Frontiers in research on the Maillard reaction in aging and chronic disease

The original scientific description of the browning reaction between amino acids and sugars was published in a paper by Professor Louis Camille Maillard of the University of Paris in 1912 [1]. This seminal work laid the foundation for a broad spectrum of research today on the role of the Maillard reaction in food and biological systems. The Maillard reaction between sugars and proteins contributes to the aroma, taste, appearance and texture of food products and also affects their digestibility, nutritional value and toxicology. In humans, slow but continuous Maillard reactions between blood glucose and its metabolites contribute to structural and functional modifications of proteins during aging, including the loss of flexibility of the vascular wall and the decrease in transparency of the lens. Maillard reactions are also implicated in the pathology of age-related diseases, contributing to the increased non-enzymatic modification of proteins in atherosclerosis, diabetes, and neurodegenerative diseases. Through interactions with endogenous receptors, these chemical modifications, known as advanced glycation end-products (AGE), contribute to oxidative stress and the inflammatory state underlying chronic diseases. The Maillard reaction, however, is only one aspect of increased chemical modification of proteins in disease. Lipid peroxidation products and reactive oxygen species also form of advanced lipoxidation end-products (ALE) and protein oxidation products. Thus, research on the Maillard reaction in vivo is only one aspect of a broad range of non-enzymatic chemistry associated with aging, oxidative stress, inflammation and chronic disease.

This special issue of *Clinical Chemistry and Laboratory Medicine* is based on presentations at the 11th International Symposium on the Maillard Reaction (ISMR11): The Maillard Reaction at the Intersection between Food Chemistry, Nutrition and Age-related Diseases. ISMR11 convened in Nancy, France, during September 2012, celebrating the 100th anniversary of publication of Maillard’s landmark paper, cited above. Maillard was born in Pont-à-Mousson, Lorraine, about 30 km from Nancy. He graduated from the Lycée in Nancy, studied at the Universities of Nancy and Paris, earned doctorates in Chemistry and Medicine, and published his first paper on what was to become known as the Maillard Reaction while a member of the faculty of the University of Paris. ISMR11 was co-sponsored by the International Maillard Reaction Society (IMARS: www.imars.org), l’Association Les Amis de Louis Camille Maillard (Nancy, France), and the Food and Agronomy Engineering School (ENSAIA) of the University of Lorraine.

This volume contains 22 papers, eight of which provide overviews on the Maillard reaction. The Roberts discuss the role of the reaction in cardiovascular disease and aging [2], while Gillery and Jaisson [3] place the reaction in the broader context of post-translational modifications of proteins in chronic disease. Monnier et al. focus on glucosepane, the major Maillard crosslink in tissue proteins [4], and Arsov et al. discuss the clinical application of skin autofluorescence measurements in studies of end-stage renal disease [5]. Frizzell and Baynes propose the development of a clinical assay to assess the level of oxidative stress in plasma, which is a catalyst of Maillard reactions [6]. Several more targeted mini-reviews address the site specificity of AGE modification of proteins [7], glycation of blood lipids [8], the health impact of dietary Maillard reaction products [9] and the relevance of the Maillard reaction to food allergies [10].

Among the original research articles, Scheijen and Schalkwijk describe advances in methodology for measurement of Maillard reaction intermediates in plasma by LC/MS [11], and Hellwig et al. describe a novel HPLC assay for measurement of fructosamine-3-kinase, the only enzyme known to reverse Maillard reaction damage to proteins in vivo [12]. Tanhäuserová et al. present an interesting analysis of genetic variability in this and other enzymes that provide protection against hyperglycemia and Maillard reaction damage to proteins in diabetes [13]. Three papers address changes in AGEs in plasma and cerebrospinal fluid in trauma [14], cerebrovascular disease [15], and Alzheimer’s disease [16]. Several papers describe the changes in AGEs and other biomarkers in cardiovascular disease, including discussion of the usefulness of skin autofluorescence as a proxy for chemical or immunological measurement of tissue AGE accumulation in cardiovascular disease [17], and changes in AGEs and other biomarkers associated with hypertension [18] and metabolic syndrome.
Four more speculative papers present directions for future research, including basic research on the role of the Maillard reaction in endoplasmic reticulum stress and the interaction between Maillard reactions and nitrosative stress, and applied research on the development of a reconstructed skin model for research on skin glycation and approaches for limiting AGE damage to skin.

The breadth of topics discussed in the various papers in this special issue attests to the broad role of the Maillard and related modifications of proteins by lipids and reactive oxygen species in aging and disease. Readers are invited to review other recent publications based on ISMR11, including a special issue of Amino Acids, which complements the biochemical and biomedical studies presented in this issue, and supplements to Food and Function and the Journal of Agricultural and Food Chemistry which describe current research on the Maillard reaction in food science and technology.

Conflict of interest statement

Authors’ conflict of interest disclosure: The authors stated that there are no conflicts of interest regarding the publication of this article.

Research funding: None declared.

Employment or leadership: None declared.

Honorarium: None declared.

References


Dedication

This volume is dedicated to Mr. Claude Mathieu of Nancy, Lorraine, France. Mr. Mathieu was a founding director and former president of L’Association Les Amis de Louis Camille Maillard. It was Mr. Mathieu’s dream to host the 11th International Symposium on the Maillard Reaction (ISMR11) in Nancy on the centenary of the publication of Maillard’s landmark paper in 1912. As a member of the Lorraine Academy of Sciences, he devoted much of his energy during the last 2 years to assist in the organization of ISMR11. Mr. Mathieu proposed the venue in Nancy and worked closely with the organizing committee, but passed away suddenly in June 2012, just a few months before the meeting. He was an enthusiastic scholar and pupil of Maillard and the Maillard reaction, and also an accomplished chef. He would have enjoyed ISMR11. It was the largest of the International Maillard Symposia. Over 260 persons registered for the meeting, contributing 94 oral and 143 poster presentations, and representing 30 nations from six continents. ISMR11 stands out as a memorial to Claude Mathieu’s dedication and effort. There is an excellent summary of Mr. Mathieu’s historical research at: http://www.als.uhp-nancy.fr/conferences/2012/BiographieMaillard.pdf.

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