Chronicle of Bioresource Management 2024, 8(1):005-008

Chronicle of Bioresource Management
An International E-magazine

March, 2024

Popular Article

Acrylamide- A Potent Threat in Fried and Baked Food Products

Manivannan Marimuthu[1], Kasturi Chattopadhyay[2*] and Vishnupriya M. S.[3]

Abstract

Acrylamide, a process-induced food toxicant, has received wide attention in recent years due to its neurotoxic, genotoxic, and reproductive-toxic effects. It also acts as a potentially carcinogenic compound for humans. It is an unsaturated amide that is easily absorbed by animals and humans after ingestion and distributed in different organs such as the thymus, heart, brain, liver, and kidney. It functions as a precursor in the development of other compounds, such as glycidamide (carcinogen). It has been formed during Maillard reactions, mainly between the reactions of asparagine and reducing sugars at high temperatures. The carbonyl groups of reducing sugars and the amine group of amino acids react to form a Schiff base, leading to the formation of acrylamide. The addition of chitosan is an excellent alternative for achieving this goal because of its richness in amino groups, which interfere with the Maillard reaction that unleashes the formation of acrylamide.

Open Access

Corresponding Author

Kasturi Chattopadhyay

e-mail: kasturifish@gmail.com

Citation: Marimuthu et al., 2024. Acrylamide- A Potent Threat in Fried and Baked Food Products. Chronicle of Bioresource Management 8(1), 005-008.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Keywords:

Carcinogenic, Chitosan, Fried products, Maillard reaction, Toxicant

Article History

Article ID: CBM5068

Received on 09th December 2023

Received in revised form on 30th January 2024

Accepted in final form on 07th February 2024

1. Introduction

Nowadays, consumers are more health-conscious and demand high-quality food products. In this regard, low fat, sugar, and salt contents are among the most important requirements. Nevertheless, deep-frying remains a popular culinary method because it confers many favourable sensory attributes on foodstuffs. Acrylamide is a process-induced food toxicant that is formed during the heating of food products that are rich in carbohydrates and low in proteins. It has been found in a wide range of fried and baked foods. Acrylamide has received wide attention in recent years due to its neurotoxic, genotoxic, and reproductive-toxic effects. Acrylamide is a potentially carcinogenic compound for humans (IARC, 1994). The International Agency for Animal Health has classified acrylamides in-group 2A carcinogens, while the European Union (EU) has categorised them in-group two of carcinogenic and mutagenic substances. After consumption, unsaturated amides are readily absorbed by both humans and animals and are found in a variety

Author's Address

[1]Dept. of Fish Processing Technology, Paraprofessional Institute of Fisheries Technology, Madhavaram Campus, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Chennai (641107), India

[2]Dept. of Fish Processing Technology, College of Fisheries Science, Birsa Agricultural University, Ranchi, Jharkhand (834 006), India

[3]Dept. of Fisheries Engineering and Technology, College of Fisheries Science, Birsa Agricultural University, Ranchi, Jharkhand (834 006), India

Journal Home: *https://ojs.pphouse.org/index.php/CBM*

of organs, including the kidney, liver, brain, heart, and thymus. It is harmful when not only consumed but also when it is used as a starting point for the synthesis of other substances during hepatic metabolism, including the carcinogen glycidamide. Food products that are taken in large quantities that even have a little level of acrylamide (like coffee) may nevertheless have negative health effects. Acrylamide-based foods are thought to provide 38% of daily calories, 36% of fibre, 33% of carbohydrates, and over 35% of certain nutrients.

1.1. Chemical nature

• Acrylamide is a chemical compound with the molecular formula C3H5NO and a molecular weight of 71.08 g. The IUPAC name of acrylamide is 2-propenamide. It is ~~a~~ white, odourless, crystalline solid that is soluble in water, ethanol, ether, and chloroform. It is incompatible with acids, bases, oxidising agents, iron, and salts. It exhibits both weakly acidic and basic properties. It is a difunctional monomer, containing a reactive electrophilic double bond and an amide group.

1.2. Sources

Sources are classified into two groups. They are Dietary source and non-dietary source

1.3. Dietary sources

• Fried, deep-fried or baked food items, such as cake, bread, French fries, and chips, are believed to contain the highest levels of acrylamide. Certain foods, especially Western-style snacks, are processed or cooked at high temperatures.

1.4. Non-dietary sources

• Non-dietary sources include cigarette smoke (about 1-2 micrograms per cigarette) and cosmetics. There is also airborne release of acrylamide during many different manufacturing processes, including the manufacturing of paper, asphalt, petroleum, photographic film, construction adhesives, varnishes, and dyes. Also, found in consumer products, such as caulking, food packaging, and some adhesives.

1.5. Factors

• Initial concentration of reactants (amino acids,carbonyls). Its ratio, temperature and time of processing, pH, and water activity have been shown to influence the formation levels of acrylamide in heat-processed foods. Heating and time parameters have a direct influence on acrylamide formation in fried potatoes and fried rice. As temperature increases and moisture content decreases, acrylamide formation increases. Limiting factors for acrylamide formation in potatoes and cereals are reducing sugars and asparagine, respectively.

2. Formation Mechanism

Acrylamide formation in fried food products occurs through two main pathways. They are the Strecker pathway, or N-glycoside pathway, and the Acrolein pathway. The formation of acrylamide is mainly dependent on free asparagine and reducing sugars, the limiting factor being the sugar. Acrylamide in food results largely from the Maillard reaction between the free amino acid asparagine and a reactive carbonyl. The carbonyl group of reducing sugars reacts with the amine group of amino acids (especially free asparagines) and creates a Schiff base, leading to the formation of acrylamide during the subsequent decarboxylation. The mechanism involves the formation of a Schiff base followed by decarboxylation and the elimination of either ammonia or a substituted imine under heat to yield acrylamide. One other compound called 3-aminopropionamide can also be formed during the Maillard reaction and can be converted to amino acids under aqueous conditions. This compound has been identified in cocoa beans, coffee, and cereal products.

In the acrolein pathway, acrolein and acrylic acids are formed through the degradation of fats and the dehydration of glycerol, followed by a reaction with the ammonia derived from the degradation of asparagine and other amino acids, and acrylamide is generated.

3. Toxicity

• Neurotoxicity

• Genotoxicity

• Carcinogenicity

• Reproductive toxicity

• Hepatotoxicity

3.1. Neurotoxicity

Acrylamide is a known human neurotoxin. It disrupts the nervous system by inhibiting human neuroblastoma and glioblastoma cellular differentiation

3.2. Genotoxicity

The primary metabolite of acrylamide is glycidamide, an epoxide that readily reacts with DNA. This raises concerns about potential genotoxicity. A study by Alzahrani in mice showed that single doses of AA at 10, 20, and 30 mg/kg significantly induced DNA damage, as shown by elevation in micronuclei and chromosome aberrations in mice bone marrow cells.

3.3. Carcinogenicity

Acrylamide is currently classified as a “probable human carcinogen” by the IARC. Acrylamide can cause tumours in different organs, such as the lung, uterus, skin, mammalian gland, and brain. The carcinogenicity of acrylamide is derived from acrylamide-DNA adducts and consequent mutagenesis.

3.4. Reproductive toxicity

Administration of 0.5 to 10 mg/kg of Acrylamide to experimental rats results in growth retardation in rats and a reduction in epididymal sperm reserves. Likewise, 20 mg/kg of Acrylamide administered to male rats for 20 days shows a decrease in testosterone and prolactin concentrations. Acrylamide also enhances reactive oxygen species (ROS) and early apoptosis, and decreasing DNA and histone methylation levels leads to reduced oocyte quality and fertility. Alkylation of SH groups in the sperm nucleus and tail damages the testis DNA.

3.5. Hepatotoxicity

Although Acrylamide is metabolised in the liver, reports of its hepatotoxicity in humans are still scarce. Acrylamide shows a significant decrease in liver GSH levels in experimental adult rats.

4. Detection Methods

Most frequently used techniques to detect Acrylamide in food products include,

- High performance liquid chromatography (HPLC)
- Gas chromatography (GC)
- Capillary electrophoresis (CE)

5. Mitigation Strategies for Acrylamide Formation in Foods

5.1. Lowering pH

Lowering the pH of the food system by adding an acidulant (citric acid) converts the free nucleophilic nonprotonated amine group (-NH2) to a non-nucleophilic protonated amine (-NH3+) in foods. Which stops the formation of the Schiff base, one of the main intermediates in acrylamide formation.

5.2. Asparaginase

It is a selective removal of asparagine. The target is to reduce the precursor levels in the raw materials. Asparaginase can reduce acrylamide levels by up to 90% by converting asparagine into aspartic acid and ammonia without altering the appearance or taste of the final product.

5.3. Probiotics

Lactic acid bacteria (*Lactobacillus),Escherichia coli, Erwinia carotovora, Bacillus sp., Enterobacter aerogenes, Corynebacterium glutamicum, Pseudomonas stutzeri and Candida utilis*are can be used to mitigate acrylamide formation. There are two mechanisms: one is the physical absorption of carcinogenic compounds by bacterial cell wall components, particularly peptidoglycan, which binds to acrylamide. Another is metabolising the compounds. Bacteria are using acrylamide as a source of carbon and nitrogen, which is also producing the enzyme L-asparaginase. *Lactobacillus* species (*casei* and *L.reuteri*) possess asparaginase genes.

5.4. Chitosan

Amino groups of chitosan would compete with amino groups of asparagine to bind to the carbonyl group of reducing sugars, which unleashes the formation of acrylamide. The higher the deacetylation degree of chitosan, the higher the reduction in acrylamide.

5.5. Processing conditions

Temperature and time of the frying process are significant factors affecting the amount of AA formed in potato foods (Pedrechi *et al.*, 2006; Romani *et al.*, 2008). Higher temperatures and a longer duration of thermal processing are associated with higher AA content.

5.6. Food additives

Food additives could affect the formation of acrylamide during food processing. Citric acid, Cysteine, sodium hydrogen carbonate, calcium chloride, NaHCO3, and $KHCO_3$ could possibly minimise the formation of acrylamide.

5.7. Mono and divalent cations

Monovalent cations (Na^+) Halved the acrylamide formation, and divalent cations (Ca^{2+}) prevented acrylamide formation completely in the model system. Cations interact with asparagine, resulting in the inhibition of the formation of the Schiff base is inhibited (Gokmen et al., 2008).

5.8. Vitamins

B1, B2, B5, B6, C, E have been shown to be more effective in decreasing the acrylamide content. The terminal functional group of the side chain at the four-position (i.e., primary amino, hydroxyl, or aldehyde) plays a key role in interrupting certain steps of the pathway to the formation of acrylamide.

6. Limit

The Food and Drug Administration (FDA) and the World Health Organisation (WHO) have suggested the daily intake of acrylamide to be 0.3–0.8 μg/bw/kg. The U.S. Environmental Protection Agency (EPA) has estimated that U.S. adults average 0.4 micrograms of dietary acrylamide intake per kilogramme of body weight each day. Tolerable daily intake of acrylamide for neurotoxicity was estimated to be 40 mg/kg/d, while that for cancer was estimated to be between 2.6 and 16 mg/kg/d.

7. Preventive Measures

• Avoid eating a lot of carbohydrate-rich foods that are cooked at high temperatures,e.g. French fries.

• Continue to eat a balanced diet rich in fruits and vegetables.

• Limit the consumption of fried, fatty, and salty foods.

• Get regular physical activity.

• Limit the rate of alcoholic intake.

• Avoid smoking.

• Avoidance of high (>180–190°C) frying and baking (>250°C) temperatures.

8. Conclusion

Consumption of deep fried and baked food products can cause acrylamide. It has to be avoided by cooking potatoes to a golden-yellow, not brown colour., toast bread to the lightest colour possible, heat the oil to 145°C–170°C for deep frying foods, use always accurate cooking instructions and avoid using the microwave especially in cooking starchy foods

9. References

Gokmen, V., Senyuva, H.Z., 2007. Acrylamide formation is prevented by divalent cations during the Maillard reaction. Food Chemistry 103(1), 196–203.

Pedreschi, F., Moyano, P., Kaack, K., Granby, K., 2005. Color changes and acrylamide formation in fried potato slices. Food Research International 38(1), 1–9.

Romani, S., Bacchiocca, M., Rocculi, P., Dalla Rosa, M., 2009. Influence of frying conditions on acrylamide content and other quality characteristics of French fries. Journal of Food Composition and Analysis 22(6), 582–588.