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Minimally Processed Refrigerated Fruits and Vegetables

Second Edition

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Editors

Minimally Processed Refrigerated Fruits and Vegetables

Second Edition

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*I dedicate this book to my mother, father,
wife, children, and grandchildren.*

Preface to the Second Edition

Never in the history of mankind were human food intake, nutrition, health, environment, and lifestyles so much interrelated and researched, as it is done today, in the twenty-first century. Never in human experience has food been available in this abundance and variety, as seen today, in the world. Humans (an average person) can eat convenient, refined, highly processed food with great speed, enabling them to consume about 3000 calories in 10–15 min. But, approximately, it takes a marathon (5 h) to burn 2600 calories (100 calories/mile/10 min).

Advances in food technologies in the last 200 years resulted in efficient food production and centralized, standardized processing systems, which enormously improved the general health, quality of life, and abundance of foods, eradicated many infectious and deficiency diseases, and increased life expectancy of majority of the people. Processing is accomplished by using one or more of a range of operations, including washing, grinding, mixing, cooling, storing, heating, freezing, filtering, fermenting, extracting, extruding, centrifuging, frying, drying, concentrating, pressurizing, irradiating, microwaving, and packaging. Recent advances in emerging food-processing technologies, such as high hydrostatic pressure or high-intensity electric field pulses, and minimal processing allow targeted and sophisticated modification and preservation of foods.

The researches in food science and nutrition over the last 200 years focused on five major areas:

(a) Basic nutrient (carbohydrates, proteins, lipids) preservation and microbial safety of foods.
(b) Micronutrient deficiency disease prevention with vitamins and minerals.
(c) Public health efforts at eradicating nutrient deficiency by the voluntary addition of iodine to salt (1922). The fortification of other foods were also used to address public health problems such as rickets (vitamin D), beriberi (thiamin), pellagra (niacin), and dental caries (fluoride) and folate fortification for pregnant woman diet (1998). Since the initiation of fortification policies in the United States, as in many parts of the world, clinically evident nutritional deficiencies have been virtually eliminated.

(d) Food and chronic diseases: the role of food in the cause of and treatment for chronic disease. Disease patterns shifted from infectious and nutrient deficiency diseases to increasing rates of cardiovascular disease, diabetes, cancer, obesity, neurological diseases, and osteoporosis.
(e) Nutrition for optimal lifelong health: superfood, phytochemicals, nutraceuticals, and bioactive food components.

The chronic conditions of cardiovascular diseases, cancers, neurodegenerative diseases, obesity, osteoporosis, arthritis, diabetes, and chronic respiratory diseases emerged as the major causes of morbidity and mortality. Nutritional and epidemiological research implicated food as a major factor in the etiology of diseases.

In response to consumer demand, the food processors produced a range of new processes and products; attention is being increasingly focused on food which can confer specific health benefits, so-called functional foods, superfoods, phytochemicals, and nutraceuticals, whose further development may help the population to attain even greater health in the twenty-first century.

Foods rich in whole and unrefined vegetables, fruits, legumes, nuts, and seeds contain high concentrations of antioxidant phenolics, fibers, and numerous other phytochemicals that may be protective against chronic diseases. Whole foods are foods that are unprocessed or minimally processed, before being consumed.

Minimally processed refrigerated (MPR) fruits and vegetables are fresh, raw, whole or cut, safe foods which are usually processed and sold to consumers in a ready-to-eat, ready-to-use, ready-to-cook, ready-to-serve forms (Wiley 1994). The fresh-cut produce industry has been the fastest-growing portion of the food retail market during the past 10 years, providing consumers with convenient and nutritious food. However, fresh-cut fruits and vegetables raise food safety concerns, because exposed tissue may be colonized more easily by pathogenic bacteria than intact produce. This is due to the higher availability of nutrients on cut surfaces and the greater potential for contamination because of the increased amount of handling.

This book is an outgrowth of our research and studies at the University of Maryland, USA; INRA Avignon, France; and the METU, Turkey, over the last 35 years. The first edition of this book was the first book written on the subject of minimally processed fruits and vegetables, about 25 years ago. It was and still is a new major development in food science.

This volume contains 4 parts and 22 chapters. The book starts with an introduction and definition of the concept. The first part deals with the fundamentals of minimal processing technologies in seven chapters. The second part of the book gives some common commodities currently minimally processed in the market in eight chapters. The third part has three chapters and gives information about the emerging and new technologies in the sector. The fourth part of the book gives some information related to safety, health, and nutritional aspects of the minimal processing in five chapters.

This volume is written for food processors, engineers, and technologist, as well as nutrition experts, medical doctors, consumers, regulatory officials, graduate and undergraduate students, researchers, and other stakeholders on the subject.

I hope the book will serve to its purpose by and large.

Gölbaşı, Ankara, Turkey
January 10, 2017

Fatih Yildiz

Preface to the First Edition

The objective of this book is to introduce, organize, and document the scientific, technical, and practical aspects involved with the manufacture, storage, distribution, and marketing of minimally processed refrigerated (MPR) fruits and vegetables. The overall function of these foods is to provide a convenient, fresh product for food service and retail consumers. High levels of quality accompanied by superior safety are essential requisites of MPR fruits and vegetables. Since refrigeration or chilling is essential to the quality and safety of these food products, "refrigeration" is included in the title of this book, i.e., *MP Refrigerated Fruits and Vegetables*.

This *swiftly* emerging area of processing requires organization and unification of thinking concerning fruit and vegetable food products which are not considered commercially sterile from a classical standpoint. Fruits and vegetables require very special attention because of the multitude of enzymic and respiratory factors as well as microbiological concerns which impact on the safety of low-acid and acidified vegetables and on the economic viability of high-acid fruit products of all kinds.

The name of this field, minimally processed (MP) fruits and vegetables, deserves attention in that there is little agreement among processors, produce dealers and merchants, and research workers regarding the proper term for these products. Many names are used as synonyms for MP fruits and vegetables, and these include ready-to-use, precut, lightly processed, fresh-cut, etc.; I think it behooves the food industry to settle on a single name and agree on a standard definition of this product. Doing so would benefit research and development efforts, data base searches, nutritional information needs, and the like.

The term "refrigerated" as opposed to chilled foods seems to be slightly confusing. These terms are synonymous, but probably one or the other should be selected to avoid confusion. Although the "chilled food" term may be easier to say than "refrigerated food," in the United States (US) at least, "refrigerated" may be more recognizable by consumers.

This volume is designed to serve primarily as a reference book for those interested and involved in the minimally processed refrigerated or chilled fruit and vegetable industry. There has been an attempt to bring together historical information available from many fields developed long before the concept of "minimally processed" foods was considered a viable field of endeavor. I have tried to gather as much knowledge as possible regarding this field but realize that there is much more research and development to be completed and that great opportunities exist in this area of food technology. The lack of information in certain areas has hampered the authors of some of the chapters. If I have been able to summarize the present knowledge of MPR fruits and vegetables and stimulate others to develop this important field in a uniform and concise manner, I think we will all feel successful.

I thank all of the contributors to this volume and thank the following individuals for reviewing chapters: Timothy P. Lydane, Imperial Produce; Dr. John Y. Humber, Kraft General Foods; Dr. Dennis C. Westhoff, University of Maryland; Dr. Harold R. Bolin, USDA-ARS; Dr. Bernard A. Twigg, University of Maryland; Dr. Charles A. McClurg, University of Maryland; and Dr. Charles R. Barmore, W.R. Grace and Co. Thanks also go to Kathleen Hunt, Robert Savoy, Lovant Hicks, David Jones, Ester Lee, and all others who read manuscripts, worked with tables and artwork for figures, entered information and data into the computer, and generally made this volume possible.

Finally, I thank Joy Wiley for her help and encouragement during the time that this work was being produced.

Robert C. Wiley, September 22, 1993

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Prof. Dr. Fatih Yildiz Dr. Yildiz received his B.S. degree from Atatürk University in Erzurum, Turkey. He started his postgraduate studies at the University of Wisconsin, Madison. He got his M.S. and Ph.D. degrees in food biochemistry from the University of Maryland in the USA. He worked as a faculty member at the University of Maryland for 5 years. He was the founding faculty member of the Department of Food Engineering, Department of Biotechnology, and Department of Biochemistry at the Middle East Technical University, Ankara, Turkey. Dr. Yildiz worked as a professor at the University of Minnesota, Department of Food Science and Nutrition, in the USA. He also has done research at INRA, France, as a visiting professor. He supervised more than 120 graduate students in these universities.

He has done research projects with FAO, UNIDO, UNICEF, OECD, and NATO as project director in the past.

Currently, he is the director of the Mogan International Research Center, Ankara, Turkey, giving lectures, organizing conferences, and supervising projects throughout the world.

Dr. Yildiz has published more than 150 research and review papers, in international and national journals, and chapters in several books as the major author, in addition to editing four international books. He was the coauthor of the book entitled *Minimally Processed and Refrigerated Fruits and Vegetables* published in 1994, which was a new concept in the food industry. He is the editor of the first book entitled *Phytoestrogens in Functional Foods* published by CRC and *Advances in Food Biochemistry and Development and Manufacture of Yogurt and Other Functional Dairy Products*. All these books brought new dimensions to food science.

His current research interests include health (phytochemicals), nutrition, and safety attributes of foods. He is the editor in numerous journals and a member of 10 scientific and academic organizations in the USA, EU, and Turkey. Dr. Yildiz is married, has two children, and three grandchildren.

Prof. Dr. Robert C. Wiley Robert Craig Wiley is professor emeritus at the University of Maryland, College Park, Department of Nutrition and Food Science and Department of Plant Science & Landscape Architecture. He got his B.S. and M.S. degrees from the University of Maryland, Department of Horticulture and Food Science, and his Ph.D. degree in food technology from the Oregon State University. Dr. Wiley authored or coauthored over 120 technical papers, book chapters, or books covering technology of fruit and vegetable processing, thermal processing systems, food engineering, membrane technology, enzymology, polysaccharides, postharvest physiology, food safety, quality measurement, and government regulations. Currently, Dr. Wiley lives with his wife at the South of Annapolis, Maryland, USA

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Part I
Fundamentals

Chapter 1
Introduction to Minimally Processed Refrigerated (MPR) Fruits and Vegetables

Robert C. Wiley and Fatih Yildiz

1.1 Introduction

Minimally processed refrigerated (MPR) fruits and vegetables are an important and rapidly developing class of foods. These convenience foods are being produced by unique applications of the basic and food sciences and their supporting technologies and engineering. MPR fruits and vegetables have attracted the interest of many facets of the food industry including such diverse areas as food manufacturers, retail food stores (deli departments), restaurants, carry-out establishments, and commissary units. Much of the developmental work in this field is now being carried out in western Europe, Japan, and the United States in response to strong consumer demand, both individual and institutional, for new types of like-fresh high-quality convenience and safe foods. The purpose of MPR foods is to deliver to the consumer a fresh-like fruit or vegetable, product with an extended shelf-life, and at the same time ensure food safety and "maintain sound nutritional and sensory quality. MPR fruits and vegetables received their original impetus from institutional users, but retail applications are gaining favor and are expected to expand rapidly.

Many countries are making significant strides toward solving the myriad of problems associated with the manufacturing, distribution, and marketing of MPR fruits and vegetables.

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This progress appears to be due to strong governmental and food industry support for MPR food applications, a conducive regulatory climate in preparation for the expanding food markets that will be available within the European Community (EC) since the trade and monetary barriers are removed.

It is clear that investigators in the fields of food science, nutrition, technology, related disciplines, and engineering have studied and conducted research on the various facets of MPR food for many years, especially in the cold preserved and raw fresh foods areas (Fig. 1.1). The early work by Smock and Neubert (1950) on controlled atmosphere (CA) storage of apples is a good example of the type of research that is now utilized and is being greatly refined with regard to MPR fruits and vegetables. It is now time to look at this field as a concise discipline investigating the continuum of product flow from harvest to consumption (Fig. 1.2). As seen in Fig. 1.2, the discipline effectively links product production (horticulture production) with manufacturing, packaging, distribution, and consumption. See Morris (1991) and Anon (1991) for good manufacturing practices (GMP) and Hazard Analysis Critical Control Point (HACCP) Systems for MPR fruits and vegetables and chilled foods in general. A unified approach and thinking of MPR foods as a specific food preservation industry/method as contrasted to canning, freezing, or drying would greatly assist in its development, which is now growing rapidly in many parts of the world.

As shown in Fig. 1.1, the major differences between MPR fruits and vegetables and raw fruits and vegetables are the rather specific processing and preservation steps taken with MPR foods. The MPR fruits and vegetables are usually living respiring tissues (Rolle and Chism 1987), but respiration is greatly "increased by cutting, slicing, low temperature heat treatments, and preservatives (Figs. 1.3 and 1.4, Anon 1989a). As seen in Fig. 1.3, the intact cell is expected to be much more resistant to oxidative browning and entrance of bacteria as compared to the cut cell. Figure 1.4a shows the intact vegetable product in a package, and Fig. 1.4b shows the condition of some cut surface cells with the majority of intact interior cells. The latter situation may greatly complicate the modeling of gas exchange in polymeric packages as suggested by Mannapperuma and Singh (1990). Refrigeration and packaging may be optional for raw fresh intact fruits and vegetables but are mandatory for MPR fruits and vegetables.

In this book, the attempt is made to differentiate between intact fresh fruits and vegetables and MPR fruits and vegetables even though the latter are somewhat difficult to define exactly. For example, whole intact apple fruit in CA storage, described by Smock and Neubert (1950), would not be considered an MPR product, whereas sliced, refrigerated apple slices treated with ascorbic acid and calcium salts (Ponting et al. 1972) would easily fall into the MPR category. As seen in Fig. 1.5, the vacuum-infused peeled oranges prepared using pectinase are a good example of minimally processed fruit Baker and Bruemmer (1989). The fruit can be segmented or handled in a tray pack as a whole fruit. Waldorf salad with diced apples, celery, walnuts, etc., in a dressing and sous vide with a portion of prepared fruits or vegetables would be considered an MPR fruit and vegetable product to carry the concept

Food Preservation and Processing Categories	Not Preserved, May be home Cooked	Minimally Processed, Refrigerated,May Be Home Cooked	Cold Preserved, Processed Frozen Storage, May be Home Cooked	Irradiation, electronic processing methods	Dehydrated	Heat Processing Canning,Sterilization, Pasteurization,Ultra High Temperature Processing,Frying	*Non-thermal and Electrotechnologies of food processing and preservation
Food Quality Color,Flavor, texture	Fresh	Like-Fresh	Slightly to fully Modified**	Slightly Modified**	Slightly to Fully Modified**	Fully Modified**,but Safe, no microbial contamination	Slightly Modified**
Storage, Shelf-life	May not be refrigerated	Requires Refrigerated, Transportation, Storage	Requires Frozen or Refrigerated storage,Transportation, and Market display	Requires Refrigerated storge	Shelf Stable at Ambient Temperatures	Long Shelf life at Ambient Temperatures	Shelf Stable, requires Refrigerated Transportation, Storage
Packaging	May not be Packaged	Requires Packaging	Requires Packaging	Requires Packaging	Requires Packaging	Requires Hermetic, Aseptic packaging	Requires Packaging
Cell Integrity	No Change	No change	Changes	Changes	Changes	Total destruction	Changes
Enzymes(Activity and structure)	No Change	No Change	Changes	Changes	Changes	Total destruction	Changes
Phytochemicals, Vitamins, Proteins	No Change	No Change	Changes	Changes	Changes	Highly changed	Changes
Dietary Advanced Glycation End Products(dAGEs), Formation before home cooking	None	None	Some dAGEs formation	dAGEs formation	dAGEs formation	High Quantity of dAGEs Formation	Some dAGEs formation
Free Radical Formation	None	None	Some Free radical	Free radicals formation	Some Free radicals fomation	Free radicals formation	Free radicals formation

*Non-thermal and electrotechnologies of food processing and preservation includes:
a-High Pressure, Ultra-high Pressure(HPP), b-Plasma, c-Pulsed Light and Pulsed electric fields, d-Ohmic Heating, e-Ionizing radiation, f-Pulsed X-ray, g-Ultrasound, h-High-voltage arc discharge, i-Magnetic fields, j-Dense phase carbon dioxide, k-Microvawes, l-Electron Beam Processing.
**Product Freshness

Fig. 1.1 Spectrum of food preservation systems related to minimally process refrigerated (MPR) fruits and vegetables (*Product freshness)

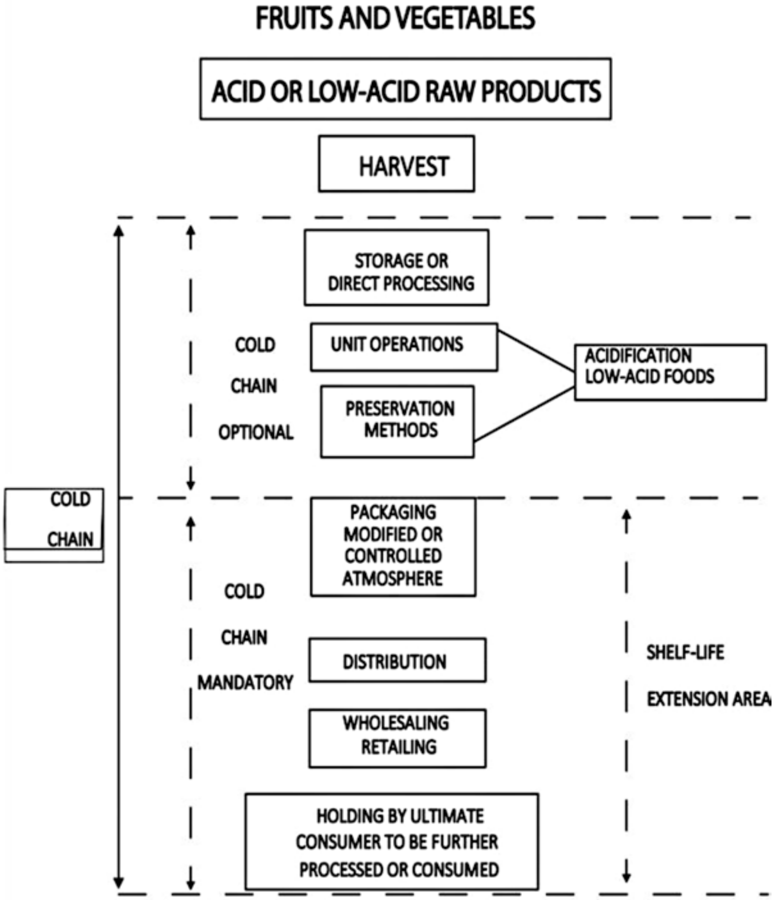

Fig. 1.2 General flow sheet for minimally processed refrigerated fruits and vegetables

into prepared foods. See Part 2 for an extensive listing of MPR fruits and vegetables.

A more difficult to define, gray area might involve the classification of washed, waxed cucumbers. These products would probably not be considered MPR foods because although they are packaged (waxed), they are also intact." Waxed intact cucumbers could be contrasted with precut or sliced cucumbers which have a relatively short shelf-life and are considered MPR foods. MPR fruits and vegetables should not include fresh intact fruits and vegetables which may undergo normal postharvest handling treatments such as sizing, grading, washing, waxing, CA, or modified atmosphere (MA) storage (see Fig. 1.1).

Frozen foods make up a portion of products normally classified as cold preserved foods. However, MPR foods are dissimilar to frozen foods in that frozen foods must be transported and stored at −10 °C or lower, whereas MPR foods require cold-chain

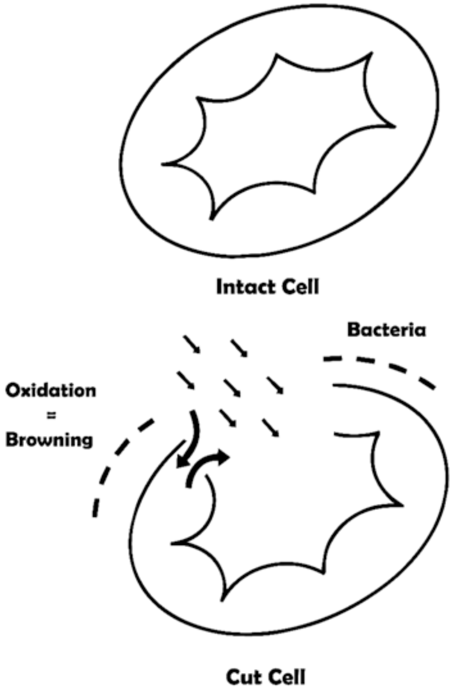

Fig. 1.3 Diagrams of intact and processed (cut) fruit or vegetable cell (From CTIFL, France)

refrigerated or slightly higher temperatures depending on the commodity or mixtures of commodities (Anon 1989b). The overall quality of frozen food is different than the like-fresh quality of MPR food. Many times the consumer can discern differences in texture between frozen and MPR foods. Some manufacturers of sous vide meals, for example, freeze their product, which makes the meal little less than a frozen food in most respects.

MPR fruits and vegetables are different from dehydrated fruits and vegetables in terms of texture and water activity (a_w). MPR fruits and vegetables which normally have a_w around 0.97–0.99 are very sensitive to a_w reduction. However, preservatives such as ascorbic acid and citric acid used on dehydrated fruits and vegetables are also used on MPR fruits and vegetables. Dehydrated foods are considered shelf-stable at ambient temperatures and thus do not require the cold-chain delivery system used for MPR foods (Fig. 1.2).

An important difference between MPR and thermally processed foods is that MPR foods do not exhibit "commercial sterility" as defined for thermally processed foods. This definition states thermally processed foods are free of microorganisms capable of reproducing under nonrefrigerated conditions and that no viable microorganisms (including spores) of public health significance can reproduce. This "sterility" may be acquired by control of water activity, reducing pH, or application of heat. There is some likelihood that the "commercially sterile" concept may be assigned to those MPR fruits and vegetables that are deemed to be safe. The microbial and

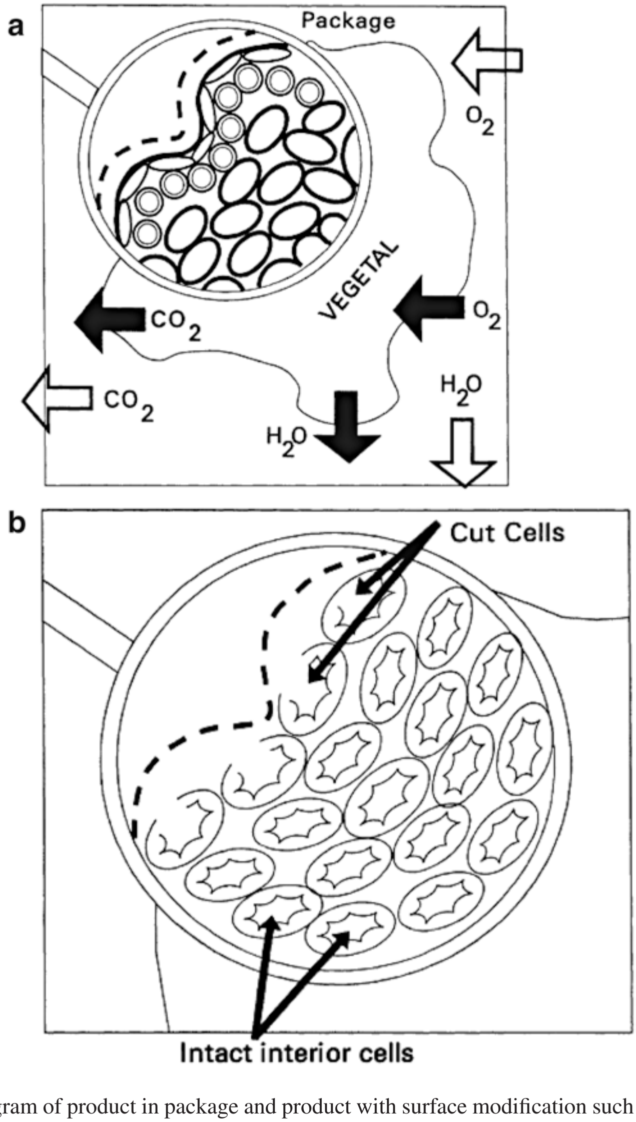

Fig. 1.4 Diagram of product in package and product with surface modification such as from peeling or slicing (From CTIFL, France)

enzyme limits for "commercial sterility" or "microbial and enzymatic safety" of MPR fruits and vegetables are yet to be developed, if in fact this term is accepted and is germane to these foods. Thermally processed food cannot be claimed to be like-fresh. Nevertheless, the tremendous amount of research conducted on handling, processing, and preservation of fresh, frozen, irradiated, dehydrated, and thermally processed fruits and vegetables can be applied where appropriate to the relatively new concept of MPR foods Kader (1986), Kantor (1989).

Fig. 1.5 Example of vacuum-infusion peeling of oranges by pectinase (From Agricultural Research Service, USDA)

A major advantage in the development and careful classification of MPR foods is that they provide a basis for separation of the traditional cold preservation field, as described by Potter (1968), into two distinct areas, that is, frozen foods and refrigerated foods. As shown in Fig. 1.1, separation of these two areas would greatly simplify the frozen food/refrigerated food classification by placing all frozen foods together and all refrigerated foods in a refrigerated category (Appendix 1). No doubt refrigerated as well as other preservation categories should be subclassed into commodity and prepared foods areas. One noticeable difference between MPR fruits and vegetables and many other refrigerated foods is the "living tissue" concept which must be considered in dealing with certain types of MPR fruits and vegetables. The shelf-life of MPR fruits and vegetables also should be limited to 3–6 months from harvest to consumption due to the living tissue and active enzymes concept.

There is a need to update and organize current information developed over many years of research in food science and technology that may apply to MPR foods. In addition, there are demands for research to make MPR foods comparable to the currently more actively used preservation methods for which so many food processing industries are named. The food industry seems interested in making the large family of MPR foods more intensively competitive. It would require several volumes to cover adequately the various food product types that could be interpreted as using the technologies and packaging systems required to produce MPR foods. To narrow the scope of this volume, emphasis will be placed on MPR fruits and vegetables, although in some chapters of the book, particularly in the regulatory and quality control areas, it is difficult to separate MPR fruits and vegetables from other MPR foods. This burgeoning area of food science requires the expertise of horticulturists, plant physiologists, molecular biologists and pathologists, biochemists, biotechnologists, microbiologists, food scientists, and food engineers and packaging experts, to name only a few specialties. A truly interdisciplinary effort will be needed to deliver to the markets MPR fruits and vegetables that will have extended high-quality shelf-life beyond 8–10 days, which is usually satisfactory for the retail European market. MPR fruits and vegetables will probably require a minimum shelf-life of 21 days to compete satisfactorily in US markets (Lioutas 1988). This author is likely referring to name-brand products requiring national distribution and not to regional operations.

1.2 Definitions of MPR Fruits and Vegetables

There have been a number of articles which have defined minimal processing. For example, Rolle and Chism (1987) suggest that minimal processing "includes all unit operations (washing, sorting, peeling, slicing, etc.) that might be used prior to blanching on a conventional processing line." They feel all these products are living tissues. A slightly different approach was taken by Huxsoll and Bolin (1989) in which they felt the "minimally processed product is raw and the cells of the tissues are alive but these characteristics are not required." There was no agreement on the definitions for minimally processed fruits and vegetables at a recent American Chemical Society symposium (Hicks and Sapers 1991). Cantwell (1991) for one, at the symposium, called these products "cut fruits and vegetables which are lightly processed."

It is generally conceded that MPR fruits and vegetables are products that contain live tissues or those that have been only slightly modified from the fresh condition and are fresh-like in character and quality. These tissues do not exhibit the same physiological responses as normal (raw) untreated intact live plant tissues (Fig.1.3 and 1.4). The cutting, abrasion, or minimal heating of these tissues can cause broadly different responses in various environmental and packaging situations. However, some fruits and vegetables that show little or no physiological activity should also be included in the MPR category. The cold preservation category (Fig. 1.1) now encompasses some of these types of foods. MPR fruits probably should include products such as chilled peaches in glass containers in which complete inactivation of cellular metabolism has recently occurred, and the product has been quickly transferred to the market in the cold chain. Sous vide dishes which may include preheated vegetables or fruits should be included in the MPR food area. In terms of physical state, the tendency has been to include only solids, semisolids, and semiliquids as MPR fruits and vegetables, but refrigerated liquids both cloud and clarified juices should be included in this class of foods. The freshly squeezed orange juices and others that are chilled and packaged in plastics, paperboard, or glass are good examples of this type of product. This type of food should probably be included with refrigerated fruit and vegetable products under the like-fresh minimal processing column (Fig. 1.1). The USFDA is still considering whether these products should be labeled fresh.

MPR fruits and vegetables (for the purposes of this book) are defined as those prepared by a single or any number of appropriate unit operations such as peeling, slicing, shredding, juicing, etc., given a partial but not end-point preservation treatment including the use of minimal heat, a preservative, or radiation. The preservation or hurdle treatment may include pH control, antioxidants, chlorinated water dips, or a combination of these or other treatments (see Chap. 3). It is important to take advantage of the synergies of all preservation treatments. The initial preparation and preservation treatments are usually followed by some kind of controlled/modified atmosphere and vacuum packaging and subjected to reduced temperatures above the freezing point during storage, distribution, marketing, and just prior to preparation for consumption. For safety and greatest retention of sensory and nutritional quality, these products must be distributed and marketed in the cold chain.

Some precut fruits and vegetables (examples are cucumber, eggplant, tomatoes, and tropicals, and subtropicals) have to be handled at higher temperatures to avoid chilling injury (Appendix, Tables 2 and 3). It should be clear that MPR fruits and vegetables are not intended for ambient shelf-life stability as expected from canned, retorted, or aseptic processed and packaged fruits and vegetables. Nor are they protected from spoilage or quality changes by freezing and being held in frozen storage. There is a need for *agreement* by workers in the food field as to the proper description (title) for these foods and definitions thereof. To be successful, MPR foods will have to be of high quality, convenient, healthier, fresh-like aroma, active phytonutrients, and safe and reduce the risk of chronic diseases. Currently, there is no other food processing methods that have all these properties.

1.3 Quality of Minimally Processed Fresh Produce and Other Plant Foods

Several parameters affect quality and shelf-life of MPR produce from field to the fork as summarized in Table 1.1 and Fig. 1.6. Quality aspects of MPR fruits and vegetables are studied and published by many researchers (Mercedes Diaz-Mendoza et al. 2016; Anna Kårlund et al. 2014). Leaf senescence is a physiological process critical for plant survival. It is characterized by the dismantling of cellular structures, massive degradation of macromolecules, and efficient relocation of nutrients from senescing leaves to growing tissues or sink organs. Shelf-life extension will be very closely related to the control of senescence and cell membrane peroxidations in MPR fruits and vegetables (Mercedes Diaz-Mendoza et al. 2016; Yildiz et al. 2007).

Health-promoting quality of minimally processed fruits and vegetables has been emphasized by many researchers in many countries in the last 20 years (Crowe et al. 2011; Carter et al. 2010). There is an increasing epidemiological and experimental

Table 1.1 Summary of the factors affecting total quality of the MPR fruits and vegetables

Parameters	Affects
Preharvest agricultural practices	Composition, phytonutrients
Growing crops practices	Size, shape, scars, pesticide residues
Harvest practices	Maturity, brix/acid, color
Postharvest handling	Mechanical damage, biochemical changes
Processing	Microbial growth, browning, weight loss
Packaging, handling, and storage	Spoilage, weight, loss, softening, surface drying
Physiological changes from harvest to fork (respiration rates of F&V O_2/CO_2)	Senescence, changes in respiration rates, ethylene production, yellowing, loss of water, size changes, loss of phytonutrients, shelf-life

Fig. 1.6 Senescence of broccoli (changes in lipids, chlorophylls, chloroplast, ethylene, and proteins metabolism during postharvest storage, yellowing)

data indicating that the consumption of vegetables and fruits confers many health benefits (Hughes et al. 2010; Cho et al. 2010). There are more than 10,000 phytochemicals in plant foods which include antioxidants, anti-inflammatory substances, and many others (Trim 2006; World Cancer Research Fund/American MPR) fruits and vegetables:Institute for Cancer Research 2007). For example, polyphenols are antioxidants and cardioprotective in humans (Anna et al. 2014).

1.4 Approach to Studying MPR Fruits and Vegetables

It is becoming increasingly recognized that low temperatures are not the defenses against foodborne illnesses that were previously accepted by the food industry and governmental agencies. The emergence to prominence of non-spore-forming psychrophilic pathogens such as *Listeria monocytogenes* and *Yersinia enterocolitica* can cause enormous problems in refrigerated foods (Chap. 19). Many vegetables, mushrooms, and legume sprouts are considered to be low-acid foods by the USFDA (pH 4.6 and over); thus, special measures will have to be taken to make these types