



Amol University of Special  
Modern Technologies

Caspian Journal of Veterinary Sciences

doi: 10.22034/CJVS.2025.534218.1040

Journal homepage: <https://Cjvs.ausmt.ac.ir/>

## A review of the risk of acrylamide in food products

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### Article Info

#### Article history:

Submit Date: 13 July 2025

Accept Date: 1 August 2025

Online Date: 4 December 2025

#### Keywords:

Acrylamide

Food products

Food safety

### Abstract

Acrylamide (C<sub>3</sub>H<sub>5</sub>NO) is a white crystal which is soluble in water as well as ethanol, ether, and chloroform. It is degraded after exposing to acidic and alkaline substances, oxidizing agents, iron, and salt. Nowadays, acrylamide is produced to prepare polyacrylamide which is widely used in wastewater treatment and paper, textile, coatings, and dyes industries, etc. Regarding food safety viewpoint, risk assessment of this toxin in foods seems to be essential. On the other hand, lack of standard inspection laws and surveillance on traditional foods, especially those prepared in restaurants and street vendors, is a main concern. Therefore, the main purpose of this study was to review acrylamide risk in food products. Despite the importance of prevention against acrylamide production in high-risk food before or during the cooking process, it sometimes seems to be difficult to achieve this goal. Therefore, developing effective strategies to inform and educate consumers to reduce hazardous food intake or use of effective compounds to reduce acrylamide toxicity in body are of practical approaches. Medicinal plants containing polyphenols and antioxidants reduce acrylamide production through the interaction between sugars and asparagine amino acids. Also, it has been shown that some antioxidant plant compounds reduce the toxicity of chemical hazards (such as acrylamide) in the body of humans and animals.

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## Introduction

Several toxins may endanger food safety (Mason *et al.*, 2015a; Mason *et al.*, 2015b; Mason *et al.*, 2016; Shahrabakia *et al.*, 2018; Hashemi *et al.*, 2021). Acrylamide (C<sub>3</sub>H<sub>5</sub>NO) is a white crystal that is soluble in water as well as ethanol, ether, and chloroform. It is degraded after exposure to acidic and alkaline substances, oxidizing agents, iron, and salt. Nowadays, acrylamide is produced to prepare polyacrylamide, which is widely used in wastewater treatment, as well as in paper, textiles, coatings, and dyes industries (Boroushaki *et al.*, 2010; Vinci *et al.*, 2012; Kahkeshani *et al.*, 2014). Acrylamide is an odorless compound which has been classified as a carcinogen, teratogen, and neurotoxicant by the International Agency for Research on Cancer. The toxin may result in some abnormalities in daughter cells of the mammals (Komthong *et al.*, 2012). It increases free radical products resulting in nervous system damaging, immune system suppression, infertility in male, and eye infection. Tolerable daily intake of acrylamide has been estimated as 40 g/kg BW/day (Boroushaki *et al.*, 2010; Powers *et al.*, 2013).

In April 2002, the Swedish National Food Administration announced that acrylamide could be produced in most heated and fried food products rich in carbohydrates. The toxin is produced during the non-enzymatic browning (Maillard) process, resulting from the reaction between reducing sugars and asparagine amino acid inside the food products. This reaction occurs at temperatures higher than 120°C. Therefore, it seems like a wide range of heated rich-carbohydrate food products like potato, popcorn, chocolate, biscuit, coffee, milk powder, and bread, etc. contain the toxin. It should be noted that acrylamide is not usually found in raw, unprocessed, and steamed food products (Boroushaki *et al.*, 2010; Kahkeshani *et al.*, 2014). Detection of acrylamide in foods is performed by various analytical methods such as Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), as well as Enzyme Linked Immunosorbent Assay (ELISA) (Oracez *et al.*, 2011; Tekkeli *et al.*, 2012; Franeka *et al.*, 2014).

To date, several studies have been published regarding occurrence of acrylamide in food products in many countries such as Turkey (Gunduz and Cengiz, 2015), Colombia (Pacetti *et al.*, 2015), India (Shamla and Nisha, 2014), Czech

(Forstova *et al.*, 2014), Poland (Mojska *et al.*, 2012), China (Chen *et al.*, 2008), Spain (Rufian-Henares *et al.*, 2007), Romania (Oroian *et al.*, 2015), and Korea (Koh, 2006). From a food safety viewpoint, risk assessment of this toxin in foods seems to be essential. On the other hand, lack of standard inspection laws and surveillance on traditional foods, especially those prepared in restaurants and street vendors, is a main concern. Therefore, the main purpose of this study was to review acrylamide risk in food products.

In research carried out previously in Iran, Boroushaki *et al.*, (2010) reported that the range of acrylamide in different industrial brands of potato chips (168-244 µg/kg) were significantly higher than that in popcorn (<30-410 µg/kg). Potato compared to the other kinds of foods has higher amounts of asparagine and reduce sugars; therefore, the formation of acrylamide is very possible. In another work, the mean contamination of Iranian domestic as well as imported potato chips was 1456 and 220 µg/kg, respectively (Saeidi Asl *et al.*, 2014). According to Iranian national standard (ISIRI, 2010), the maximum acceptable concentration of acrylamide in potato chips is 1200 µg/kg, therefore, Saeidi Asl *et al.* (2014) concluded that the contamination rate was relatively high in Iranian domestic potato chips. This difference may be due to various factors such as cooking temperature, heating time, and amount as well as type of consumed frying oil (Keramat *et al.*, 2011; Vinci *et al.*, 2012; Mesias and Morales, 2015). It is reported that the geographical area of plant cultivation and climate conditions are effective in the plant composition such as reducing sugars and amino acids involved in acrylamide formation (Shamla and Nisha, 2014). Scientific evidence also suggests that storing potatoes in the appropriate temperature (<10°C) reduces the accumulated reducing sugar occurrence due to starch degradation during storage (Boroushaki *et al.*, 2010). It was demonstrated that the lower thickness of the potato, the higher the accumulation of acrylamide in the final product; because increased contact surface with the heat source could accelerate this process (Keramat *et al.*, 2011; Vinci *et al.*, 2012). Motaghi *et al.*, (2012) reported that mean concentrations of acrylamide in breads sold in Kerman, south of Iran, including Taftoon, Sangak, Lavash, and Barbari were 146, 86, 26 and 135 µg/kg, respectively. The higher concentration of toxin in dried bread may be because of its longer time of heating process in comparison with the

other ones.

Similar investigations have been carried out in other countries showing obvious variation in their results. According to research on assessing acrylamide residue in some Colombian food products, the highest amount of the toxin was orderly reported in wafer (1449 µg/kg), biscuit (1104 µg/kg), and potato chips (916 µg/kg). Also, the mean concentration of toxin in popcorn and white bread were 452 and 231 µg/kg, respectively (Pacetti *et al.*, 2015). Shamla and Nisha (2014) showed that acrylamide contamination in potato chips in India varied from 82 to 4245.5 µg/kg with a mean concentration of 1456.5 µg/kg. In a similar study in China in which acrylamide levels were evaluated in 349 samples of food products, including drinking water, dairy products, potatoes, fruit and vegetables, chocolate, hazelnut, tea, coffee, beer, and seasonings; the highest rate of contamination (1467 µg/kg) was observed in potato products (Chen *et al.*, 2008). Rufian-Henares *et al.* (2013) reported a wide range of acrylamide in biscuits produced in Spain from undetectable to 2085 µg/kg. In another research, mean concentration of acrylamide in chips made from potato flour in Korea was 1368 µg/kg, however, the concentration of toxin in the chips made from wheat flour was 95 µg/kg (Koh, 2006). Mesias and Morales (2015) investigated 40 different kinds of potato chips brands produced by 18 Spanish factories and reported that the range of acrylamide contamination was 108 to 2180 µg/kg with a mean concentration of 630 µg/kg. In similar work on 50 potato chips samples in Romania, minimum and maximum concentrations of acrylamide were 18 and 1782 µg/kg and the mean concentration was 600 µg/kg.

Gunduz and Chengiz (2014) showed that acrylamide concentration in 43 bread samples in Turkey ranged from undetectable level to 695 µg/kg and mean contamination was 225 µg/kg. The highest concentration of toxin was observed in whole wheat bread. Forstova *et al.* (2014) reported that acrylamide concentration in bread consumed in Czech ranged from 7 to 22 µg/kg. It is known that when the dough leavening time is complete, it reduces the concentration of acrylamide in bread by reducing the final pH and control of intensity of Maillard reaction (Anese *et al.*, 2009). Evidence suggests that in most of Iranian bread, leavening period is very short, therefore, the fermentation process and subsequent degradation of reducing sugars does not occur perfectly and results in higher

acrylamide production after heating. One way to solve this problem is using a variety of commercial yeasts or the ones with more asparaginase enzyme in dough production process to accelerate fermentation process (Anese *et al.*, 2009).

Despite the importance of prevention against acrylamide production in high-risk food before or during the cooking process, it sometimes seems to be difficult to achieve this goal. Therefore, developing effective strategies to inform and educate consumers to reduce hazardous food intake or use of effective compounds to reduce acrylamide toxicity in body are of practical approaches. Medicinal plants containing polyphenols and antioxidants reduce acrylamide production through the interaction between sugars and asparagine amino acids. Also, it has been shown that some antioxidant plant compounds reduce the toxicity of chemical hazards (such as acrylamide) in the body of human and animals (Saeidnia and Abdollahi, 2013a; Saeidnia and Abdollahi, 2013b; Bahadar *et al.*, 2014; Maqbool *et al.*, 2016). Consumption of spices and plant flavors such as mustard, mint, oregano, and pepper can significantly mitigate the detrimental effects of the toxin (Kahkeshani *et al.*, 2014). Since potato chips are a popular and highly consumed meal for children, serious efforts should be made to reduce acrylamide risk in this at-risk population group. If food is not immediately cooled after cooking, acrylamide production may continue (Anese *et al.*, 2009), so, one useful activity is training of bakers to cool bread instantly after cook by cookinging it on racks subjected to airstream. Considering high bread per capita consumption rate in Iran, it seems that continuous and intensive surveillance and supervision by national health authorities and organizations is crucial.

## Conflict of Interest

No conflict of interest has been reported among the authors.

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