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Benzopyrene in Seafood: Formation, Occurrence and Toxicity

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Abstract

Benzopyrene, a main representative of polycyclic aromatic hydrocarbons is present in high concentrations in aquatic sediments and soil, while low concentrations are present in surface waters. It is naturally formed by forest fires and volcanic eruptions and can also be found in coal tar, cigarette smoke, wood smoke, and smoked food products. Outdoor air is often contaminated with BaP at concentrations that consistently exceed acceptable standards. This substance is very toxic, carcinogenic, genotoxic, mutagenic, epi genotoxic, teratogenic, and neurotoxic, and it impairs fertility. Formation of BaP involves incomplete combustion of organic compounds, chemical reactions, and limited oxygen availability. The EU legal limit for benzo[a]pyrene for fish considered safe for human consumption is 2 μg kg^{-1}. Fried and smoked products will have a greater number of benzopyrene content in food, especially when the fish occurred anxious burnt benzopyrene content will increase rapidly. BaP is a carcinogen and can cause epigenetic changes such as DNA methylation and histone acetylation

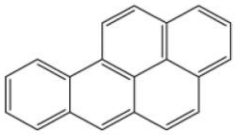
INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals with two or more fused benzene rings in several structural configurations and do not contain hetero atoms. Fish is an important source of PAH exposure in humans. Fish and marine invertebrates may naturally contain small amounts of different PAH absorbed from the environment (Stolyhwo and Sikorski, 2005). These are inevitable pollutants in the environment formed through the partial combustion of organic materials. PAHs with less than four rings are known as light PAHs and more than four rings are heavy PAHs. Farmed fresh fish may be contaminated by PAHs through ingredients used in fish feed manufacturing (Nácher-Mestre et al., 2010). Bivalves and fish are exposed to PAHs that is present in the marine environment due to polluted sediments, spill residues, shipping activities, industrial and urban run-off, and atmospheric pollution (Soriano et al., 2006). Benzopyrene (BaP) is one of the high molecular weight carcinogenic PAH which possess high lipophilicity, low biodegradability, and are genotoxic and mutagenic (Bartoszek,2006). It is used as

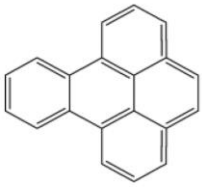
an indicator for the occurrence and effect of carcinogenic PAHs in food. BaP has been observed to scrape together in marine organisms and plants which could accidently cause human exposure through food consumption. It has been used as a surrogate for other PAHs. Pure BaP crystals are pale yellow and needle-like with a faint odor (ATSDR 1995).

CHEMICAL STRUCTURE OF BENZOPYRENE:

A benzopyrene is an organic compound with the formula $C_{20}H_{12}$ and a molecular weight of 252.31 g/mol. BaP consists of four fused benzene rings including one benzene ring and three cyclopentane rings, forming a structure known as a "bay region.". Two colorless isomeric species of benzopyrene are benzo[a]pyrene and the less common benzo[*e*]pyrene.



Benzo[a]pyrene



Benzo[e]pyrene

Fig 1.Isomers of Benzopyrene

FORMATION OF BENZOPYRENE:

Benzopyrene formation during a high-temperature process is a result of the complex chemistry involved in the decomposition and transformation of organic materials particularly those rich in carbon, under conditions of heat and limited oxygen availability. High temperatures, typically above 400°C are conducive to the formation of BaP. It can form during the incomplete combustion of coal, wood, tobacco, or oil. Incomplete combustion occurs when there is insufficient oxygen available for complete oxidation of the carbon-containing compounds present in the material, which results in the formation of soot or smoke containing a complex mixture of PAHs including benzopyrene. PAHs can form when fats and juices from the seafood drip onto hot surfaces or coals, where they undergo pyrolysis and produce smoke. The smoke then deposits PAHs onto the surface of the seafood, potentially increasing exposure to these compounds when consumed.

Chemical reactions: The formation of BaP involves complex chemical reactions, including ring closure reactions and cyclization of aromatic compounds. These reactions can occur through mechanisms such as radial reactions, hydrogen abstraction, and addition-elimination processes. **Pyrolysis:** It involves the decomposition of organic compounds at high temperatures in the absence of oxygen. When seafood such as fish or shellfish is smoked, it is exposed to heat and smoke generated from burning wood. This exposure can lead to pyrolysis of complex organic molecules which break down into simpler compounds, often including PAHs like benzopyrene in seafood. It can occur during high-temperature processes such as grilling, and smoking of foods as well as industrial processes like coal tar distillation (M. Reinik *et al.*,2007*)*.

OCCURRENCE IN SEAFOOD PRODUCTS:

In a study of children's exposure to PAHs in Minnesota, BaP was found to be 43-58% of different types of air samples, 19% of household dust samples, and 22% of food samples (Clayton et al. 2003). The

concentrations of BaP in Canada's worst contaminated areas of soil were found to be higher in homes near steel processing plants than in homes far off. Investigations on Korean municipal middle school students manifested that, BaP with its metabolites have been encountered in the urine of pregnant women and children (Kang et al. 2002). Department of Biochemistry and Nutrition, Central Food Technological Research Institute, Mysore 570 013, India has detected BaP in placenta, maternal blood, and human breast milk. A study in Spain of BaP in diet detected BaP in foods that, daily intake of BaP was found to be higher in children ages 4-9 years old, as compared to adults and adolescents (Falco, G., et al. 2003).

TOXICITY OF BENZOPYRENE:

BaP is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC), this means there is sufficient evidence to indicate that it is carcinogenic to humans. DNA adducts can be formed when BaP binds to DNA molecules (CEFAS, 2000). It is observed as a critical step in the carcinogenic process, as it can begin the development of cancerous cells. These adducts moreover interfere with the normal structure and function of DNA, leading to mutations (DeMarini *et al*., 2001). Benzopyrene is metabolized in the body by enzymes, predominantly in the liver, into reactive metabolites that can additionally interact with DNA and other cellular components. BaP exposure has been correlated with other adverse health effects, together with respiratory irritation, cardiovascular effects, and reproductive toxicity. In vivo tests on mammals have been reported that benzopyrene can induce sister chromatid exchange, chromosomal aberrations, sperm abnormality, etc.

REGULATORY LIMITS

Products	Limits/Maximum level	Reference
Muscle meat of smoked fish and smoked fishery products	5 µg/kg	Commission Regulation (EC) No 1881/2006 of 19 December 2006 (Official Journal of the European Union)
Muscle meat of fish other than smoked fish	2 µg/kg	
Bivalve molluscs	10 µg/kg	
Crustaceans, cephalopods other than smoked	5 µg/kg	
Traditionally smoked meat and fishery products	5 µg/kg	
Smoked sprats and canned smoked sprats	5 µg/kg	

CONCLUSION

Benzopyrene, a carcinogenic PAH is present in high concentrations in smoked fish products and low concentrations in canned fish products. Cold- and hot-smoked fish contain much more PAH than raw fish, depending on the properties of the fish, method and parameters of smoking, the composition of the smoke, and exposure of the edible parts to the smoke.By liquid smoking, we can minimize environmental pollution such as carcinogens and hazardous compounds such as BaP.

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