Food Toxicology

Part A

Principles and Concepts

Jose M. Concon

Food Toxicology

(in two parts)

PART A: PRINCIPLES AND CONCEPTS

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Food Toxicology

PART A: PRINCIPLES AND CONCEPTS

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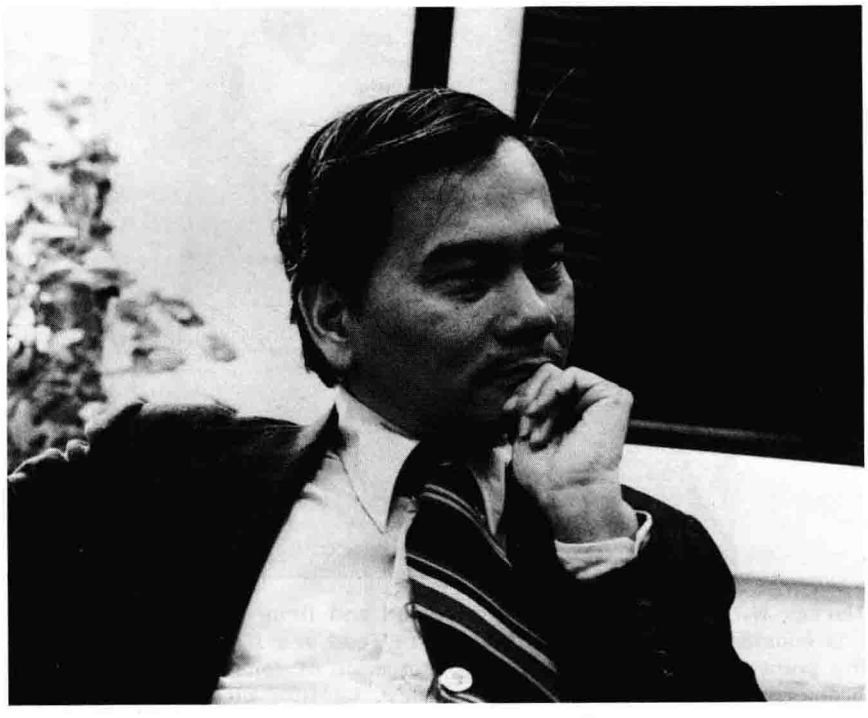

Jose M. Concon (1932–1984)

Dr. Harvey W. Wiley, head of the first Food and Drug Agency of the United States, 1907, is considered the "Father of the Pure Food and Drug Act," which marked a turning point in his untiring fight for protection of consumers. As consumers, we owe a sincere debt of gratitude to Dr. Wiley, because without such legislation many of the toxins and contaminants discussed in these books would be far more numerous in our nation's food supply and the nation would not have the degree of good health that it enjoys.

To my wife, Jayne,
whose untiring effort, love, and dedication
have made this book possible

Preface

At a meeting of the American College of Nutrition, the nutrition curricula in medical schools were being discussed. I asked one of the speakers why the subject of food toxicology was not included in any of the curricula. I added that it was unfortunate that the study of nutrition ignored the subject of food toxicants—or, at the most, treated it superficially. "Do you know of any comprehensive book on the subject?" he asked. I answered that there were only a number of books on scattered subjects in the field and that there is no single book that treats the subject of food toxicology as a unit as there is in most other disciplines. "Why don't you write one?" he challenged. Thus, the idea of initiating this project was nurtured during that conversation.

The subject of food toxicology is complex, and at the same time intriguing and challenging. Consider just the endogenous components. Thousands of compounds have already been identified; and by the time food has reached the table, the number of substances in it that nature has not intended has already increased to a staggering proportion. Many of the substances are introduced by manufacturers (given the impetus of progress) influenced by such factors as technology, leisure and convenience, profit motive, the pressure of overpopulation, and the insatiable human desire and penchant to improve on nature. Many are in foods as contaminants because of ignorance, apathy, carelessness, and neglect. A large number of new compounds are produced in the food because of chemical reactions within and between individual food components, aided no doubt by human activity.

Most of these substances have no known nutritional value, and because they are reactive compounds they can be expected to have some effects. The questions to be asked are: What are these substances and what are their effects? What conditions or factors influence these effects?

Research in the past several decades, and especially the last decade, has provided some of the answers. A tremendous amount of information has accrued since the biblical account of the poisoning of the Hebrews with normally nontoxic quails. A majority of the information developed piecemeal, and not as a result of systematic inquiry. There has been little attempt at formalization of the discipline. Therefore, practitioners in the health field, especially the physicians, nutritionists, and public health professionals, are often uninformed or have scattered knowledge in an area of tremendous importance to health.

This lack of formalization explains why the subject of food toxicants is often superficially treated, if not left out, in many nutrition curricula. These two volumes represent an attempt at such formalization.

Inevitably, the subject matter that can be dealt with within the confines of two volumes will be limited. Thus, the materials I have chosen are, in my opinion,

sufficient to give the reader a cohesive perspective on the subject. Chapters 1-7 deal with toxicological principles relevant to the question of toxicants in foods. The subjects covered in these first seven chapters are intended to give the reader a balanced view of the toxic phenomena as circumscribed by the factors and conditions affecting the toxicological response.

Chapters 8-11 cover a whole range of endogenous toxicants as defined in Chapter 1. However, for the sake of completeness and relevance, some subjects that appropriately belong under a different heading are included, such as ciguatera and paralytic shellfish toxins.

Chapters 13-17 cover the subject of micro- and macrobiological contaminants. The inclusion of bacterial pathogens as food toxicants may foment some controversy. However, this is hardly the space to indulge in apologia, except to say that the action of the pathogens involved in "food poisoning" are mediated by means of toxins. Thus, the phenomenon of bacterial action in this case is truly toxicological.

Chapter 19 covers the subject of manmade chemical contaminants. The so-called "incidental" or "unintentional food additives" are also included as contaminants. The reason for considering these substances as contaminants is discussed in the chapter. Naturally occurring radionuclides are also included here for the sake of completeness and relevance (Ch. 20).

Chapters 12 and 21 include "intentional" food additives and derived toxicants. The latter term is used for the first time to designate those toxic compounds formed by chemical reactions occurring in the food during processing, preparation, or storage.

The two volumes do not cover methodologies. For example, little discussion is devoted to risk-benefit estimation—a subject of considerable controversy.

I want to thank sincerely the individuals who were helpful in the preparation and writing of *Food Toxicology, Parts A* and *B*, particularly the following: E. P. Baxter, J. M. Lane, A. P. Powell, A. M. Bushnell, J. C. Gilmore, and E. R. Pray.

My special thanks to Dr. Donald Tressler, whose interest in this project allowed the glow of my efforts to remain undiminished in spite of the many problems and frustrations encountered during its writing.

Above all, my heartfelt gratitude to my wife, Jayne, for her most valued assistance in preparing, typing, and editing the manuscript, and especially for her understanding and encouragement.

Jose M. Concon

Acknowledgments

When my husband passed away suddenly after completing the manuscripts for Parts A and B, there was still quite a bit of work left to be done. There were references that still needed to be checked and completed, to name just one of the remaining tasks.

Since I had worked with my husband on his project since 1975 (mainly typing and helping to locate and check references), it seemed only natural that I finish the basically clerical work that remained to be done. I was prepared to work long hours for many months, but I wasn't prepared for the outpouring of love and help from some very special people. Without their support, I couldn't have completed such a large volume of work under such difficult circumstances.

I wasn't prepared to redraw all the chemical structures in India ink either, but a former student of my husband's was. To Carol Charles, the commercial artist whose expertise in drawing the chemical structures was crucial to getting the manuscript in a form acceptable for publication, go my heartfelt thanks. I also wish to thank Dr. David Newburg for initially contacting Carol and securing her participation.

For adding to the already heavy demands on their time and their thoroughness when helping me crosscheck the hundreds of references in the text, I want to express my deep appreciation to Carol "Robin" Luger, Linda Smith, Joan Williams, and Mildred Yates.

For their consistent resourcefulness in helping me find information, journals, books, and locating and checking references, I want the following librarians to know that their expertise created a sense of security that enabled me to continue working when I often felt like quitting—Stephanie Allen, Peter Costich, Jane Lane, Kerry Kressie, Tony Powell, Joyce Gilmore, Diane Brunn, Barbara Hahn, and Sara Bushnell.

For all her help, encouragement, and interest, plus the time she gave to me on the manuscript to ensure its accuracy, I am most indebted to Dr. Linda Chen, Chairman of the Department of Nutrition and Food Science, College of Home Economics, University of Kentucky.

And a very special word of thanks to Creed and Elsa Black, who provided the kind of environment and steadfast support required for the written manuscript to develop into a document suitable to be submitted for publication.

Jayne W. Concon

Contents of Part B

Food Toxicology

PART A: PRINCIPLES AND CONCEPTS

Contents of Part A

1

General Toxicological Principles Applicable to Foods and Food Toxicants

DEFINITION OF TOXICOLOGICAL CONCEPTS

Food toxicology is a science which deals with the nature, sources, and formation of toxic substances in foods, their deleterious effects, the manifestations and mechanisms of these effects, and the identification of the limits of the safety of these substances. Food in this sense includes all substances or mixtures of substances, both solid and liquid, which are intended for human ingestion for their nutritional and/or pleasurable benefits. This definition includes not only natural solid and liquid foods but also drinking water and synthetic or manufactured products, such as formulated or engineered products and alcoholic and other beverages.

A substance is toxic when it causes cellular or tissue injury by mechanisms other than physical trauma. Such substances are said to possess toxicity, which is defined as the capacity to produce toxic injury to cells or tissues. Toxic injury in this sense refers to an actual or potentially harmful alteration of cellular or tissue constituents and processes, which may or may not be manifested by clear clinical symptoms.

A substance may not be actually toxic but the conditions are such that it presents a hazard (the probability that a toxic substance will cause toxic injury under the conditions of use). Thus, hazard is a relative term, dependent on various exogenous and endogenous factors. Toxicity is similarly dependent on these factors.

A substance is deemed safe when it is practically certain that under the conditions of use, no toxic injury will result. The safety of any substance is dependent similarly on exogenous and endogenous factors. The safety, hazard and toxicity of a substance are relative properties which depend on various factors and conditions. Without the proper reference to these factors, they are meaningless by themselves.

SCOPE OF TOOD TOXICOLOGY

The scope of food toxicology comprises the factors and conditions which define toxicity, the hazard and safety of various substances found in foods, and the nature of the response of the host to these substances. These factors are varied and complex. Endogenous factors arise from the complexities of the biochemistry and physiology of the host and its interaction with the environment. Exogenous factors are determined by the nature of the toxic compounds, their chemical and biological relationships with other components in the food, and chemicals in the environment.

A primary objective of food toxicology is the understanding of the nature and properties of all toxic substances in foods and the nature and magnitude of the hazard

they present under various conditions. Such an understanding results in a clear delineation of the safety limits. A specification of the safety limits presupposes knowledge of the underlying toxicological mechanisms associated with each toxicant. While such knowledge is incomplete (e.g., in carcinogenesis), an unambiguous definition of safety will not be possible and can only be specified tentatively and relatively.

Principal concern is the toxicological interaction of food components and environmental chemicals. This is an area where information is minimal and vigorous research is needed.

Toxic compounds occurring in foodstuffs present a far more complex toxicological dimension than isolated compounds. In many instances, food toxicants incite the entire spectrum of human concern. These substances, being a part of foods, present not only health implications but also involve economic, social and political factors. Modern technology has made the concern for food safety more urgent and profound and the field of food toxicology more relevant.

It is also the aim of the study of food toxicology to put food toxicants in perspective so that hysteria or apathy arising from ignorance will give way to rational assessment. Rationality can only be accomplished when accompanied by scientific judgment. Because many food toxicants occur in foods in minute quantities, a rational assessment of their hazard or safety can only be made by studying their toxicological effects and the body.s response to their presence in tissues. For example, one may contend that the small amounts of cyanogen in lima beans (Chap. 8) present no hazard. However, this will be pure speculation if we do not have knowledge of how the body responds to traces of cyanide. Fortunately, such information is available (Chap. 4), and the contention regarding the safety of small amounts of cyanogen in lima beans has a scientific basis.

Food Toxicology and Nutritional Science

Food toxicology is indeed a part of the discipline of nutritional science. A study of toxic substances in foods should be as much a concern of nutritional and medical scientists as the nutrients themselves. One can view food toxicants as counteracting the beneficial effects of nutrients as a whole, although in many cases, one-to-one, nutrient-toxicant interactions are evident. Clearly, a study of nutritonal science without food toxicants is incomplete and inappropriate. Such a narrow view, which has persisted for decades up until a few years ago, may account in part for the lack of a systematic approach to the study of food toxicants.

TOXIC POTENTIAL OF FOOD

Paradoxical as it may seem, food whose principal function is the maintenance of life and well-being is also the source or cause of toxic injury, which in many cases is devastating and fatal. This has been known through the centuries. The Bible describes an incident of nonbacterial acute mass food poisonings among the early Hebrews. During the wanderings of the Hebrews in the desert after their exodus from Egypt, quails descended on their campsite in large numbers. The Hebrews, who had hungered and complained for meat, greedily ate large numbers of the birds and "while the flesh was yet between their teeth, ere it was chewed, . . . The Lord smote the people with a very great plague." The Bible narrative suggests that many of the Hebrews died of this poisoning (Numbers 11:31–34). Quail poisonings, in fact, have been described by ancient writers, and Sergent (1941) suggested that the quails mentioned in the biblical incident had become poisonous by feeding on hemlock seeds *(Conium maculatum)*, to which most quails are resistant.

During the Middle Ages, an epidemic of ergotism, a convulsive and gangrenous mycotoxicosis, plagued many countries in Europe. The disease was caused by the