

Is Our Food Really Safe - Contaminants Induced during Food Processing

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Abstract—All forms of food contaminations, either of microbiological, physical or chemical origin are of highest concern for consumer. Food contaminants generally occur in food because of over use of food additive or ingredient beyond permissible limits, processing-induced reactions, food packaging migration, deliberate adulteration and/or presence of chemical contaminant or natural toxin in the environment. Processing induced contaminants like acrylamide and nitrosamine are generated during processes like frying, grilling, baking and roasting. Benzene another processing induced contaminant is generated in beverages due to reaction of ascorbic acid and benzoates under certain conditions. Contaminants from packaging material like dioxins generated by incineration or migration from packaging material to milk, tin from cans to food, copper from utensils, bisphenol A and phthalates from plastic bottles is of great concern. Food additives like BHA, BHT, artificial sweeteners, flavours, colors etc beyond permissible limit are threat to consumer health and life. Heavy metal and radioactive contamination have been the most persistent types of contamination occurring since the beginning of green revolution and industrialisation accounting for serious health issues among consumers. Various contaminants even enter the food chain through auto oxidation of fats and oils. Other contaminants like natural toxins, fumigants, veterinary drugs enter food chain from raw material, storage room, and animal foods respectively. A wide overview is presented in this paper, which deals specifically with process contaminants that are induced in food at various stages of processing.

1. INTRODUCTION

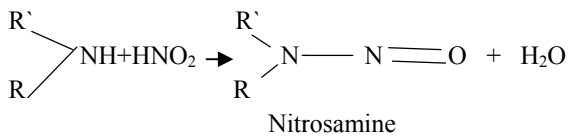
Contaminants are substances that **have not been intentionally added to food**. These substances may be present in food as a result of the various stages of its **production, packaging, transport or holding**. They also might result from **environmental contamination**. Since contamination generally has a negative impact on the quality of food and may imply a risk to human health, the EU has taken measures to minimise contaminants in foodstuffs [1]. Process contaminants are substances that form in food or in food ingredients when they undergo chemical changes during processing. Processing methods include fermentation, smoking, drying, refining and high-temperature cooking. However, baking, frying, grilling or barbecuing, either at home or in manufacturing, can have undesired consequences. Besides the loss of some nutrients like vitamins, potentially harmful by-products can develop too [2].

2. FOOD CONTAMINANTS THROUGH PROCESSING

Toxins are formed in food during their processing, such as smoking, heating, grilling, baking, fermentation. For example, Nitrosamines, Acrylamide, Benzene, Polychlorinated biphenyls (PCB)

2.1 Nitrosamines

N-Nitrosamines are aliphatic or aromatic derivatives of secondary amines which have nitroso (-NO) group attached to it. The nitrosamine most commonly found in foods is dimethylnitrosamine. Nitrosamines are formed during some forms of cooking (grilling, frying) through reaction of amines naturally present nitrous oxide (NO) in flame gases, or through reactions of amines with NO present in the food on account of accelerated elevated temperature. Nitrosamine are powerful carcinogen and some are found to be mutagenic and teratogenic. Foods most commonly contaminated with N-nitrosamines are Nitrite Cured meat, cheese preserved using nitrite, Dried products (milk, malt) using combustion gases, Smoked fish, Barbecue product, Ascorbic acid and tocopherols prevent formation of nitrosamines in food by converting nitrite to nitric oxide [3].



2.2 Acrylamide

Acrylamide is a chemical that can form in some foods during high temperature cooking, such as frying, roasting, and baking of foods that are rich in carbohydrate. The major mechanism for the formation of acrylamide during cooking is due to the reaction of the free amino acid asparagine with reducing sugars, such as glucose or fructose at high temperatures (120°C). Foods most commonly contaminated with acrylamide are Potato crisps and snacks, Roast and ground coffee, cookies, Bread. The International Agency on Research on Cancer (IARC) classifies it as probably carcinogenic to humans. The acrylamide is also a neurotoxicant, carcinogenic, mutagenic, and teratogenic. Acrylamide itself is not a genotoxic but generation of GLYCIAMIDE has been shown to have genotoxic effect at low level. The No Observed Effect Level (NOEL) in rat is 0.2mg/kg body weight [3,4].

2.3 Benzene

Benzene is an organic chemical compound that has the molecular formula C₆H₆. Benzene can form in beverages through the reaction between ascorbic acid and sodium/potassium benzoate in the presence of heat, light and transition metal ((Ferric ions and Cupric ions). Food processing conditions such as irradiation and high temperature processing (e.g roasting) also promote formation of benzene in Food.

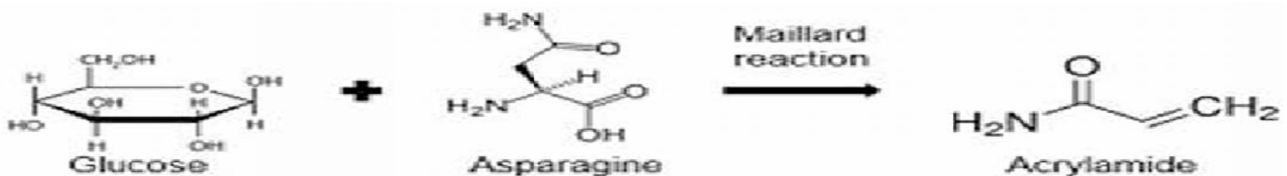
The International Agency for Research on Cancer has classified benzene as carcinogenic to humans. Benzene causes acute myeloid leukaemia. Chronic exposure to benzene can reduce the production of both red and white blood cells from bone marrow in humans, resulting in aplastic anaemia.

At low level exposures benzene is rapidly metabolized in body and excreted mostly as conjugated urinary metabolites. Maximum contaminant level for benzene is 5 microgram/liter [3,4,5].

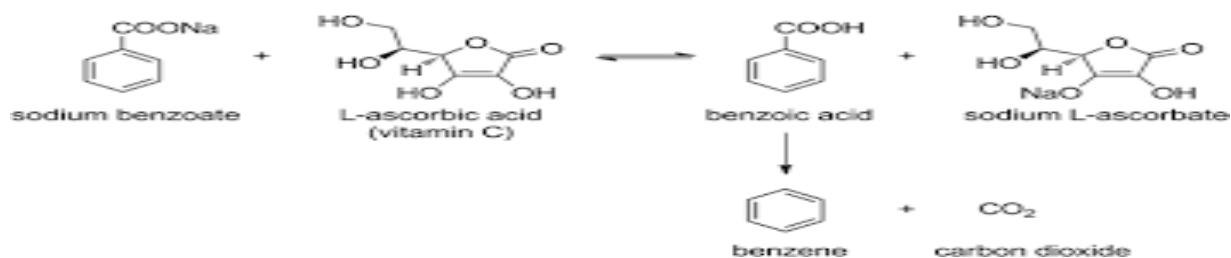
3. PERSISTENT ORGANIC POLLUTANTS

Persistent organic pollutants (POPs) are chemicals that are resistant to environmental degradation through chemical, biological, and photolytic processes.

The most commonly encountered POPs are organochlorine pesticides, such as DDT, industrial chemicals, most notably polychlorinated biphenyls (PCB), as well as unintentional by-products of many industrial processes, especially polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF), commonly known as 'dioxins'. POPs bio-magnify throughout the food chain and bio-accumulate in organisms. The highest concentrations of POPs are thus found in organisms at the top of the food chain. Consequently, background levels of POPs can be found in the human body [3,6,7].

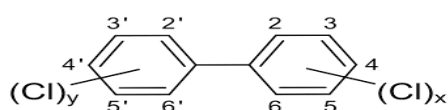


Human exposure to low levels of POPs - can lead, to increased cancer risk, reproductive disorders, alteration of the immune system, neuro behavioural impairment, endocrine disruption, genotoxicity and increased birth defects.



3.1 Polychlorinated Biphenyls

PCBs are a group of organic chemicals consisting of carbon, hydrogen and chlorine atoms. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including: vElectrical, heat transfer and Plasticizers in paints, plastics and rubber products, Pigments, dyes and carbonless copy paper, Other industrial applications [3, 7].



PCBs can be released into the general environment from poorly maintained toxic waste sites; by illegal or improper dumping of PCB wastes, such as transformer fluids; through leaks or fugitive emissions from electrical transformers containing PCBs; and by disposal of PCB-containing consumer products in municipal landfills.

PCBs are lipophilic; they preferentially separate from water and adsorb to sediment at the bottoms of lakes and rivers. Bottom feeders and other aquatic organisms then ingest and accumulate PCBs, resulting in bioconcentration upward in the food chain. Animal products especially fish, milk, meat are mostly contaminated with PCB.

Chronic exposure of animals to PCBs can lead to disrupted hormone balances, reproductive failures, or cancer. The Food and Drug Administration (FDA) requires that milk, eggs, other dairy products, poultry fat, fish, shellfish, and infant foods contain not more than 0.2–3 parts of PCBs per million parts (0.2–3 ppm) of food.

The toxicity of PCBs was dramatically illustrated in 1968 when over 1600 people in Japan were poisoned by cooking oil contaminated with PCBs from a heat transfer unit. Rice bran oil produced by Kanemi Company in Kyushu was contaminated with PCBs and polychlorinated dibenzofurans (PCDFs) during production. For deodorization, the oil was heated using PCB as the heating medium, circulating through pipes. Due to holes in the pipes the PCB leaked into the rice bran oil. The contaminated rice bran oil was then sold to poultry farmers for use as a feed supplement and to consumers for use in cooking.

4. CONTAMINANTS FROM PACKAGING MATERIAL

Food packaging contaminants are inorganic or organic chemicals that originate from packaging material. They are intentionally added substances with a technical function, manufacturing byproducts, impurities of starting material or contaminants that are present due to recycling of packaging material. Food packaging contaminants originate either from the direct food contact material itself or from the printing inks and secondary packaging [3,8-11].

4.1 Dioxins

Dioxins are environmental pollutants. When an organic substance is incinerated in the presence of chlorinated compounds, dioxins can generate unintentionally due to incomplete combustion. The name "dioxins" is often used for the family of structurally and chemically related polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The most toxic known dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and significant concentration of this compound can be measured in parts per trillion (PPT). Once dioxins enter the body, they last a long time because of their chemical stability and their ability to be absorbed by fat tissue, where they are then stored in the body. Their half-life in the body is estimated to be 7 to 11 years. In the environment, dioxins tend to accumulate in the food chain. The higher an animal is in the food chain, the higher the concentration of dioxins. Sources of dioxin contamination are incineration from polyvinylchloride and paper, migration from packaging in milk, automobile exhaust, chlorine bleaching of wood pulp. Chronic exposure of animals to dioxins has resulted in several types of cancer.

4.2 Tin and copper

The use of tin cans for packaging foods and beverages can lead to contamination with tin. Tin can also enter food through the use of tin-containing organo-pesticides. Chronic exposure to tin and its compounds through food can cause GI effects, liver damage, reproductive effects, developmental effects, as well as cancer. Copper contamination of food can occur if the cooking utensils, including pots and pans are made of uncoated copper, especially if acidic foods are cooked. Copper can also enter the human food chain by the use of copper-containing fungicides. Chronic exposure to copper can cause liver failure.

4.3 BisPhenol A and Phthalates

It is found in some plastic food and beverages container including baby bottles. It is also used as resins to coat the inside of the cans. Phthalates are used predominantly as "plasticisers" to make plastics more flexible as a solvent and in ink manufacturing of other food packaging material. Phthalates are soluble in fat and therefore are commonly found in fat-containing foods (. Phthalates can also migrate into foods (particularly fatty foods such as cheese and meat) from plastic food wrappings and possibly printing inks used on wrappers. They can disrupt endocrine function and also affect reproductive system.

4.4 Polyvinyl chloride

Polyvinyl chloride (PVC) is one of the most versatile plastics because of its blending ability with a variety of additives such as plasticizers and stabilizers to produce a wide range of products including packaging materials. Films and sheets followed by bottle production are the largest applications for PVC in food packaging. Vinyl chloride which is a monomer of polyvinyl chloride can contaminate food through migration from PVC. Vinyl chloride is known carcinogen. The maximum residual limit set by Codex is 0.0mg/kg of food [3,,8-11]

5. SULFITES

Natural source of sulphites are asparagus, eggs, garlic, tomato, onion etc. Sulfites due to their antimicrobial and antioxidant property are used widely in processed foods and beverages like Wines & beer, biscuits, bread, pickles, jams, squashes, shrimps and prawns. Active component of sulfite due which it is used as preservative and cause allergy in human is Sulphur Dioxide . Three major mechanism of sulfite allergy are

- **Inhalation-** Reflex contraction of respiration pathway on inhaling sulphur dioxide gas.
- **Ig-E-** Some people have positive skin allergy to Sulfites in which an Ig-E mediated allergic response is given out by the body due to the release of histamine from mast cells.
- **Sulfite oxidase-** Asthmatic people who react to Sulfite have a partial deficiency of enzyme Sulfite oxidase which helps in breakdown of sulphur dioxide.

Symptoms of sulfite allergy are wheezing, laboured breathing, chest tightness, blue discolouration of skin, respiratory arrest, hives, laryngeal edema, swelling of hand, feet, eye, diarrhoea, nausea, abdominal cramps, vomiting, drop in B.P etc. In extreme cases, it can lead to anaphylactic shock; can be life threatening [12-16]

6. FUMIGANTS

Fumigation is a process involving chemicals in the form of smoke, fog, mist aiming to kill air borne microorganisms including spores, insects etc. Fumigant is a chemical which, at a required temperature and pressure can exist in gaseous state, in sufficient concentration to be lethal to target organism. Common fumigants used are formaldehyde, phosphine, methyl isocyanate, hydrogen cyanide, sulfur dioxide etc. Problem with fumigants is bioaccumulation and biomagnifications which further become threat to human health as potential carcinogens. Some evidences even show leaching of fumigants in groundwater. E.g. Fumigant like ethylene dichloride was used in fumigation of wheat grains. Major issues were observed after processing of fumigated wheat into flour and various other products like cake, bread etc. Alteration in physical properties of flour like color, flavour, viscosity and baking performance, tenderness, crumb texture of bread was observed [17].

7. AUTOXIDATION PRODUCTS

Free fatty acids are acted upon by oxygen in the presence of initiators to form free radicals like R*, ROO*, RO* which further form primary, secondary and tertiary products like hydrogen peroxide, keto, epoxy and hydroxy compounds, esters, hydrocarbons, acids, epoxides, alkyl trioxan etc. Many of these secondary and tertiary products of lipid oxidation are potential carcinogen. Hydrogen peroxides are known to damage DNA. Carbonyl compounds may affect cellular signal transduction.

Epoxides, hydroxy compounds are known carcinogens. Some aldehydes, ketones and esters formed during autoxidation lead to off flavour, off odours development.

Table 1. Heavy Metals [10,11]

Metal	Source	Toxic Form	Mechanism	Health Effects
Mercury	Soil, Water, Fish, Fungicides	Dimethyl Mercury, Methyl Mercury Salts And Phenyl Mercury Salts	Absorb and Accumulate In Erythrocytes And Cns (Lipid Soluble)	Harm Brain, Heart, Lung, Kidney And Immune System
Lead	Emissions From Automobile Industry And Vehicles, Soldered Cans	Pbo, Pbcl ₂ , Tetra Ethyl Lead	Accumulation Toxicant In Liver, Kidney, Brain, Bones	Immunotoxicity, Kidney Damage, Miscarriage, Premature Birth, Behavioural Disorders, Coma, Death
Cadmium	Wild Mushroom, Ocean Fish, Animal Foods(Liver, Kidney), Industrial Waste Water, Fertilizers	-----	50% Of Cd Is Stored In Liver And Kidney, High Concentrations In Salivary Glands And Pancreas, Other Storage Sites- Joint & Arteries	Lead To Cancer, Diabetes, Heart Disease, Birth Defects, Brain Dysfunction, Interferes In Metabolism Of Divalent Metals Like Ca, Cu, Zn Etc
Arsenic	Ground Water, Pesticides, Feed Additives, Tobacco	Trivalent Arsenic, Arsine Gas, Inorganic Forms	Forming Bonds With Various Enzymes Involved In Body Pathways (Respiratory)	Skin Lesions, Lung & Bladder Cancer

8. VETERINARY DRUG RESIDUES

These components include all antibiotics, feed additives given to animals for: Promoting growth, Shortened time for growth(faster growth), feed time, Improve quality in terms of nutrition, Improve feed utilization. These residues may be found in egg, milk (after mastitis treatment), meat and other animal foods. Few drugs are tetracycline, ampicillin, streptomycin, neomycin etc. These veterinary drug residues may be cause infections from microorganisms which may become drug resistant, causes hypersensitivity reactions, can induce carcinogenicity, mutagenicity, teratogenicity, allergic reactions and disruption of intestinal microflora etc [3, 8,9]

9. FOOD ADDITIVES

Additives are used in food for variety of purposes to name few; enhance shelf life, colour, flavour etc. but these additives can pose a threat to health in one way or the other. These additives are mainly added intentionally in food for their properties but many of them enter the food during processing. These may cause serious health implications which may induce carcinogenicity, mutagenicity and teratogenicity. Preservatives like benzoates are very low order toxicity causing substances and can be easily degraded and excreted from the body, whereas nitrites used especially in meats are toxic in nature, can affect oxygen carrying capacity of haemoglobin therefore respiratory system is adversely affected. Colours like tartrazine inhibit the release of histamines from mast cells and formation of cyclo-oxygenase and prostaglandin. MSG which is being studied as recent contaminants in food. Glutamate acts as precursor of neurotransmitter acetyl choline which reaches toxic levels in very short periods of time which subsequently acts on brain and central nervous system. Artificial antioxidants especially phenolic ones i.e. BHA (Butylated hydroxy anisole) and BHT (Butylated hydroxy toluene) are used in fat rich foods to protect them from lipid oxidation. Metabolites of these are not digested by some consumers as a result their liver and kidney are affected. It is also studied that metabolites of these antioxidants contribute to carcinogenicity and tumorigenicity, abdominal pain and behavioural changes.

Artificial sweeteners like aspartame and cyclamates added to food are contributors to many symptoms to humans. Cyclamates are converted to cyclohexylamine by intestinal microflora which is carcinogenic; similarly patients with phenylketonuria cannot breakdown phenylalanine of aspartame (dipeptide of phenylalanine and aspartic acid) therefore affecting them the most.

From the above effects of additives on body, it is therefore important to regulate the quantities and levels of these substances used for food. Animal studies, toxicological studies (levels of effects, duration of exposure etc.) should be done time to time to study the levels and dose requirements for different foods [3,4,8,9,11]

10. CARCINOGENS IN SMOKED FOODS

Smoking is the process of flavouring, cooking or preserving food by exposing it to the smoke from burning or smouldering plant materials like wood i.e. hard wood. Foods like fish, meat, cheese, nuts, vegetables and beverages like tea, whisky etc. are smoked to enhance their characteristic flavour. Compounds formed during smoking are polycyclic aromatic hydrocarbons (PAHs), Nitrosamines etc and these compounds are potential carcinogens. Short term health effects are nausea, vomiting, diarrhoea etc.

Long term health effects are kidney & liver cancer, jaundice etc.

E.g. During smoking of fish following compounds are formed:

Polynuclear aromatic hydrocarbon groups which contains many highly carcinogenic compounds like 3,4 benzopyrene.

Nitroso compounds, which are capable of forming carcinogenic nitrosamines by reaction with amines in fish flesh. [11]

11. RADIONUCLIDE

A radionuclide is a atom with an unstable nucleus which to become more stable emits energy in the form of rays or high speed particles. These are called ionizing radiation. These compounds are present in environment in food like milk, fish, animal food, fruits & vegetables etc., soil, water. Radionuclides are generated by human activities like nuclear weapon testing, nuclear power plants, uranium milling & mining, nuclear accidents etc. Radionuclides naturally in food are potassium-40, radium-226, radium-228, carbon- 14, rubidium- 87, polonium- 210 and thorium- 228. Mode of action is radiations that can cause cell death, abnormal cell formation, damaging genetic material of cells, cancer, cataract, benign tumor, potentially harmful genetic changes etc [3,18].

11.1 CASE STUDY [18,19]

Japan was rattled by the powerful March 11, 2011 earthquake and tsunami which claimed close to 20,000 lives across swathes of the eastern coast. Fukushima Daiichi nuclear power plant, was severely damaged by the earthquake and tsunami with its crucial cooling systems knocked out, resulting in a series of explosions, meltdowns - and the world's worst nuclear accident in 25 years. Farm produce and tourism all strongly affected by associations of the name Fukushima with nuclear contamination. This major accident was rated at Level 7 on the International Nuclear Event Scale due to high radioactive releases to air in the first few days. The bulk of releases occurred with the explosions, while a leak of contaminated water to sea continued for two months. Further releases of radioactivity to the air were brought to insignificant levels before the end of 2011, although much radioactivity remains dispersed on the ground in the surrounding area. Regarding releases to air and also water leakage from Fukushima, the main radionuclide from among the many kinds of fission products in the fuel was volatile iodine-131, which has a half-life of 8 days. The other main radionuclide is caesium-137, which has a 30-year half-life, is easily carried in a plume, and when it lands it may contaminate land for some time. It is a strong gamma-emitter in its decay. Cs-134 is also produced and dispersed, it has a two-year half-life. Caesium is soluble and can be taken into the body, but does not concentrate in any particular organs, and has a biological half-life of about 70 days. Groundwater travels naturally from the land to the sea and, in doing so, is believed to mingle with heavily contaminated water in the basements. Radioactive material continues to run off from the land through rivers to the sea and can be found in certain species of fish. However, all food from affected areas has been strictly monitored since the accident and prevented from sale if in excess of highly conservative standards. While Japanese food produce was once synonymous with safety and high quality production, a string of food safety scares from green tea and beef to rice and even baby milk formula have resulted in a growing sense of distrust among the public for government contamination safety testing.

12. CONCLUSION

Food containing a contaminant to an amount unacceptable from the public health viewpoint and in particular at a toxicological level, shall not be placed on the market. Contaminant levels shall be kept as low as can reasonably be achieved following recommended good working practices. Maximum levels must be set for process contaminants in order to protect public health.

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