FOOD TOXICANTS FORMED DURING THERMAL PROCESSING – A REVIEW

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Abstract—This review paper describes about the food toxicants such as acrylamide, acrolein, polycyclic aromatic hydrocarbons (PAHs) formed in some food products, mainly protein and starch-based food products during thermal processing like roasting, baking and frying. And these toxicants are related with the development of colour, aroma, flavours which gives the overall organoleptic properties and characteristics of the food product. In this review paper we have discussed about the frequently occurring heat generated food toxicants its mechanism, adverse effects to human health, human exposure, the strategy to be held to reduce the toxicants during thermal processing and some of the food which form these toxic compounds.

Index Terms—Toxicants, thermal processing, protein and starch-based foodstuff, frying

I. INTRODUCTION

Food quality and safety plays a major role in food processing. Heating of food is a common process to generate the flavour, colour, aroma, appearance and to ensure microbiological safety. Thermal processing may also create health promoting compounds such as antimicrobial agents, antioxidants in food. However, thermal processing may also lead to the formation of mutagenic and carmogenic by-products in food due to the chemical reaction during the heat treatment. The thermal processing also changes the chemical and physical structures of macro-nutrients such as protein and carbohydrates. The foodborne toxicants such as acrylamide, acrolein, polycyclic aromatic hydrocarbons (PAHs) have been identified as a risk factor concerning cancer.

In April 2002, the Swedish researcher detected the acrylamide formation in thermally processed food products such as coffee, biscuits, potato fries, bread and snacks which was related with the Maillard reaction and that was originated from amino acid asparagine. Heat treatment has been reported to induce the oxidative process in lipids and proteins caused by their decreasing effect in antioxidant protection and increasing effect of free radicals in food. This paper summarizes the mechanism behind the formation of food toxicants, the effects of consuming these toxicants and the exposure of toxic formations in food during thermal processing.

ACRYLAMIDE

Acrylamide (CH2=CHCNH2) is an unsaturated amide with a lower molecular weight of 71.08 g/mol and high solubility in water. Acrylamide is a monomer and is used to form polyacrylamides and these polyacrylamides are used in the cosmetics, textile, paper industry and in the purification of water. It is an odourless white crystalline solid. It has a boiling point of 125 °C (25 mmHg) and melting point of 84.5°C. Acrylamide is typically found in the plant-based food products such as potato, bakery products like bread, cake, cookies, cereal-based products, ready to eat products and coffee when it is thermally treated with a high temperature of >120 °C. It is also a component of tobacco smoke.

ACRYLAMIDE FORMATION IN FOOD PRODUCTS

The Acrylamide is an intermediate compound of Maillard reaction, which is formed when reducing sugars react with amino acid, asparagine during thermal processing such as baking, roasting, frying. However, this Maillard reaction is closely linked with the formation of important characteristics of cooked food such as colour, aroma and flavour. When decahydroxylated asparagine (3-aminopropionamide) is heated it has the capability to generate the acrylamide in the absence of reducing sugar. This acrylamide formation is mainly found in starch and protein-based food products.

II. HEALTH EFFECTS

The acrylamide affects the nervous system of the human body. Recent studies shows that the acrylamide is toxic and it can lead to cancer, congenital problems and induce the developmental issues in animals. Now there is an insufficient evidence for carcinogenic effects in human. But WHO and IARC have classified the acrylamide as genotoxic carcinogen for humans which comes under group 2A category. However, epidemiological studies have still given us insufficient data for dietary exposure of acrylamide in association with cancer.

III. HUMAN EXPOSURE

Based on various experiments and analyses of acrylamide in foods, WHO estimated that the average intake of acrylamide is 0.3 – 0.8 µg/kg per day, while daily intake for some groups of people may be much higher than the average level.

MINIMISING STRATEGY

- Based on raw materials used in thermal processing:
- Lots of factors influence the levels of reducing sugar
in raw materials such as storage temperature and climatic condition.

- E.g., potato – the immature potatoes have higher reducing sugars which will lead to a higher formation of acrylamide during thermal processing.
  - Based on thermal processing of food:
    - Thermal processing such as boiling, steaming, vacuum frying or blanching before frying instead of direct frying will reduce the formation of acrylamide.
  - Based on food processing conditions:
    - Avoid frying or baking with very high temperature or over cooking.

IV. ACROLEIN

Acrolein (C3H4O) is the α, β unsaturated aldehyde. It has high volatility and a boiling point of 52.5ºC and a melting point of -88ºC. It is colourless and soluble in water. Acrolein is formed from fat, carbohydrates, protein during frying and deep frying. Acrolein formation from carbohydrates is also due to Maillard reaction. Acrolein occurs in fruits and vegetables such as grapes, strawberry, blackberry and raspberry, tomato. It was also found in some thermally processed food products such as potato chips, cheese, fish, wine and spirits when exposed to high temperature of 180ºC.

V. FORMATION OF ACROLEIN IN FOOD PRODUCTS

Acrolein can be formed by the thermal processing of protein, fat and carbohydrates. The Glycerides/glycerol in fat are the primary reason to form acrolein in thermally processed food products. Thermally processed proteins such as threonine and methionine form acrolein. The thermal processing of carbohydrates can also lead to the formation of acrolein. The acrolein also forms the precursor of the acrylamide. The ammonia that is liberated with amino acids will lead to the conversion of acrolein to acrylamide. The hydrolysis or decarboxylation of amino acids also lead to the formation of acrylamide. Acrolein is also found in non-thermal fruits, vegetables and cheese in small amount. It is typically found in foods containing animal fats, plant oils and in volatile compounds of certain food products such as poultry, bread and fish. The formation of acrolein in oil is dependent on the composition of fatty acid, heating time and temperature. The acrolein content is 20µg/kg in refined oil, but the crude oil has high acrolein content of 0.2 - 1.4 mg/kg when it is exposed for deep frying of food.

VI. HUMAN EXPOSURE

Acrolein has a toxic potential which is formed by the reaction of α, β unsaturated carbonyl compounds, which causes cytotoxic effect in the mucous membrane when acrolein directly approaches with the tissue. WHO concluded that the ADI of acrolein is 7.5 mg/kg body weight per day.

VII. POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

PAHs are an organic compound which is fused with benzene ring structures of hydrogen and carbon atoms, which are high in hydrophilic and organic lipophilic compounds. These are weak volatile compounds with weak dissolving capability in water. Usage of contaminated soil and polluted water for crop production, agricultural burning in contact with the deposition of air on post-harvest food items can also lead to the PAHs formation and also contamination in food. Polycyclic aromatic hydrocarbon also found in food products when it exposed to thermal processing such as roasting, grilling and frying more than 120ºC and these are considered as food contaminants. The formation of PAHs in food products such as fruits, vegetables, cereal products, meat, beverages, coffee, medicinal plants, oils, nuts, spices and herbs.

VIII. FORMATION OF PAHS IN FOOD PRODUCTS

Polycyclic aromatic hydrocarbons are formed in many food products with focus to their cooking methodology, packaging and thermal processing such as drying, smoking, baking, roasting, grilling, frying. The PAHs are formed with free radicals in food which when exposed to high temperature, leads to the formation of small amount PAHs thereby increasing the formation and finally will be retained in fat rich food.

HEALTH EFFECTS

- PAHs may lead to carcinogenic effect by ingestion
- Benzo(a)pyrene (BaP) exhibit carcinogenic effect in food
- PAHs has genotoxic effect

HUMAN EXPOSURE

The IARC identified 12 polycyclic aromatic hydrocarbons (PAHs) with carcinogenic, effect and possible effects in the category of group 1, group 2A and group 2B respectively. The ADI of PAHs in India is 11µg/day per person. The
normal PAHs exposure of 3.1x10^-5 induces incremental cancer risk.

**MINIMISING STRATEGY**

- Avoiding direct contact of smoke, flame of food
- Prevention of melting fat from the heat source, while grilling the food also reduces the PAHs contamination in food.

**IX. RESULT AND DISCUSSION**

These food toxicants are primarily found in the thermally processed food products, which are in high demand now-a-days. These have many health effects when taken in high dosage. The IARC and WHO classified the toxicants with the carcinogenic effect in animals, but there is no scientific evidence that acrylamide is related to cause cancer in humans and more toxicants are under research. Apart from this JECFA are aiming to detect new technological strategies to reduce the acrylamide formation and acrolein during thermal processing of food products.

**CONCLUSION**

Thermal processing plays a major role in a food product to enhance the flavour, texture, colour and to ensure the microbial safety. However, it paves way to the formation of some food borne toxicants. JECFA has suggested some reducing strategy in food processing sectors/food industries during thermal processing. The exposure and the health effects of these toxicants are tested with animals. Many studies are done to estimate the high dose of carcinogenicity of a particular food borne toxicants but there is no sufficient data to conclude it. Further, more researches are needed to find the formation of these toxicants in the thermally processed food products.

**REFERENCES**

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