BIOLOGICAL EFFECTS OF MAILLARD
BROWNING PRODUCTS THAT MAY AFFECT
ACRYLAMIDE SAFETY IN FOOD

Biological Effects of Maillard Products

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Abstract: The heat-induced reaction of amino groups of amino acids, peptides, and
proteins with carbonyl groups of reducing sugars such as glucose results in the
concurrent formation of so-called Maillard browning products and acrylamide. For
this reason, reported studies of adverse biological effects of pure acrylamide may not always be directly relevant to acrylamide in processed
food, which may contain Maillard and other biologically active products. These may either antagonize or potentiate the toxicity of acrylamide. To
stimulate progress, this paper presents an overview of selected reported studies
on the antiallergenic/allergenic, antibiotic, anticarcinogenic/carcinogenic
antimutagenic/mutagenic, antioxidative/oxidative, clastogenic (chromosome-
damaging), and cytotoxic activities of Maillard products, which may adversely
or beneficially impact the toxicity of acrylamide. The evaluation of biological
activities of Maillard products and of other biologically active food ingredients
suggests that they could both enhance and/or ameliorate acrylamide toxicity,
especially carcinogenicity, but less so neurological or reproductive
manifestations. Future studies should be directed to differentiate the
individual and combined toxicological relationships among acrylamide and the
Maillard products, define individual and combined potencies, and develop
means to prevent the formation of both acrylamide and the most toxic Maillard
products. Such studies should lead to safer foods.

Key words: Acrylamide; Maillard products; beneficial effects; adverse effects; food safety.
1. INTRODUCTION

The relationship between dietary content and human diseases such as cancer and atherosclerosis has become increasingly a major concern for human health. A need exists to more precisely define the relationship between specific diet components and disease and to devise strategies to minimize the formation of the harmful compounds. The potential for formation of mutagens and carcinogens in foods during processing is a major area of concern for human health and safety. Adverse and beneficial effects of Maillard products formed during the processing of food may occur concurrently with the formation of acrylamide.

Reactions of amino with carbonyl groups of food constituents involve those changes commonly termed browning reactions. These include reactions of amines, amino acids, peptides, proteins with reducing sugars and vitamin C (non-enzymatic browning, often called Maillard reactions). These reactions cause deterioration of food during storage and processing. The loss of nutritional quality is attributed to the destruction of essential amino acids, a decrease in digestibility, and inhibition of proteolytic and glycolytic enzymes. The production of both antitoxic and toxic compounds may further impact the safety of heated foods. Studies in this area include influence of damage to essential amino acids on nutrition and food safety, nutritional damage as a function of processing conditions, and simultaneous formation of deleterious and beneficial compounds. These compounds include carcinogens, mutagens, antimutagens, antioxidants, antibiotics, and allergens, and antiallergens (Friedman, 1973, 1974, 1975a, 1975b, 1977a, 1977b, 1977c, 1978, 1982, 1984, 1986, 1989a, 1989b, 1991, 1992, 1994, 1996, 1997, 1999a, 1999b, 2003, 2004a, 2004b). Multidisciplinary studies are needed to reveal the complex interplay between the chemistry, biochemistry, nutrition, pharmacology, and toxicology of food ingredients.

2. BIOLOGICAL EFFECTS OF ACRYLAMIDE

Heat induces the formation of acrylamide (CH$_2$=CH-CO-NH$_2$) in food under conditions that also induce the formation of Maillard browning products. This observation stimulated interest in the underlying chemistry that may be responsible for the formation of acrylamide as well as the chemical and biochemical basis of the toxicological effects of this animal carcinogen, neurotoxin, and reproductive toxin (Friedman, 2003). A recent study showed that even extremely low doses of acrylamide adversely affected the lifespan of nematodes (Hasegawa et al., 2004). Because most of the reported studies on the biological effects of acrylamide in animals were