



*A Brief History
of
The International Symposia
on
The Maillard Reaction*

Edited by John Baynes and Susan Thorpe

*Distributed at the
8th International Maillard Symposium
Charleston, South Carolina, USA
August, 2004*

*Celebrating the
25th Anniversary of the
1st International Maillard Symposium
Uddevalla, Sweden
September, 1979*

Preface

At this 8th International Symposium on the Maillard Reaction, we will discuss the formation of an International Maillard Society, an organization designed to foster research on the Maillard reaction and to provide a formal structure for sponsoring future symposia in this expanding area of research. It is helpful at times like this to look back on our history, to look at the evolution of our science, and to gain a perspective to assist us in forming a vision for the future.

This booklet assembles excerpts from the Prefaces and Forewords of previous Proceedings of International Maillard Symposia. As you peruse this material, you will see ample evidence of the broad span of our research across the food and biomedical sciences and the continuing interdisciplinary nature of our meetings. These symposia document the critical role that food scientists have played in unraveling the chemistry of the Maillard reaction, setting the stage for current studies in biological systems. As the field has expanded into the biological sciences, we have evolved a new vocabulary with acronyms – advanced glycation, glycoxidation, lipoxidation, glucotoxicity, glycotoxin, AGE, ALE, RAGE. New structures – more than 25 novel Maillard products - have been identified and structurally characterized in tissue proteins during the last 25 years, and new products are being described at this meeting. Our focus has gradually shifted from an interest in glycation to advanced glycation, from studies on the effects of Maillard products on protein structure and function to studies on the interplay between the Maillard reaction and regulatory biology – oxidative stress, apoptosis, and the mechanism of glucotoxicity and lipotoxicity. Our attention has expanded from the original interest in aging and diabetes to the much broader scope of research today on human health and disease – the influence of dietary and endogenous Maillard product on renal and vascular function and on chronic neurodegenerative disease. We have also tested our hypotheses – with some success - by development and clinical testing of pharmaceutical agents to inhibit the Maillard reaction and to block the undesirable, downstream effects of endogenous receptors for AGEs. All of these trends are recognizable in earlier volumes in these Proceedings, and are identifiable in the many oral and poster presentations at the 8th International Maillard Symposium.

We hope that this overview of previous meetings provides you with an historical appreciation of research on the Maillard reaction, and we thank you for your participation in this meeting and your contribution to our future history.

**THE 1st INTERNATIONAL SYMPOSIUM ON
THE MAILLARD REACTION**

**Uddevalla, Sweden
September, 1979**

Organizing Committee:

C.E.A. Eriksson, The Swedish Food Institute and Chalmers University, Göteborg,
N.-G. Asp, University of Lund, Chemical Centre, Dept. of Nutrition, Lund, Sweden
O. Theander, Swedish Univ. of Agricultural Sciences, Dept. of Chemistry, Uppsala,
Sweden

MAILLARD REACTIONS IN FOOD

CHEMICAL, PHYSIOLOGICAL AND TECHNOLOGICAL ASPECTS

C. Eriksson, Ed.

Progress in Food and Nutrition Science, Vol. 5,
Pergamon Press, Oxford, 1981, 501 pp.

PREFACE to the Proceedings of the 1st International Maillard Symposium

The Maillard reaction is a non-enzymatic browning reaction, caused by the condensation of an amino group and a reducing compound. In food the reactants are commonly amino acids, both free and peptide-bound, and reducing sugars. A great number of both desirable and undesirable changes occur in raw materials and foods due to the Maillard reaction. During heat treatment like frying, roasting and baking the reaction creates positive attributes in terms of flavour and colour. In the drying of milk or storage of instant potatoes, on the other hand, the Maillard reaction gives purely unfavourable effects, such as decreased nutritional value and colour deterioration. Roasting of cereals is an example of processes in which the reaction brings about a compromise between positive and negative effects.

Being so central in food chemistry and food processing, the Maillard reaction is often treated in textbooks and at different types of meetings about food. However, because of the complexity of the reaction, modern textbooks still contain mostly overall schemes, together with the initial reactions, but rarely more detailed chemistry. The literature about different aspects of the Maillard reaction is extensive and appears in journals of chemistry, food technology and nutrition. During recent years, considerable experience has been gained about the chemistry of intermediate and low molecular compounds, whereas the chemistry of higher molecular weight material is still basically unknown. From a nutritional standpoint the effects of the Maillard reaction have been long studied, especially regarding the loss of biologically available lysine in milk processing and storage. However, investigations of the absorption and metabolism of reaction products and their possible adverse effects have begun quite recently. Technologically, the Maillard reaction has been studied particularly in connection with the drying of milk and fruits. Ways of reducing browning and nutritional impairment by either programmed processes or the addition of inhibitory substances like sulphite have also been subject to considerable interest. The recent introduction of dried lactose- hydrolyzed milk has revived the interest in the drying processes, since the hydrolysis products are even more likely to participate in Maillard reactions than lactose itself.

Low molecular weight Maillard reaction products have long been known to possess antioxidant properties. During recent years higher molecular weight products have also been reported to have strong antioxidant properties, which opens possibilities of protecting foods from lipid oxidation by optimization of recipes and processes.

Due to the rapid development in the chemistry and physiology of the Maillard reaction as well as in its technological implications, we found it worthwhile to try to gather scientists from these three areas of research at a common symposium. The guiding idea was to try to bridge the gaps often existing between the three categories of scientists working in the field and thereby catalyze further cooperation between them.

It is the hope of the organizers that the great interest shown in this symposium will lead to fulfillment of our first and basic intention, i.e. to introduce scientists of different kinds to each other for future cooperation on the still very complex Maillard reaction and its impact on the processing, wholesomeness and stability of foods.

Meeting Agenda: A critical review of nutritional aspects of the Maillard reaction, followed by 37 presentations addressing Chemical, Physiological and Technological Aspects of the reaction. Two of these papers dealt with the Maillard reaction in physiological systems. These papers were supplemented by summaries of workshops on Caramelization, Separation and Fractionation, Toxicology, Water Activity, and Volatile Products.

**THE 2nd INTERNATIONAL SYMPOSIUM ON
THE MAILLARD REACTION**

**Las Vegas, Nevada
March - April, 1982**

Organizing Committee:

George R. Waller, Oklahoma State University, Stillwater, Oklahoma, USA

Milton S. Feather, University of Missouri, Columbia, Missouri, USA

**The Maillard Reaction
in Foods and Nutrition**

G.R. Waller, M.S. Feather, Eds.

American Chemical Society Symposium Series #215

American Chemical Society
Washington, DC, 1982, 585 pp.

PREFACE to the Proceedings of the 2nd International Maillard Symposium

Seventy years ago, the French scientist Louis-Camille Maillard first reported on the browning reaction that now bears his name. This reaction occurs between sugars and amino acids, polypeptides, or proteins; and between polysaccharides and polypeptides or proteins. Examples of the reaction are nonenzymatic browning reactions and change of taste when a steak is cooked, and the coloring of a slice of apple exposed to the air. During heat treatment such as frying, roasting, and baking, the Maillard reaction improves food in taste, flavor, and color. When foods are stored, however, the reaction often yields unfavorable effects, such as decreased nutritional value and color deterioration. Thus, better and safer preservation of food and its nutritional value is the goal of scientists studying the Maillard reaction. In the last few years there has been an increased interest in the Maillard reaction from scientists in the fields of agriculture, foods, nutrition, and carbohydrate chemistry.

This book summarizes the program of the 2nd International Maillard Symposium. In addition to the oral presentations, there were Panel discussions with audience participation on the subjects of food and nutritional benefits of Maillard reaction products and the toxicology of Maillard reaction products; these are not reported here. Interaction between participants during this meeting helped cement relations for continued help and perhaps will promote some new areas for cooperative research between American and foreign scientists. This symposium was also an important element in the training of graduate students; it provided them with increased awareness of the breadth of the scientific field. We hope that it is true of each of you!

Although this book cannot give a complete account of the meeting, we hope that it will serve as a starting point to help guide the research of others. We are pleased that the Maillard reaction and its products will now be the subject of on-going international meetings.

Meeting Agenda: An historical overview on the Maillard reaction, followed by 28 presentations in separate sessions on: 1) Chemistry of the Maillard reaction; 2) Flavors, Tastes and Odors; 3) Food Technology; 4) Nutrition; 5) Maillard reactions *in vivo* (2 papers); and 6) Toxicology.

**THE 3rd INTERNATIONAL SYMPOSIUM ON
THE MAILLARD REACTION**

**Fuji Institute, Shizuoka, Japan
July, 1985**

Organizing Committee:

Masao Fujimaki, President, Ochanomizu Univ., and Professor Emeritus,
Tokyo University, Tokyo, Japan

Mitsuo Namiki, Professor, Dept. of Food Sciences and Technology,
Nagoya University, Nagoya, Japan

Hiromichi Kato, Professor, Dept. of Agricultural Chemistry,
University of Tokyo, Tokyo, Japan

**AMINO-CARBONYL REACTIONS
IN FOOD AND BIOLOGICAL SYSTEMS**

M. Fujimaki, M. Namiki, H. Kato, Eds.

Developments in Food Science, Vol. 13
Elsevier, Amsterdam, 1986, 588 pp.

PREFACE to the Proceedings of the 3rd International Maillard Symposium

In contrast to the limitless number of constituents of living systems and derived foods, the number of reactive functional groups, i.e. OH, NH₂, COOH and C=O, contained in common constituents as proteins, carbohydrates, lipids, and other forms is limited. Among the reactions that take place between these groups, amino-carbonyl reactions are unique and important; they proceed rapidly without the aid of biocatalysts. After the initial reversible Schiff base formation, the products of irreversible Amadori rearrangement give rise to a number of complex reactions by, e.g., dehydration, oxidation, cyclization, and scission. The reaction is significant in our lives, involving amino acids, proteins and sugars that occupy a large part of the functional constituents of living systems and foods.

A nutritionally satisfactory food consisting of starch, proteins and lipids, together with other necessary minor components is conceivable. The food would contain very few functional groups, and would undoubtedly have poor taste. The kind of food we wish to have daily usually contains larger amounts of low molecular compounds such as amino acids, sugars and fatty acids. Not only do these components make food taste good as is, but they are also sources of desirable flavors, as well as appetizing colors and smells when the food is cooked, processed or stored properly as a result of amino-carbonyl reactions. Fondness for good food is the heritage of mankind through the ages. The Japanese have for centuries possessed keen interest in developing flavorful food as an art, producing such good and nutritious foods as miso, soy sauce, sake, and others, with the aid of fermentation techniques. The rich flavors of these foods come mainly from the small molecular constituents and products of amino-carbonyl reactions.

Since Maillard's seminal publication in 1912, many scientists have investigated this reaction. The description of the browning reaction proposed by J. E. Hodge has been regarded as the foundation for research in this field for more than a quarter of a century. However, we now realize that the reaction that the Maillard reaction is a set of reactions of great complexity. Even melanoidin formation and browning, first observed in 1912, are still not fully understood, and new proposals concerning the mechanisms have recently been made.

Historically, the Maillard reaction was first studied with regard to humus formation, later to become a major factor concerning color and flavor formation in food. The significance of the reaction in nutritional physiology and food safety is also drawing attention. Recently, relationships of the reaction to functional disturbances concerning proteins and to the process of aging have been recognized. These developments were strong incentives for scientists to organize an international meeting for mutual communication and discussion of the latest topics.

At the 2nd Maillard symposium, it was decided to hold the next symposium in Japan. With the advice of many scientists, the committee agreed that this symposium should focus on recent trends in "AminoCarbonyl Reactions in Food and Biological Systems". The proceedings of this meeting are a collection of the foremost works in this developing field. Not only is the material informative for the specialist, but it should be stimulating and challenging to workers in other fields.

Meeting Agenda: An historical introduction, followed by 56 presentations in sessions devoted to Food Chemistry, Food Technology, and Biological (mostly nutritional and toxicological) Aspects of the Maillard reaction. There were three workshops devoted to: Low Molecular Weight Products, AminoCarbonyl reactions of protein in vitro and in vivo; and Melanoidins. Seven papers dealt with the Maillard reaction under physiological conditions in vitro or the growing evidence for the role of the Maillard reaction in diabetes and aging.

**THE 4th INTERNATIONAL SYMPOSIUM ON
THE MAILLARD REACTION**

**Lausanne, Switzerland
September, 1989**

Organizing Committee:

P.A. Finot, H.U. Aeschbacher, R.F. Hurrell, R. Liardon
J. Chauffard, M. Cordoz, T. Meyer
Nestle Research Centre, Nestec SA, Lausanne

**The Maillard Reaction in Food Processing,
Human Nutrition and Physiology**

P.A. Finot, H.U. Aeschbacher, R.F. Hurrell, R. Liardon, Eds.

Birkhäuser Verlag
Basel, 1990, 516 pp.

PREFACE to the Proceedings of the 4th International Maillard Symposium

The 4th International Symposium on the Maillard Reaction, which took place at the Nestlé Research Centre in Lausanne Switzerland, came exactly 10 years after the first Symposium. As with the previous Symposia, the Scientific Program was multidisciplinary, covering: Chemistry, Food Science, Analytical Methods, Nutrition, Toxicology and “In Vivo” Reactions.

The large number of industrial scientists attending the Symposium demonstrated the importance of the Maillard reaction in the food industry and emphasized the need for food technologists and nutritionists to better understand the reaction so as to control its extent in food products.

In addition to the chemical and food aspects of the Maillard reaction, a number of presentations were devoted to recent aspects of research such as toxicology and “in vivo” reactions. These recent aspects of the reaction which were considered as secondary several years ago have developed rapidly as a result of knowledge already accumulated by chemists and food scientists. Because of its implications in human health and in the ageing process, the Maillard reaction is becoming a new science with its own vocabulary, with new chemical structures, with specific methodologies and with new approaches which can in turn now be of use to food scientists.

The Proceedings contain the plenary lectures, the short communications and certain selected posters providing an up-to-date source on the multidisciplinary nature of the Maillard reaction and opening up the way for cross-fertilization between the different sciences. Topics discussed include the chemistry and analysis of Maillard reaction products; the role of intermediate Maillard reaction products in the production of aromas and pigments; the organoleptic and functional properties of Maillard reaction products in foods; the formation of Maillard reaction products during microwave cooking; the relevance of Maillard reactions in food to human nutrition and physiology; the formation of mutagenic and antimutagenic substances; and the metabolic consequences in vivo glycosylation during ageing and diabetes.

Meeting Agenda: A total of 59 presentations were divided into sessions on Chemistry, Food Science, Nutrition, Toxicology, and In Vivo Reactions. Sixteen papers dealt with the Maillard reaction in living systems, including one paper on the use of organic germanium compounds and aminoguanidine to inhibit the Maillard reaction.

**THE 5th INTERNATIONAL SYMPOSIUM ON
THE MAILLARD REACTION**

**Minneapolis, Minnesota
August - September, 1993**

Organizing Committee:

Theodore Labuza, Gwen Reed, Gary Reineccius
Department of Food Science and Nutrition, University of Minnesota

**Maillard Reactions in Chemistry,
Food, and Health**

T.P. Labuza, G.A. Reineccius, V. Monnier, J. O'Brien, J. Baynes, Eds.

The Royal Society of Chemistry
Special Publication No. 151
Cambridge, UK, 1994, 440 pp.

PREFACE to the Proceedings of the 5th International Maillard Symposium

The 5th International Symposium on the Maillard Reaction reviewed the new developments in nonenzymatic browning reactions and their relevance to food technology and the medical sciences. The conference addressed aspects of the chemistry, kinetics, technology and toxicology of the reaction in foods and reviewed new developments in the study of Maillard reactions *in vivo*. By coincidence, 1993 was the 40th year since the publication of the classic review of the reaction by John E. Hodge in the first volume of the *Journal of Agricultural and Food Chemistry*. The original review by Hodge was named a Citation Classic by the Institute of Scientific Information in 1979 and the scheme used to describe the Maillard reaction in that review is still the most satisfactory representation of the reaction. The fact that the paper is the most cited ever to have been published in the *Journal of Agricultural and Food Chemistry* and one of the most cited in food science is testimony to the importance of Maillard browning reactions in food science and technology. Luc De Bry (General Biscuits, Belgium) emphasized, during an after-dinner lecture on the anthropology of the Maillard reaction, that the potential impact of the reaction in food technology first became apparent some 700,000 years ago when Peking Man began to use fire to cook foods. De Bry suggested that, in addition to producing attractive colors and flavors, the Maillard reaction affords safe access by humans, to rich sources of kilocalories through the destruction of antinutritional factors.

Meeting Agenda: A total of 4 Plenary and 61 research presentations were made in the areas of Chemistry, Food, and Health. This meeting was the first at which presentation were equally drawn from research in the food and biomedical sciences. Approximately half of the presentations dealt with physiological aspects of the Maillard reaction, including the first papers on AGE receptors in biological systems.

**THE 6th INTERNATIONAL SYMPOSIUM ON
THE MAILLARD REACTION**

**London, England
July, 1997**

Organizing Committee:

Jennifer M. Ames, University of Reading, UK
M. James C. Crabbe, University of Reading, UK
Harry E. Nursten, University of Reading, UK
John O'Brien, University of Surrey, UK

**The Maillard Reaction in Foods
and Medicine**

J. O'Brien, H.E. Nursten, M.J.C. Crabbe, J.M. Ames, Eds.

The Royal Society of Chemistry
Special Publication No. 223
Cambridge, UK, 1998, 464 pp.

FOREWORD to the Proceedings of the 6th International Maillard Symposium

by Dr. George K. Radda, Medical Research Council, London UK

It is surprising that an international conference should be devoted to a single chemical reaction. After all, I have not heard of such a symposium on the Claisen rearrangement or the Reformatsky reaction. So what is so special about the Maillard reaction? I decided to search MEDLINE from 1992 to 1997 for the reaction by name only (*i.e.*, not by ‘glycation’ or ‘advanced glycation end-product’, AGE) and found 92 references. I learned some interesting facts. Among them, I learned that the Maillard *in vivo* reaction may contribute to uremic and diabetic complications. Products of the Maillard reaction *in vitro* are also said to be genotoxic and, in coffee, to have mutagenic properties. Thus, in principle and in practice, this conference deals with a remarkable wealth of problems requiring a range of expertise.

You are dealing with chemical mechanisms, food preparation, food safety, human nutrition, public health and diseases that include diabetes, Alzheimer’s, renal failure and cancer. There is an underlying trend in these diseases that involves protein deposits following glycation. It is interesting to compare these deposits to other forms of amyloid fibres and ‘tangles’. Max Perutz put forward the notion that some proteins may undergo a transformation from predominantly α -helical structure to β -sheets and thereby aggregate. He referred to these transformable proteins as ‘chameleon proteins’. It is entirely possible that the prion proteins, so much in the news because of bovine spongiform encephalopathy (BSE) and its human equivalent, may well behave in this manner.

This conference exemplifies the range of disciplines and experts involved in studying the Maillard process and its consequences – from food to biomedical sciences. One of your roles is to integrate the two sets of approaches. In a way your problem is no different than that of the Medical Research Council - to “promote and support, by any means, high-quality basic, strategic and applied research and related postgraduate training in the biomedical and other sciences with the aim of maintaining and improving human health.” We therefore must bring together the basic science and clinical communities to provide the necessary interactions to integrate studies on the structure of genes and gene products (proteins) with cellular observations and whole organism human physiology. Biomedical research is a continuum from molecules, through cells, to clinical and population studies. Perhaps the Maillard reaction provides this continuum from basic chemistry through foods and proteins to medical problems. The papers presented at this symposium represent a wide range of research programs, but it is the integration of the different sciences that is of particular value.

Meeting Agenda: A total of 4 Plenary and 58 research presentations were made in sessions on Reaction Mechanisms, Food Technology, Kinetics and Analytical Chemistry, Flavour Chemistry, Toxicology and Antioxidants, and Health and Disease. At the 5th and subsequent International Maillard Symposia, the presentations were approximately equally derived from laboratories in the food and biomedical sciences, with a substantial number of presentations being interdisciplinary in nature.

THE 7th INTERNATIONAL SYMPOSIUM ON THE MAILLARD REACTION

**Kumamoto, Japan
October - November, 2001**

Organizing Committee:

Seikoh Horiuchi, Department of Biochemistry, Kumamoto University School of Medicine

Naoyuki Taniguchi, Dept. of Biochemistry, Osaka Univ. Graduate School of Medicine

Fumitaka Hayase, Department of Agricultural Chemistry, Meiji University, Kanagawa

Tadao Kurata, Institute of Environmental Science, Ochanomizu Univ., Tokyo

Toshihiko Osawa, Department of Food Science & Biodynamics, Nagoya University

The Maillard Reaction in Food Chemistry and Medical Science: Update for the Postgenomic Era

S. Horiuchi, N. Taniguchi, F. Hayase, T. Kurata, T. Osawa, Eds.

Elsevier
Amsterdam, 2002, 527 pp.

PREFACE to the Proceedings of the 7th International Maillard Symposium

The postgenomic era has already been launched, and the Maillard reaction is one of the most important post-translational modifications of proteins in life science. Two major multidisciplinary topics of this meeting were food science and medical science. The former covered the reaction mechanism, kinetics and analytical aspects of the Maillard reaction, food technology, flavor chemistry, ecology and antioxidants, whereas the latter covered *in vivo* aspects of the Maillard reaction affecting human health and diseases, which included oxidative stress, glycation and cell biology, pharmacological prevention of glycation, new horizons in glycation research, and glycation and diseases.

Meeting Agenda: A total of 6 plenary lectures and 48 original research presentations were made. The program was divided equally into oral presentations in the food and biomedical sciences. An additional 84 presentations were made in four separate poster sessions.

This meeting was followed by a two, one-day Satellite Symposia: a Symposium on Medical Science at Lake Biwa in Shiga Prefecture, and a Symposium on Food Science at the University of Tokyo.

**THE 8th INTERNATIONAL SYMPOSIUM
ON THE MAILLARD REACTION**

**Charleston, South Carolina
August - September, 2004**

Organizing Committee:

John W. Baynes, University of South Carolina, Columbia, SC
Vincent M. Monnier, Case Western Reserve University, Cleveland, Ohio
Jennifer M. Ames, University of Reading, United Kingdom
Suzanne R. Thorpe, University of South Carolina, Columbia, SC
Laurie M. Barnwell, University of South Carolina, Columbia, SC
Timothy C. Mesaric, The ADEC Group, Simpsonville, SC

**The Maillard Reaction in Food
and Biological Sciences**

J.W. Baynes, J.M. Ames, V.M. Monnier, S.R. Thorpe, Eds.

Annals of the New York Academy of Sciences
New York, 2005

