Molecular Techniques in Food Biology
Molecular Techniques in Food Biology

Safety, Biotechnology, Authenticity and Traceability

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WILEY
To my beloved wife, Omnia who has been an excellent intellectual companion and renewable source of inspiration for me

To my wonderful sons, Omar and Moaz who motivated me

Aly El Sheikha
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Preface

With increasing population size and heightened awareness of food quality, safety, and authenticity, food production and food safety have never been more important in human history. Over the decades since the introduction of molecular biology, significant improvements have been made to enhance food production, enrich food nutrition, and increase food quality and food authenticity. This book describes recent advances in food biology from the viewpoint of the development and use of molecular techniques. Our focus is the microbes associated with food and food products and the diversity of microbe-food interactions.

*Molecular Techniques in Food Biology: Safety, Biotechnology, Authenticity & Traceability* presents a summary of the broad microbe-food interactions, covering food microbiology, food mycology, biochemistry, microbial ecology, food biotechnology and bioprocessing, food authenticity, food origin, and food science and technology. Particular emphasis is placed on how modern molecular techniques have been and can be used to enhance food biology research, to help monitor and assess food safety and quality, and to establish effective food traceability and inspection systems.

The book comprises 19 chapters, broadly divided into six sections. The first section contains five chapters that deal with general topics to provide a global overview of safety, biotechnology, authenticity, and traceability issues related to plant- and animal-based foods. The second section includes two chapters on the molecular techniques used in studying microbes found in fruits and vegetables. The third section consists of two chapters dealing with the assessment of microbial ecology of non-fermented fish and meat products at the molecular level. The fourth section includes five chapters capturing the excitement of recent advances in molecular approaches made to decipher the microbial mechanisms in fermented foods and beverages. The fifth section comprises four chapters covering the detection of foodborne pathogens by new molecular strategies. The last chapter provides an overview of the current status and future prospects of molecular food fingerprinting.

An emerging theme among these chapters is that the detection, differentiation, and identification of microorganisms associated with food are ambiguous when they are exclusively based on morphological, physiological, and biochemical characteristics. The application of molecular tools has vastly enhanced our ability to identify these microbes and analyze their activities. In addition, there is increasing recognition that a systematic view of food products is needed in order to reveal the complexities of microbe-food interactions. These complexities include the changing trophic relationships among interacting organisms throughout the food production process. For example, beneficial
microbes can help plant and animal growth while pathogenic ones cause diseases and deter their growth. During harvesting, environmental microbes from their immediate environments are introduced which could cause spoilage. During the preparation of fine processed food, microbes and/or microbial enzymes are often needed to achieve desirable properties. Throughout these processes, microbes leave their signatures on the food that can be used for tracking and authentication purposes. For contaminated foods associated with disease outbreaks, analyses of microbial communities and populations are needed to help track the origins and spread of the specific pathogens.

We are fortunate to have experts from diverse backgrounds and agencies contributing to this book. They bring perspectives from academia, research institutes, industry, and government agencies. We believe the book will be a useful reference for research scientists, regulatory authorities, food microbiologists and technologists, epidemiologists, biotechnologists, food manufacturers, policymakers involved in food regulation, and the general public interested in food biology.

_Aly Farag El Sheikha_
_Robert E. Levin_
_Jianping Xu_
The work presented here represents a collective effort from many individuals. We are indebted to all contributors who have so willingly offered their time, effort, and expertise in making this book a reality. Without their cooperation, enthusiasm, and timely submission of the chapters, this work would not have been possible.

The Editors wish to thank all the researchers whose contributions were cited in this book. We also want to thank the earlier pioneers whose work enabled the applications of the diversity of molecular techniques in food biology.

Special thanks to John Wiley & Sons Limited for publishing this book. We are indebted to David McDade, Publisher (Life Sciences), who initiated the discussion about the book with Aly El Sheikha. We are thankful to Bella Talbot, the Senior Editorial Assistant, Athira Menon, the Project Editor, Kavitha Chandrasekar, the Senior Production Editor, and Holly Regan Jones, the Copy Editor for sparing no pains to ensure a high standard of publication.
Section I

General Topics
1

How to Determine the Geographical Origin of Food by Molecular Techniques

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1.1 Linkage Between Food and Its Geographical Origin: Historical View

Historically, food products have always been linked with a specific geographical origin. Regional product identities have a long history. In ancient Egypt, places of origin were used to identify products and to signal their quality. In the Middle Ages, European guilds gave their products certain names to ensure consumers got consistent quality, assure market exclusivity, and protect producers legally (Institut National des Appellations d’Origine [INAO] 2005). The history of some well-known cheeses can be traced back to this period, for example Parmigiano Reggiano in Italy, Stilton in the UK, and Comté in France. The process of establishing a regional reputation went parallel with the emergence of the concept of individual brands. In both cases, producers tried to enhance their products’ value by associating consumers with a name: a single producer in the case of a brand, on a collective scale in the case of regional products (Boto et al. 2013).

Several regional products identified in the marketplace by geographical names date from the 19th century, including Opperdoezer Ronde potatoes (Netherlands) and Washington apples (USA). While such regional indications remained important, their significance gradually shrank with time. National and international trade evolved, and technical grades and standards developed and became more important in trade. During the 20th century, internationalization expanded rapidly. The urge for economies of scale meant that certain regions began to specialize in producing a few products. Firms marketed their products over an ever wider area. Product specialization also occurred; instead of producing a broad product assortment, companies specialized in a few standard products. This mass production resulted in the loss of many unique, specific regional products. In time, the globalization of business and markets increased further (Boto et al. 2013).

By the late 1990s, a new geographical diversity of foods had emerged. While the globalization of trade in food produce continues apace, Europe has experienced an increasing interest in foods with local and regional identities. Local food production
systems have indeed been characterized by various strategies to promote local/regional food products (Goodman 2004; Ilbery & Maye 2005; Marsden et al. 2002; Murdoch 2000).

An image of the region and regional names are often used to market products that may have a strong reputation associated with their place of production (INAO 2005). As Bérard and Marchenay (2005) point out, products do not just “come from” a region; they “are” from a region. This means that they convey values and culture, that is, an identity. In general, these products have, to a greater or lesser extent, specific qualities based on human expertise and the natural environment where they are produced. The mix of these specific qualities and the regional image creates a unique identity for the product, therefore raising its value (van de Kop & Sautier 2006).

Food quality and authentication are becoming of primary importance for both consumers and industries, at all levels of the production process, from raw materials (farm) to finished products (fork). Moreover, consumers around the world have shown an increasing interest for typical food products with reliable indicators of geographical origin. Typical food products have an important economic role at both national and international levels, as confirmed by certifications and trademarks of quality (e.g., Protected Denomination of Origin, PDO; Protected Geographical Identification, PGI; and Traditional Specialities Guaranteed, TSG), assigned to guarantee typicity and quality standards (Longobardi et al. 2015).

Figure 1.1 highlights the significant stages in determining the geographic origins of products through human history.

1.2 Scope and Approach

This chapter focuses on how to determine the geographical origin of food. Figure 1.2 illustrates the scope of the chapter and the major issues related to determining the geographical origin of foodstuffs. The demand to know the geographical origin of food has been a driving force for implementation of determining the geographic origins of food. Technological innovations, the benefits of using molecular techniques, and the drawbacks of existing approaches are reviewed below.

1.3 Definitions Related to Tracking of Food Origins

1.3.1 Geographical Area

This is the area in which the production and/or processing take place. Generally, the limits of the area are defined by natural and/or human factors which give the final product its particular characteristics. Supporting documents, such as maps, must be provided (Patent Office of the Republic of Poland [PPO] 2010).

1.3.2 Regional Products

In a general sense, van de Kop and Sautier (2006) defined a regional product as a “local product based on a territorial identity and reputation, and/or a typical product based on specific mode of production and whose quality, reputation or any other characteristics
Figure 1.1 Developments in the history of geographical origin determination.

Figure 1.2 Analytic structure illustrating the scope of this chapter on determining the geo-origin of food.
are attributable essentially to its geographical origin.” The geographical origin can be a province, state, department or country, but also cross-border areas that are culturally, naturally or climatically similar.

1.3.3 Appellation of Origin (AO)

This term is defined through the World Intellectual Property Organization (WIPO 2013) as “The geographical name of a country, region, or locality, which serves to designate a product originating therein, the quality and characteristics of which are due exclusively or essentially to the geographical environment, including natural and human factors.”

Appellation of Origin was one of the earliest forms of Geographical Indication (GI) recognition and protection (WIPO 1979). Although mentioned in earlier treaties, the 26 contracting parties to the Lisbon System in 1958 first formally recognized the term “Appellation of Origin” as a form of GI, by using a single registration procedure, effective for all the signatories (Boto et al. 2013).

1.3.4 Geographical Indication (GI)

Geographical Indication is defined by the TRIPS Agreement 1994 as “Indication which identifies a good as originating in the territory of a member (country), or a region or locality in that territory, where a given quality, reputation or other characteristic of the good is essentially attributable to its geographical origin” (World Trade Organization [WTO] 2005).

1.3.5 Protected Designation of Origin (PDO)

The Protected Designation of Origin is for products closely associated with the area whose name they bear (European Commission 1992, Regulation No. 2081/92). Such a product must meet two conditions.

- Quality or characteristics of the product must be connected with the particular geographical environment of the place of origin; this environment includes inherent natural and human factors, such as climate, soil quality, and local know-how.
- Production and processing of the raw materials, up to the stage of the finished product, must take place in the defined geographical area whose name the product bears.

The PDO covers agricultural products that are produced, processed, and prepared in a given geographical area using recognized know-how. Well-known PDO products are prosciutto di Parma (ham) from Italy, Kalamata (olive oil) from Greece, and Camembert de Normandie (cheese) from France (Drivelos & Georgiou 2012).

1.3.6 Protected Geographical Indication (PGI)

Protected Geographical Indications also designate products attached to the region whose name they bear but the link is different from that between a product with a PDO
and its geographical area of origin (European Commission 1992). To be eligible to use a PGI, a product must meet two conditions.

● It must have been produced in the geographical area whose name it bears. Unlike the Protected Designation of Origin, it is sufficient that one of the stages of production has taken place in the defined area. For example, the raw materials used in production may have come from another region.

● There must also be a link between the product and the area which gives it its name. However, this feature need not be essential, as in the case of a designation of origin. It is sufficient that a specific quality, reputation or other characteristic be attributable to the geographical origin of a given product.

The PGI covers agricultural products and foodstuffs closely linked to the geographical area. At least one of the stages of production, processing or preparation takes place in the area. Typical products with recognized PGIs are Scotch beef from the UK, Calcot de Valls (onion) from Spain, and Budějovické pivo (beer) from the Czech Republic (Drivelos & Georgiou 2012).

1.3.7 Generic Name

A term or sign is considered “generic” when it is so widely used that consumers see it as designating a class or category name for all goods or services of the same type, rather than as referring to a specific geographical origin (Boto et al. 2013).

1.3.8 Food Safety

Food safety is defined as the style of preparing, handling, and storing food to prevent infection and to help ensure that food retains enough nutrients to support a healthy diet.Unsafe food means that it has been exposed to pathogens or is rotten, which can cause diseases or infections (e.g., diarrhea, meningitis, etc.) (El Sheikha 2015a; Food and Agriculture Organization of the United Nations [FAO] 2004).

1.3.9 Food Quality

Quality is a measure of the degree of excellence or degree of acceptability by the consumer. It can be defined as “a summary of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs” (FAO 2004). In simple words, the product should have attributes to “satisfy the wants/needs of the consumer or conformance with the user’s requirements.” Quality also covers safety and value for money.

Food quality can be considered as a complex characteristic of food that determines its value or acceptability to consumers. Thus it may be defined as “the composite of those characteristics which have significance in determining the degree of acceptability by the buyer. These characteristics should also have the ability to differentiate individual units of the product” (Leitzmann 1993). The important components of food quality are food safety, sensory characteristics, and nutritional value. Safety of food is a basic requirement of food quality.
1.3.10 Geo-traceability

Geo-traceability can be defined as the result of combination of geographic information and traditional data used in traceability procedures (El Sheikha 2010). In the agriculture-food sector and more particularly in the field of plant production, geo-traceability is concerned with the relationships between a production plot, its geographical location, its environment, and cultural practices. Geo-traceability requires the implementation of spatial analysis and information acquisition and processing tools that will be combined in geographic information systems (GIS) (GeoTraceAgri [GTA] 2005).

1.4 Driving Forces for Determining the Geo-origin of Food

There are many driving forces behind the development and implementation of technologies for determining the geographic origin of foodstuffs. These forces can be put into five different categories: why do people buy “origin” food products, safety and quality importance, regulatory focus, economic and social concerns.

1.4.1 Why do People Buy “Origin” Food Products?

Food consumption habits were created by the local natural resources and the social or cultural factors of the community (Delamont 1995). Such links between food and origin have disappeared over time, the main reason for this being globalization of the food industry, following the extensive growth in technology over the past century (Montanari 1994). This has led to a similarity of lifestyles across regions such that food consumption patterns within a region no longer necessarily reflect food production of that area (Ritzer 1996). However, in recent years, consumers have renewed their interest in food strongly identified with a place of origin (Drivelos & Georgiou 2012; El Sheikha 2015b). There are a number of reasons for this increasing interest, including organoleptic qualities, health, psychology (patriotism and confidence in the product), media information, and concern about animal welfare and environmentally friendly methods of production (Gilg & Battershill 1998; Mitchell 2001).

Figure 1.3 shows the interaction between consumers, food product, and origin.

1.4.2 Food Safety, Food Quality, and Consumer Protection Linked to Geographic Origin

Food scares have occurred throughout history. Atkins (2008) has discussed that, in Europe, food scares (especially zoonotic hazards) have been present in the UK for at least 150 years. Saltini and Akkerman (2012) mentioned that in Europe, foodborne illness affects about 1% of the population (approximately 7 million people) each year. In 2011, approximately 16.7% of the US population (47.8 million people) experienced food-related illness (Resende-Filho & Hurley 2012). Other types of food scare such as contamination with radioactive materials disturb the food supply chain. After the release of radioactive materials from damaged nuclear plants due to earthquake in Japan in 2011 (World Health Organization [WHO] 2011), many countries implemented intensive food control measures concerning their food trade relationship with Japan while some countries suspended food imports from Japan.