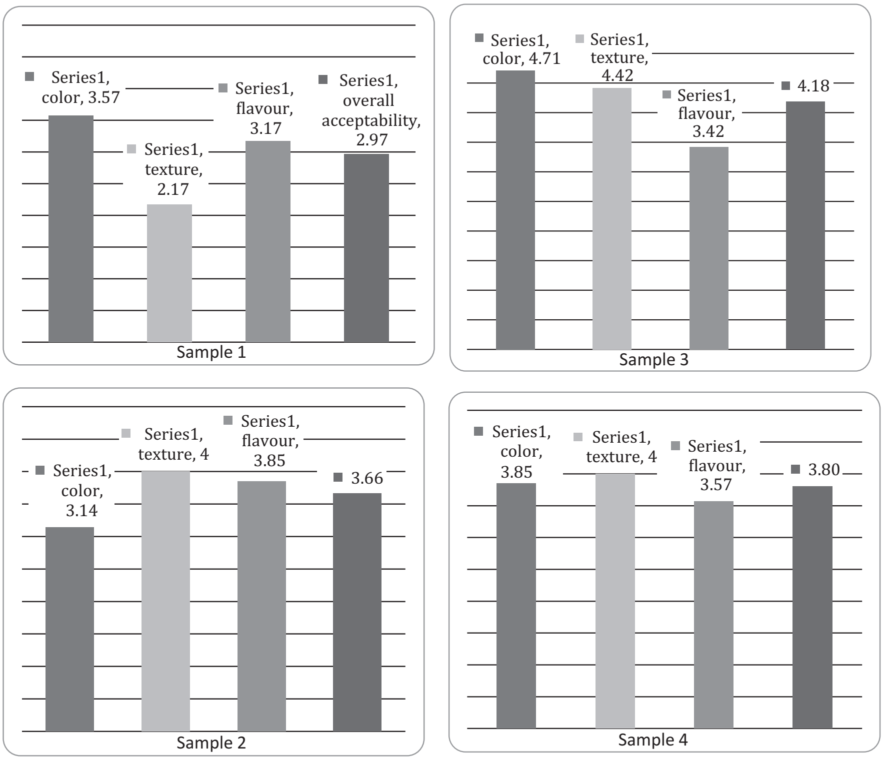

Fig. 23.1 Graphical representation of overall preference of various samples

Sample D (Orange):

A. Orange has rated the best sample in terms of flavour. Average score was 4.22.
B. Consistency was dilute and could have been thickened by the addition of more starch. Average score was 3.52.
C. Colour was poor as no artificial colour was added; hence it was creamish white which should have been orange. Average score was 3.11.
D. Its overall acceptance was very good. Average score was 4 (Fig. 23.1).

23.4 Conclusion

The instant custard powder was successfully prepared by using grade D potatoes. Various flavours were prepared, and their sensory evaluation was conducted on the basis of various sensory attributes, namely, flavour, colour, consistency and overall acceptability with a panel of 20 members, and orange flavour was voted the best out of all the samples. The cost analysis was done and it came out to be Rs 7/per packet. This research can be extremely useful in utilizing the grade D potatoes and is an economical source of nutrition. This product has a wide scope as custards are in high demand in the market.

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Studies on Comparative Determination of Ochratoxin A (OTA) in Coffee Beans with Different Origins

24

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Abstract

Ochratoxin is a secondary metabolite produced by different species of *fungi*. Coffee is the second most consumed beverage by most of the population globally. The incident of ochratoxin A (OTA) contamination was found early in food commodities and especially in coffee beans and possesses serious health risks for human beings. OTA is also proved to exhibit various carcinogenic properties. The OTA contamination in coffee beans is in the complete production chain and depends upon crop management, harvest, post-harvest storage and the process of roasting. The study is focused on the determination of OTA level in the beans of seven different origins.

Keywords

Ochratoxin A (OTA) · Mitochondrial poison · Coffee bean contamination · Mycotoxin

24.1 Introduction

Fungi metabolites can produce mycotoxins in agricultural commodities based on the favourable environmental conditions that prevail which is then coupled with crop harvesting, handling and storage (Abdulkadar et al. 2004). The commonly found mycotoxins have been derived from various species of fungi like *Aspergillus, Penicillium*, *Fusarium*, etc. The toxicity syndromes linked with the consumption of

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contaminated agricultural commodities with these mycotoxins are known as mycotoxicoses (Huff and Hamilton 1979). The most predominant ones are B1/B2/G1/G2 aflatoxins, patulins, B1/B2 fumonisins, zearalenone (ZON), T-2 and HT-2, OTA, deoxynivalenol, etc. OTA is of prime concern in relation to the coffee beans (Abdulkadar et al. 2004; Araguas et al. 2005; Brera et al. 2003; Boqué et al. 2002; FAO 1997).

Huff and Hamilton (1979) mentioned mycotoxin contamination as a serious concern during storage and production of coffee beans. He observed that the development of mycotoxins is dependent upon various intrinsic and extrinsic growth factors like temperature, duration of storage, rate of contamination, broken grains, damage by insects, O_2 concentration, damage during and after harvest, transportation, etc. The biological behaviour of OTA showed immunosuppressive, tetratogenic, fertility inhibitor, mutagenic and other carcinogenic properties (Joosten et al. 2001). These mycotoxins in food commodities cause renal toxicity, nephropathy, genotoxicity, and have carcinogenic properties.

OTA is found in different food commodities like cereals, wine, beer, coffee, grape juices, pork products, cocoa, spices, oilseeds, etc. Significantly, OTA is most common in concern in roasted, instant and green coffee (Moss 1998). Coffee fruits and coffee beans are more prone to ochratoxin. Contamination takes place during several stages starting from field to the final storage. The presence of fungi not only affects the aroma and flavour of the beverage but also extends to possess safety risk based on the level of concentration. HPLC with fluorescence detector is the best opted method for the quantification of OTA in coffee beans (Lau et al. 2000).

Based on the risk factors associated with its presence in biological systems, there has been a great need for the standard protocols for the characterization and qualitative determination of OTA in coffee beans (Guillamont et al. 2005). Recent survey revealed that a total of 12% of OTA intake in human beings is from coffee consumption. The present study has been designed to determine the OTA concentration in beans from seven different origins, viz. Uganda BHP, Uganda Arabica, Vietnam, Peru, Kenya, Honduras and Indonesia.

24.2 Materials and Methods

24.2.1 Coffee beans samples

Coffee beans from different origins (Uganda BHP, Uganda Arabica, Vietnam, Peru, Kenya, Honduras, Indonesia) were collected from TaTa Coffee Private Limited, Theni, Tamil Nadu, India. Coffee samples were obtained from the Freeze-Dried Unit, TaTa Coffee Private Limited, ICD Division, Theni. The bean samples for the analysis are segregated based on their origin. The OTA content was analysed by AOAC Official Method (2000.09) and purchased form Sigma-Aldrich.

24.2.2 Determination of OTA

24.2.2.1 Sample Preparation

The green coffee beans were ground using a coffee grinder (Gritter). 15 g sample was weighed in Erlenmeyer and 150 mL of extraction solvent was added. The Erlenmeyer was kept on a shaking device for 30 min and filtered by Whatman filter paper no. 4.

24.2.2.2 Extraction of OTA

An aliquot of the 10 mL filtrate was diluted with 10 mL of extraction solvent and passed through Immunoaffinity columns (IAC) (Ochraprep™, R-Biopharm). Procedures suggested by the manufacturers were followed. For the Ochraprep™, diluted eluent from the IAC was passed through the IAC at a flow rate not >5 mL/min. Later the column was washed with 10 mL of PBS and air-dried for 10–20 s. The toxin attached to the absorbent bed of the column was eluted using methanol (1.5 mL) into a vial. The solvent was then evaporated under a stream of air leaving the toxin with some extraction residue remaining in the vial.

24.2.2.3 OTA Analysis

For the HPLC analysis, the residual material in the vial was redissolved into 1 mL of mobile phase (water/acetonitrile/acetic acid (51:48:1)) by vortexing for 1 min. The solution was filtered using 0.2 μm filter discs.

Different sets of standards—20, 10, 5 and 1 ng of OTA/mL—were used to prepare a standard curve. Samples and standards (100 μL) were injected into the HPLC system.

A Dionex Ultimate 3000 series with a C18 column (30 × 2.1 mm, 1.8 μm, CA, USA) was used for the HPLC analysis, and fluorescence detector was used for quantification and detection of OTA. The mobile phase used was a combination of water/acetonitrile. Acetic acid (51:48:1 v/v) at 1 mL/min flow rate.

24.2.2.4 Recovery Rates

Recovery rates were calculated based on the amounts of the OTA spiked into the sample and the amount quantified by the HPLC method, and the significance level of the test was at least 5% ($p \leq 0.05$):

$$\text{Recovery}\left(\%\right) = \frac{\text{OTA in the sampleas determined by HPLC}}{\text{OTA spiked into the sample}} \times 100$$

24.2.2.5 Quantification

OTA mass concentration of the test sample was calculated using the following equation:

$$W_{\mathrm{m}} = W_{\mathrm{a}} \times \left(\frac{V_{\mathrm{f}}}{V_{\mathrm{i}}}\right) \times \left(\frac{1}{V_{\mathrm{s}}}\right)$$

where

W_m—Numerical value of OTA mass concentration in the test sample in ppb (ng/g or ng/mL)

W_a—Numerical value of the amount of OTA corresponding to the area of OTA peak of the sample extract (ng)

V_f—Numerical value of the final volume of redissolved elute (μL)

V_i—Numerical value of the final volume of injected elute (μL)

V_s—Numerical value of volume or mass of prepared test portion passing through the column (mL or g)

24.3 Results and Discussion

24.3.1 Analysis of Ochratoxin - A

The standard methodology was adopted for each sample of coffee, and the low and high levels of spiking were determined based on regulatory limits.

24.3.2 Coffee

The standard procedures have been used for the OTA analysis as AOAC Official Method (2000.09). The solvent acetonitrile/water (in ration of 60:40) did not perform well and provides very less (below 14%). The clean-up with Ochraclean™ (Pickering, CA) columns, when manufacturer's recommendations were followed, did not produce recovery rates above 23%. The solvents and clean-up columns showed promising results and the testing was done in triplicates.

Therefore, based on recovery rates from the preliminary results, two solvents were evaluated: 3% sodium bicarbonate/methanol (50:50) and 3% sodium bicarbonate/methanol (40:60). The recovery rates provided by the solvents were used to determine the best one. All the extractions were then followed by clean-up procedures using Ochraprep as the immunoaffinity column.

Statistical analysis by ANOVA indicated that extraction with 3% sodium bicarbonate/methanol (50:50) provided the highest extraction efficiency, while the other solvent tested showed a significantly lower recovery rate. Therefore, further extractions were performed with that solvent at the 5 μg/kg spiking level and at 10 μg/kg. Tables 24.1 and 24.2 showed the recovery rates for all extractions done

Table 24.1 Recovery rates for two different extraction solvent mixtures

Extraction solvent	Spiking level (μg/kg)	Recovery (%)			
		Rep 1	Rep 2	Rep 3	Avg
SB1:M2 (50:50)	5	83	87.6	83.6	80.6
SB:M (40:60)	5	64.06	45.55	43.64	51.1

SB1 = 3% aqueous sodium bicarbonate; M2 = 100% methanol

Table 24.2 Recovery rates for analysis of OTA in green coffee samples using 3% sodium bicarbonate/methanol (50:50) as extraction solvent

	Recovery rate (%)					
Spiking level (μg/kg)	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg
5	74.7	74.1	83	87.6	83.6	80.6
10	97.4	64.5	89.2	97.7	80.1	85.8

Table 24.3 Mean GC-OTA (μg/kg) in coffee bean samples

S. no	Origin	Mean GC-OTA (μg/kg)
1	Uganda BHP	9.51
2	Uganda Arabica	0.6
3	Indonesia Robusta 30/35	7.4
4	Peru Arabica	1.4
5	Vietnam Robusta	2.8
6	Kenya BHP	21.9
7	Honduras	8.5

using 3% sodium bicarbonate/methanol (50:50) at both spiking levels of 5 μg/kg and 10 μg/kg.

The recovery rates obtained with 3% sodium bicarbonate/methanol (50:50) from spiked coffee samples ranged from 64.5% to 97.7%. Lombaert et al. (2002) and Pardo et al. (2004) also found similar results.

24.3.3 Quantification of OTA in Green Coffee Samples

The samples were categorized based on sampling procedures. A total of 21 coffee samples were analysed, and the experiments were performed in triplicate. Of all the samples analysed, 95.23% (20/21) showed OTA values in detectable levels and 4.76% (1/21) below quantifiable limits.

Among those samples that could be quantified for OTA, the contamination levels ranged between 21.9 and 0.6 μg/kg (Table 24.3, Figs. 24.1 and 24.2). Only one sample from Kenya BHP (21.9 μg/kg) out of 21 samples showed contamination with OTA above regulatory limits, and it's because of the low-grade quality and its OTA contamination is significantly reduced after the removal of foreign and husk matter.

24.4 Conclusion

In this study, the extraction solvent showed the best recovery results (83.2% and 82.7%) compared to other solvents for analysis of OTA in green coffee beans. Uganda Arabica origin-based sample showed the lower incidence of OTA contamination, while Kenya BHP showed the higher-level OTA contamination and

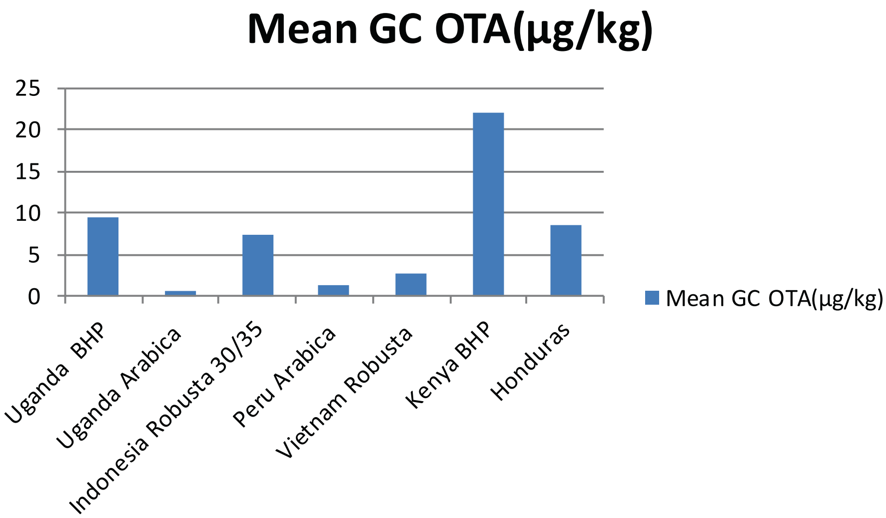

Fig. 24.1 Mean GC-OTA

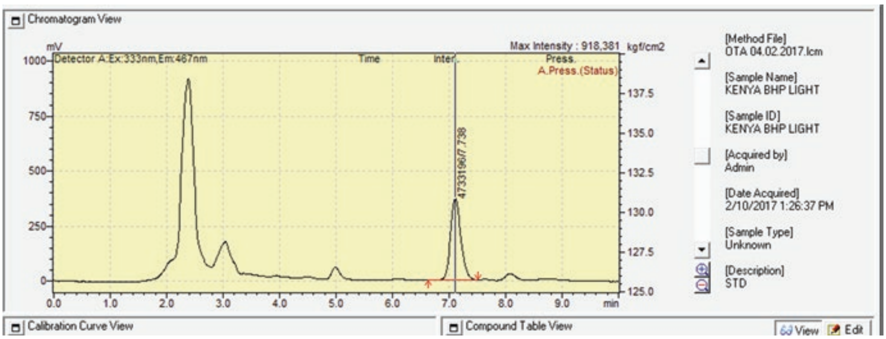

Fig. 24.2 Chromatogram of Kenya BHP

significantly reduced after the removal of chaff and foreign matter. Studies also suggested that thermal destruction also reduces the OTA contamination in the coffee beans. Though Kenya BHP showed higher incidence of OTA, processing steps can reduce the OTA concentration significantly to a lower limit which is considerably acceptable by regulatory bodies. The 'Broca' also known as coffee berry borer (*Hypotenemu shampei*) is a vector of *A. ochraceus* (Mantle and Chow 2000). The insecticides used to control these insects have been found to lower the OTA contamination of coffee beans.

The application of insecticides worked in reduction of ochratoxin-producing fungal species. While harvesting, various other factors also affect the harvest, e.g. weather conditions before and during harvest, time before drying, driers, physical parameters for grains, harvesting temperatures, fungal species interactions, hygiene of harvesters, transportation, etc. (Pardo et al. 2004). Once the beans are stored, they must be inspected regularly, and the storage conditions must be kept safe. Some important factors for keeping grain safe are cleanliness of storage containers, absence of structural leaks, condensation and temperature. In coffee, managing the risk of OTA contamination involves key factors, including good hygiene practices along the production chain, rapid drying and avoiding the re-wetting of coffee by ensuring clean and dry storage and transportation (Pardo et al. 2004; Pitt and Hocking 2009). This paper highlights the integrated approach for controlling various factors which helps in deterioration of the beans, and the OTA free beans will deliver a better-quality product.

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3D Food Printing: A Technology for Fabricating Customized Artistic Food

25

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Abstract

3D food printing is a technology developed in combination with 3D printing and gastronomy and acts as a tool for fabrication of customized foods as per individual needs. With increasing public interest, this technique has the potential to turn out into the best approach for the fabrication of foods for personalized nutrition. The concept of artistic foods into the food processing sector could be possible through mass customization. The food products are printed by molding them in a layer-by-layer fashion in uniform quality without human intervention. It serves as a model for new product development and also has the capability to restructure the food supply chain by serving customers at a short time and economically, with fewer resources. However, the application of technology is still in a primitive stage and requires a study to investigate platform design, printing technologies, and their influences on food fabrication.

Keywords

3D food printing · Artistic food · Fabrication · Ethical issues

25.1 Introduction

In the upbringing of technology to revolutionize food deliverance, the three-dimensional (3D) food printing technology acts as a tool that is sharpened in our millennial. The scope of additive manufacturing using three-dimensional printing technology is vastly explored by research industries to achieve customized fabrication of food geometrics, color, shape, texture, flavor, material, and tailored nutritive

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components in and at one place cost-efficiently broadening the artisanal culinary sector. The food sector has shown significant research in understanding the future consumer's substantial requirements to explore next-generation technology such as three-dimensional food printing to experience new realms of food fabrication. Today online fast food delivery services have made our lives stress-free from cooking and grocery management at our home. Further a step ahead Moley Robotics, a UK-based company, has introduced a prototype concept artificial intelligence-assisted robotic kitchen. While we think how astounding the future will be with such advances in our culinary practices, every element of artificial food fabrication has been put in the creative minds of scientists. Digital food fabrication used to customize the confectinery shapes and colourful images onto suface of soild edible substrates (Zoran and Coelho 2011). This digital command is run to surprise the future. A preceding mechanism in the burger bot restaurant in San Francisco was set up by Momentum Machines featuring an automatic burger dispenser with processed and perishable ingredients. The ergonomy of fabricating a custom food is a three-dimensional entity where not only the recipe as information is fed to the interface but blueprints of the object are compiled and executed (Wegrzyn et al. 2012). The concept of customization in food means that any such blueprint data can be made by our own choice of material provided it holds the mere level of chemical and physical feasibility; a very similar cookie can be made at different total calories they provide (Lipson and Kurman 2013). The flexibility in such advances diversifies the spectrum of options in the kitchen also satisfying highly specific requirements. The evolution of 3D food printing has integrated subtractive and additive manufacturing methods like selective sintering, extrusion, power bed binder jetting, and inkjet printing technology which allows using different compositional phases of raw materials. An ideal meal plate can be achieved by the combinations of the manufacturing methods and exploring the properties of the raw materials. Edible growth matrix biscuits are part of experimenting creative food fabrication where a matrix of seeds and spores allowed germinating and budding out edible organic mushrooms and sprouts altering the flavor and texture of the matrix aided by a 3D printer to construct a biscuit over the matrix. Adaptation of 3D printing by industries will shift from centralized manufacturing units to manufacturing outlets reaching out closer to the final customers redefining the supply chain model by reducing volume transportations (Chen 2016; Jia et al. 2016; Sun et al. 2015). The sophisticated technology may scratch the way to a better future; therefore this chapter aims to understand better about the technical aspects of 3D additive manufacturing techniques. The strength, weakness, opportunity, and threat (SWOT) analysis for the 3D food printing technology was also discussed in brief.

25.2 Motive Behind the 3D Food Printing Technology

Mass customization in food fabrication gives low-efficiency products and high costs for manufacturing, but in the case of 3D food printer, it increases production efficiency and reduces construction cost. Robotics is an automated process; it takes the place of the manual process in food manufacturing industries. But 3D food printer also performs the same function and addition to that it also helps in manipulating the various food forms and material based on user's creativity and can control at the center of the process.

3D food printer satisfies the individual consumers' need by printing the food according to their nutritional dietary requirements. It controls calories, energy intake, protein, and fat content according to individual diet. 3D food printing helps in improving public health in the long term by providing good quality of food in a very short period.

25.3 Evolution of 3D Food Printing

Using stereolithography, Charles Hull created the first commercial 3D printer in the year 1984. In 2001, rapid prototyping and the manufacturing method for 3D food objects were patented by Nanotek Instruments Inc. There is no physical prototype. NicoKabler integrated the application of molecular gastronomy with 3D. Massachusetts Institute of Technology works under this 3D printer and used digital gastronomy into a food printer and introduced three designs. These designs are realistic and focused on mixing, modeling, and transformation.

The key skills of 3D food printing are geometric complexity and mass customization. 3D food printing is also called additive manufacturing because it adds ingredients into the printer directly, instead of taking it from away. It forms the layers of components using the ingredients. It mixes all the additives into a fine paste and makes intricate shapes which are tough to make by hands. 3D food printer uses CAD software so that 3D printer can handle easily by simply clicking the mouse button. In order to construct the food pieces, 3D food printer uses digital gastronomy and 3D techniques. The food product can be made at any place using design data files in a 3D food printer. Customers find food design online and send that design data to the nearby printing service where the product has been made and delivered to the customer. It takes very less time, has high efficiency and low costs and the product will be fresh and appealing.

25.4 Role of 3D Food Printing Technology in Food Fabrication

The decoration of food products like carving letter into cookies, frosted pattern of chocolates and biscuits, logo painting on foods are exceptionally received in the food sector in the current trend. Such decorated foods are made by trained artisans which tends to take a long time for preparation, and it is found to be more expensive than that of food products from mass production. Designing of traditional foods with advanced food processing technologies could not meet the demands of the consumers (Zoran and Coelho 2011). In order to bridge this gap, 3D food printing technology also known as Food Layered Manufacture (Wegrzyn et al. 2012) came into existence. The introduction of this technology helped in fabricating food products as per the need of the consumer with different artistic features and meeting the individual needs of the consumer according to their health conditions and nutritional intake.

In food printing, the products to be printed are preprocessed to make them suitable for printing and to obtain thermal stability during post-processing. Hence, the recipes that are used in printing are found to be slightly different than that of the traditional food recipes (Lipton et al. 2010). It is necessary that ingredients, which have very well-defined properties, need to tailor before each printing application.

25.5 Food Printing Platforms

Food printing platforms manipulate food fabrication in real time with the help of computer-controlled material feeding system. A food printing platform is basically comprised of three axis stages X-Y-Z (i.e., a Cartesian coordinate system), dispensing/sintering units, and a user interface. For food printing technology, both commercial and self-developed programs have been used.

25.5.1 Commercial/Universal Platforms

Commercial platforms have been extensively used in the food printing process for simplifying the development process and in reducing the development time. It is also used by researchers for producing quick 3D food shapes and in investigating the properties of the food products. But they are not used in in-depth researches as they are restricted to only certain materials.

25.5.2 Self-Developed Platforms

This platform is used by the researchers to support their researches related to the fabrication. The researchers can design the platforms in such a way to optimize food fabrication as per the requirement (Hao et al. 2010).

25.6 User Interface

User-friendly interfaces are built based on the knowledge level of the consumers and their requirements and also considering the platform development and working environments Lipton et al. (2010) and Malone and Lipson (2007) have tried in developing an open-access web-based template library which paves way for more innovations in food designs.

25.7 Printing Materials

The printing materials that are used in the food printing industry can be classified into three major types:

1. Natively Printable Material
   With the help of a syringe, natively printable materials can be extruded easily, and they are found to be more stable in holding the shape, even after deposition.
2. Nonprintable Traditional Food Material
   Pasta dough is the most successful printable traditional food material accounting to its viscosity, consistency, and solidifying properties (Fabaroni et al. 2007). Foods that are largely consumed by people such as Rice, wheat, meat, and vegetables are not printable by nature. Hence to make them extrusive, gastronomy tricks like adding hydrocolloids are being followed.
3. Alternative Ingredient
   Alternative ingredients include proteins and fibers extracted from algae, fungi, seaweed, and lupine. Agricultural and food processing residues can be modified into biologically active metabolites, enzymes which act as eco-friendly printing material source.

25.7.1 Food Printed Recipes

The recipes that are fabricated by food printing are classified into two types:

1. Element-based recipe printing
2. Traditional recipe printing

In element-based recipe printing, the fabricated food pieces are obtained by using a standard set of ingredients that control the color, taste, texture, and flavor. In traditional recipe printing, customized food fabrication is achieved by modifying the existing recipes. Combining both the element and traditional recipe printing will let us experiment diverse recipes and also lets the consumers/users to customize the shape and design of the food product to be fabricated.

25.8 Food Printing Techniques in Food Fabrication

The food products are processed and fabricated into various shapes and designs by 3D food printing through various techniques which are as follows:

1. Sintering technology

2. Extrusion technology
3. Power bed binder jetting
4. Inkjet printing technology

25.8.1 Sintering Technology

In sintering technology, both laser and hot air can be used as sintering (powdering) source for fusing powder particles and forming a solid layer. The sintering source (hot air/laser) is made to move in X-Y axis to fuse the powder particles. The fused surface is continuously covered by repeating the sintering process until a 3D object is formed. The sintered part forms the object, while the unsintered part supports the structure of the food object formed and then is recycled. Food materials with relatively low melting points such as sugar- and fat-based materials are suitable for performing this technology (Deckard and Beaman 1988).

25.8.2 Extrusion Technology

Crump (1991) describes the hot melt extrusion technique, which is also known as fused deposition modeling (FDM). From a movable FDM head, extrusion of melted semisolid thermoplastic material takes place which is then deposited on a substrate. The material is now heated slightly above its melting point so that the solidification of the material occurs immediately after the extrusion and molds into previous layers. Extrusion technology has its applications in creating personalized 3D chocolate products (Hao et al. 2010; Causer 2009). "Digital chocolateir," a functional prototype printer based on extrusion technology, used hot melt chocolate to fabricate customized chocolate candy (Zoran and Coelho 2011). 3D printers built based on extrusion technology have low maintenance cost and are compact in size. Long fabrication time and delaminating which occurs as a result of temperature fluctuations are some of the disadvantages that are needed to be taken care of.

25.8.3 Power Bed Binder Jetting

The fabrication platform is distributed evenly with each powder layer, and two consecutive powder layers are bind by liquid binder sprays. The disturbance caused by binder dispensing to the powder material is stabilized by water mist. To fabricate customized shape and complex structures, sugars and starch mixtures were used as the powder materials and a binder 3D printer as a platform for fabrication (Walters et al. 2011). Higher fabrication rate and low maintenance cost are found to be the advantages of the binder 3D printer, whereas rough surface finish and high machine cost are some of the disadvantages that have to be mentioned.

25.8.4 Inkjet Printing

This works on a syringe head platform which dispenses steam/droplet in a drop-on-demand way. 3D edible food products such as cookies, cakes, and pastries have to undergo multiple layers of processing for layer formation which also involves pre-patterning of food items.

In addition to 3D printing technologies, the introduction of established technologies such as electrospinning and microencapsulation will further improve the food printing process. In food science, electrospinning and microencapsulation are applied in extracting fibers and encapsulating nutrients, which are the sources of food printing. With the help of a multi-print head platform, the two technologies can be implemented in the food printing process, to control fibers and nutritional dispensing, which is a potential way to customize and fabricate on-demand food. 3D printing food technology is economical in small-scale production. It does not require any costly setup when compared to manually customized food fabrication. The quality of the fabricated food items is achieved by process and planning rather than skill and manpower. It can be easily controlled based on the consumer's demand. It can be said as a complementing technology to food processing.

25.9 Role of 3D Food Printing Technology in Personalized Nutrition

In the current trend, addressing the individual's nutritional intakes according to the person's dietary needs, allergies, or taste preferences is given more importance by the food industries rather than exploring existing nutritional preferences. Studies say that an individual's response to various nutrients might not be the same, and it also says that dietary components may show benefit/risk in a person's health according to his nature; hence personalized nutrition is the way through which an individual can make his dietary plan based on his health status and body type requirements. TNO, the Netherlands Organisation for applied scientific research, suggests that persons with varying dietary requirements such as elderly people, sportspersons, expectant mothers, and infants can have printed customized meals as per the need of protein and fat in their body (Gray 2010). A 3D edible gel printer using a syringe pump has been developed (Serizawa et al. 2014), for making easier consumption of food for the elderly people.

In traditional food production, making personalized nutritional foods might not be possible as it requires an additional cost and takes a long time. Marketing and distribution of such personalized foods look not feasible in many ways. In a technical perspective, it is a challenging task to prepare such personalized nutritional foods with controlled ingredient formulation.

Food printing can provide customized foods that can meet the needs and preferences of the individuals, and it enables precise control over an individual's diet by churning out healthy and fresh fabricated foods. By controlling the amount of food to be printed and calibrating nutritional ingredients during design, personalized nutritional foods are made by food printing. As the food can be printed in house/service stores, the additional costs for distribution can be reduced. Ingredients with well-known material properties have to be tailored to undergo food printing. It requires more effort to make such highly customized food products.

25.10 Advantages

25.10.1 Saving Time and Effort

3D food printing can save both time and energy when it comes to experimenting with cocktail garnishes or chocolate/sugar cake toppers. Even a trained pastry chef cannot achieve the perfection that 3D printing can.

25.10.2 Innovation in Healthy Food

Today, 3D printing has gone beyond the kitchen. Chloé Rutzerveld, a Dutch food designer, has used food printers to create cracker-like yeast structures that include spores and seeds that sprout with time. He feels that snacks like this and other such natural and transportable products will transform the food industry someday.

25.10.3 Food Sustainability

3D food printing has the ability to supply an ever-growing world population as compared to traditional food manufacturing systems. At the same time, food printers could also minimize waste with the use of hydrocolloid cartridges that form gels when combined with water. Even rarely used ingredients like duckweed, grass, insects, or algae can be used to form the basis of familiar dishes.

25.10.4 Personalized Reproducible Nutrition

As 3D food printers follow digital instructions, the idea of being able to make personalized food containing the correct percentage of nutrients for a particular age or gender does not seem so far-off. Food printers can easily help determine the exact quantity of vitamins, carbohydrates, and fatty acids as per the input, without any hard work.

Table 25.1 Recent advancements in 3D food printing

Food products	3D food printer specifications	Major findings	References
Lemon juice gel as a 3D food printing material	The major parts of the printer are as follows: 1. Feed hopper with augmented mixer and conveyor 2. An extrusion system 3. X-Y-Z positioning system using stepper motors Extrusion of food products is the basic principle under which the printer works	• Rheological property and mechanical property of lemon juice gel with 15 g/100 potato starch is found to be suitable for designing of 3D objects • In process optimization of 3D printing, factors such as nozzle diameter, nozzle movement speed, and the extrusion rate are found to affect the product quality • To obtain well-printed lines and exquisite products, it is necessary to consider the following parameters: the nozzle diameter (1 mm), the extrusion rate (24 mm^3 362/s), and the nozzle movement speed (30 mm/s) • A new equation is proposed to explain the relationship between the nozzle diameter, the nozzle movement speed, and the extrusion rate	Yang et al. (2018)
3D printed food pastes made from protein, starch and fiber-rich materials in the development of customized food products	1. Extrusion technology 2. Based on an air pressure controlled extrusion of the pastes through a nozzle (tip) of a syringe 3. Syringes with a volume of 3 mL were filled with the pastes prepared for the 3D printing	• Pastes containing 10% cold swelling starch, 15% SMP, 60% SSMP, 30% rye bran, 35% OPC, or 45% FBPC were found to give best printing results • Applicability of diverse food materials (e.g., cold swelling starch, milk powder, rye bran, oat and faba bean protein concentrates, cellulose nanofibers) in 3D food printing is a starting point for future development of healthy, customized 3D printed foods	Lille et al. (2018)
3D printed burgers, pizza	A 3D food printing machine named "Foodini" which works on the basis of fused deposition modeling, where the food materials are squeezed out of stainless steel capsules	• Wide range of dishes can be printed from sweet to savory • Time required for printing is usually faster than regular • 3D printing and food arranged in unusual shapes that require more dexterity and precision can be printed using "Foodini"	Prisco (2014)
3D printed chocolates	3DS's (3D Systems) CocoJet. CocoJet prints custom designs in dark, milk, or white chocolates	• In collaboration with Hershey's company, 3D Systems introduced CocoJet a chocolate 3D printer device, in order to create unique, exciting, and personalized edible experiences • CocoJet has been regarded as the "most advanced 3D printer chocolate in operation" • It has been called "ideal for the baker and chocolatier"	Horsey (2015)

(continued)

Table 25.1 (continued)

Food products	3D food printer specifications	Major findings	References
3D printed sugar, candies	3DS's (3D Systems) ChefJet Pro It uses extrusion technology (FDM, fused deposition modeling) It also makes use of powder 3D printing technology	• It creates candies and sweets with variety of flavor options • The complex geometries found in sugar structure are found to be accurately met by the ChefJet Pro 3D printer • The ChefJet Pro uses technology very similar to an inkjet printer to print a design on thin layers of sugar • ChefJet Pro features intuitive, chef-friendly digital cookbook software	Shukla (2015)
3D printed pizza	BeeHex's Chef 3D The liquified dough is applied by the nozzle layer by layer A pressurized system pushes each ingredient from the cartridges through the tubes and then out the nozzles	• As NASA was looking for a device that could easily make delicious, normal, unappetizing space food for future mars missions, BeeHex came forward in designing Chef 3D which will serve a possible solution in future • Chef 3D can produce any type of pizza • BeeHex's system can take any jpg file and turn it into a shape of a pizza • Customers can order pizzas through BeeHex app • The customers can choose the pizza's size, dough, sauce, and cheese as per their desire	Garfield (2017)
3D print chocolate, sugar, cookie dough, and icing	XYZ 3D food printing machine works on the basis of extrusion technology, where pressure injection method is handled	• This 3D food printer has been demonstrated in International CES 2015, Las Vegas, one of the largest gatherings for consumer technology in the world • The required design for the printed food can be chosen by imputing premade designs from the web or from a USB drive • The design can also be selected with a help of a touch screen which lets us choose the preset food shape easily • XYZ 3D food printer is found to be very economical which implies its usage in restaurants, bakeries, and private kitchens in the coming years	Alec (2015)

(continued)

Table 25.1 (continued)

Food products	3D food printer specifications	Major findings	References
3D printed pasta	Barilla 3D food printer—Firstly the 3D model in which the pasta has to be printed is downloaded. Then printer is loaded with cartridges of semolina dough. Then by allowing that to print the pasta is built layer by layer with the help of a nozzle that moves along *x*, *y*, and *z* axes, spitting out the dough in steady stream	• Barilla, world's biggest pasta company, hosts a competition every year to create innovative pastas for their 3D printer • Barilla built its own food printer by 2015 • Barilla focuses ultimately on innovation in 3D printed pasta • It insists on developing software that can sculpt forms which cannot be pulled off by mere hand or mechanical extruders • It also has its application in determining how geometry of the printer affects flavor and texture of pasta	Siniauer (2017)

25.11 Ethical Issues

Printing of meat is one of the controversial ethical issues faced by food printing technology. High-quality proteins can be obtained from 3D printed meat without increasing stress on arable land or fishing farms. However, vegetarians feel that printing of meat is unethical as it harms and results in the destruction of animals for food. The 3D printing was studied widely in last few years, even some of the 3D printed foods are commercially exploited in a successful manner. A brief summary on the list of recent findings related to 3D printed foods was listed in Table 25.1.

25.12 SWOT Analysis

25.12.1 Strength

1. 3D food printers can print food more attractive and appearance makes one's mouth watering (Sun et al. 2015).
2. By using individual biometrics, 3D printing can customize the nutrition of the same food for different people (Lipson and Kurman 2013).
3. But 3D food printer also performs the same function, and in addition to that it also helps in manipulating various food forms and material based on users' creativity and can control at the center of the process.
4. The food product can be made at any place using design data files in 3D food printer (Beetz et al. 2011).
5. Customers find food design online and send that design data to the nearby printing service where the product has been made and delivered to the customer.
6. It takes less time, has high efficiency and low costs and the product will be fresh and appealing (Winger and Wall 2006).

7. Food which is not edible in its natural form can be printed through the 3D printer, and one can get a meat protein from beet leaves and insects, where this change of replacement can be done by the 3D printer (Koslow 2015).
8. 3D printers can prepare food in a very short time, and moreover food won't be wasted and additionally, food will be more fresh and healthy.
9. Appearance and texture of the traditional food printing can be improved by controlling the macro- and microstructural levels in food materials (JelmerLuimstra 2014).
10. More multiplex and tremendous food designs can be made by using 3D food printing technology. Even an individual can prepare food from a 3D food printer by using prefixed data files (Sun et al. 2015).
11. 3D food printer provides different and complex shapes and structures and provides new flavors.
12. 3D food printer made the food supply chain easier and simple by reducing transportation space, packaging, distribution, and overall costs (Chen 2016; Jia et al. 2016; Sun et al. 2015).
13. Using high-fiber plant and animal-based products, a non-traditional food material has been used to print the 3D food (Payne et al. 2016; Severini and Derossi 2016; Tran 2016).

25.12.2 Weakness

1. 3D food printer is available in the market for household use, and it can make a product through simple layer-by-layer deposition of ingredients, whereas multi-material printing is still in early stages and its related projects, and area of this subject interest is still growing (Lipson and Kurman 2013).
2. Over the past 30 years, still 3D food printer technology is quiet growing, but the bad news is we haven't reached yet, but in recent years researchers are showing interest to study and innovate many new 3D food printer technologies. So our future looks brighter than the present situation.
3. The major weakness of the current 3D food printer is it consumes more energy. In the UK, Loughborough University researchers were working in "Atkins project" where they found that the consumption of electricity is more in 3D food printer than injection molding machines. Apart from that, they found that wastes from 3D food printers are considerably less, but it is due to it containing less material. If it is a support material, then at the end of 3D food printing process, user will discard it. If it uses supporting material as printing part, then the wastage will increase.
4. Initial expenses of 3D food printers are too costly. Especially capital investment setup for the single 3D food printer is high.
5. The ingredients used in the 3D food printer are more expensive than the ingredients of traditional manufacturing.
6. Food materials should be made into a paste form before entering into the 3D food printer, and it is a time-consuming process (Lipton et al. 2010). Food

components must be in a dry and stable state because most of the protein and dairy products can lead to spoilage. Therefore, 3D food printers suit only for a stable and dry product, and this is one of the major weaknesses of 3D food printer.

25.12.3 Opportunities

1. To feed astronauts for space missions, NASA expects that 3D food printing can be used to cook food in space (Terfansky et al. 2013).
2. In the coming future, the consumer can instantly make their ready-made meal, and there is no need to depend on food manufacturing and preparation. This leads to less labor connected with it which reduces the food cost as well as the labor cost. An individual can prepare their own food at any time according to their comfort in their home. 3D food printer is the next-generation kitchen appliance.
3. Storage costs for mass production have been eliminated once the 3D food printer is used.
4. 3D printing technology requires skilled designers and technicians so this leads to increases in job opportunities. For scientists working on geological and environmental contributions, who get to stay in isolated areas for their work, they might need 3D printed foods, as preparing foods on such an isolated area is a risky task to perform.

25.12.4 Threats

1. In 2013, Illinois Institute of Technology researchers found that the 3D food printers which are used in enclosed place can cause toxic emissions and have the potential to cause cancer. Ultrafine particles and dangerous volatile organic compounds have been produced during printing by the 3D desktop computers. This discharged radiation is the same as that of burning a cigarette and may cause health risks like cancer, asthma, and other ailments.
2. 3D food printers that are less in cost will produce more ultrafine particles and hazardous volatile organic compounds than the costliest one.
3. 3D printers print the food within a certain hour, and it removed most of the intermediate process involved in the food supply chain so there are no requirements of labors. So this leads to manufacturing job losses and also affects the country's economy that depends on this low-skill job.
4. Intimate fraudulence is one of the major threatening remarks of 3D food printing. The person who has the blueprint of the food design can copy it, and the finding of fraudulence is impossible so the patent holders who have a unique technique for producing products will suffer.
5. 3D printed foods are porous so there is a risk of bacterial growth. Due to this, the shelf life of the final product will be affected.

6. 3D printed food has lots of splitting so that it can be contaminated by bacteria very easily. Children will be subjected to bacterial infection when they come in contact with that 3D printed food.

25.13 3D Printed Foods in Space

Terfansky et al. (2013) conducted extensive research in developing 3D printed foods on space where their taste level remains on par with the taste in the earth. With the introduction of contour crafting technology, an offshoot technique of food printing, various experiments are conducted. They state that it is possible to make living in space a more tolerable one, by printing foods that are tastier and provide the same quality as provided in the earth, even though they are printed.

25.14 Conclusion

With 3D printers now becoming more affordable for the average consumer, 3D food printing stands to gain a lot from this newfound interest in the technology. Food printing manufacturers are already lauding the capability of 3D food printers to boost culinary creativity, nutritional and ingredient customizability, and food sustainability. Hence we conclude that 3D food printing technology will revolutionize the food industry sector in the near future with its unique features and unprecedented capabilities.

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