Significance of Biogenic Amines in Seafood Safety

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Introduction

The consumption of seafood is growing at a rapid pace and so are its associated problems, one of them being biogenic amines. Biogenic amines are important anti nutritional factors formed during decomposition of seafood, mainly by storing at high temperature abused condition or>8 °C. Formation of biogenic amines in fish is species specific. Its implications in quality, safety and freshness of seafood have created great interest among researchers.

What are biogenic amines?

Biogenic amines are biologically active organic bases of low molecular weight. These nitrogenous compounds are synthesised in micro organisms, plants and animals as a result of metabolic activities at the cellular level. There are three categories of biogenic amines as per chemical structure which includes:

- Aromatic amines – Histamine, Tyramine, Serotonin, β- Phenylalanine and Tryptamine
- Aliphatic diamines – Putrescine, Cadaverine
- Aliphatic polyamines – Agmatine, Spermidine and Spermine

They can be found in most food items in our daily diet with higher amounts in processed foods. They are usually produced by decarboxylation of free amino acids or by amination and transamination of aldehydes and ketones. Removal of α - carboxyl group from precursor amino acids leads to the production of biogenic amines by enzymatic action in raw material or due to microbial activity during aging and storage of food. They have also been associated with protective mechanism of micro organisms against acidic environment in foods such as cheese, sausage etc. Amino acid decarboxylases are found in certain enterobacteriaceae, clostridium, lactobacillus, streptococcus, micrococcus and pseudomonas species. The formation of biogenic amines due to microbial activity depend upon many factors such as presence of specific bacterial strains, levels of decarboxylase activity and the availability of amino acid substrate.

Role and metabolism of biogenic amines

They play important regulatory roles in human body which include stomach pH, secretion of gastric acid, immune system response, cell growth and differentiation. They are also important for the growth, renovation and metabolism of all body organs and maintenance of metabolic activities and immunological system of gut. Besides, consumption of foods containing high level of biogenic amines can lead to adverse effects such as nausea, headache, cardiac palpitation, oral burning, hot flushes, gastro intestinal problems, renal intoxication, rashes and changes in blood pressure.

There is a detoxification system of monoamine oxidase (MAO) and *diamine oxidase* (DAO) in the human body which rapidly degrades biogenic amines to physiologically less active form. In case of allergic individuals, MAO's are used when high levels of biogenic amines are ingested, altering the detoxification system which can result in the accumulation of amines in the body. Presence of mono and diamines can activate the enzymes and play an important role in the defensive mechanism. Enzyme action can be influenced by one or more substances known as potentiators that can inhibit the detoxification process. Food borne putrefactive amines can act as potentiators. Putrescine and cadaverine can act as histamine detoxifying enzymes.

Safety aspects – Histamine poisoning

Though all types of biogenic amines can be formed in fish, the most toxic amine detected in fish is histamine. It is a powerful biologically active chemical present in the mast cells and basophils in large amounts. Histamine poisoning is the most common form of toxicity. It can result from ingestion of fish or generally due to foods containing unusually high levels of histamine. The commonly implicated incidents of histamine poisoning are associated with the fish families Scombridae and Scomberesocidae. It is also known as Scombroid poisoning.

Histamine poisoning is often manifested by a wide variety of symptoms. Major symptoms affecting the cutaneous system include rashes, urticaria, edema and localised inflammation etc. Gastrointestinal effects include nausea, vomiting, diarrhoea and abdominal cramps. Other symptoms are hypotension, headache, palpitation, tingling and flushing. Severe suffocation and respiratory distress have been reported in severe cases of histamine poisoning. The onset of this poisoning can extend from 10 minutes to 1 hour following consumption of contaminated fish and can last from 12 hours to a few days.

Histamine concentration required to produce poisoning varies with respect to the susceptibility of each individual. In case of susceptible individuals, concentration between 5 - 10 mg/100g can cause symptoms. Many foods contain small amounts of histamine which can be tolerated easily. The human intestinal tract has a fairly efficient detoxification system which can metabolise ingested histamine and the histamine formed by the intestinal bacteria during normal dietary intake. This system fails in situations of ingestion of large amounts of spoiled Scombroid fish. A metabolic disorder of high sensitivity to dietary histamine due to reduction in the histamine degradation capacity is known as histamine intolerance or enteral histaminosis. It varies between individuals as per their susceptibility to dietary histamine. It can happen in certain situations where antidepressants and tuberculostatics act as inhibitors of diamine oxidase. Low content of dietary histamine can induce symptoms of histamine intolerance in individuals under treatment of drugs containing diamine oxidase inhibitors. It can be reduced by use of histamine free diet or by the substitution of diamine oxidase.

As per USFDA guidelines, the toxicity and defect action level established are 50 mg/100g and 5 mg/100g respectively. According to EU regulation No 2073/2005 mean value all samples (nine) must not exceed 10 mg/100g, two samples may be > 10 mg/100g but < 20 mg/100g and no sample may exceed 20 mg/ 100g. According to USFDA guidelines for the control of histamine production, a core temperature of 4.4 °C or less should be achieved and maintained throughout handling, processing and distribution of susceptible species.

Tyramine toxicity

Tyramine is a vasoactive amine and its importance in foods is principally due to its toxicological implications. Poisoning caused by tyramine is known as cheese reaction. It is slightly toxic itself and can react with monoamine oxidase inhibitor drugs resulting in hypertensive crisis. Tyramine can release nor-adrenaline from sympathetic nervous system and which can increase blood pressure due to peripheral vasoconstriction. It can also result pupil dilation, lacrimation, salivation and increase in respiration and blood sugar. Monoamine oxidase inhibitor drugs used for treatment of mental depression can eliminate the detoxification process of tyramine. High concentrations of tyramine derived from foods can lead to hypertension crisis of patients. Allowable maximum level of tyramine in foods is 100-800 mg/Kg and a level of 1080 mg/Kg of tyramine is toxic to humans.

Toxicity due to other amines

Toxic dose of biogenic amines depends on the metabolic efficiency of individuals. Tryptamine and phenylethylamine can cause headache, migraine, increased blood pressure as they are potent vasoconstrictors. A toxic dose of phenylethylamine is 3 mg/100g. Cadaverine is found to be associated with halitosis in patients with periodontal disease. Spermine, spermidine and putrescine can accelerate the development of tumors and their ingestion is forbidden to cancer patients.

Biogenic amines as precursors of carcinogenic nitrosamines

Nitrosamines can be formed through reaction between amines and nitrites used for colouring, flavouring and preservation of fish. Use of salt in crude form and heat treatment can enhance nitrosamine formation in fish. Trace levels of nitrosamines of dimethylamine, diethylamine, pyrrolidine and piperidine in many fried foods is reported. Putrescine and cadaverine in spoiled fish on heating are converted to pyrrolidine and piperidine respectively from which N-nitroso- pyrrolidine and N- nitrosopiperidine are formed by heating. Treatments like salting and smoking induces nitrosamine formation, while frying enhances their formation. A mutagen compound can be formed from dietary tyramine known as 3-diazotyramine which can induce oral cavity carcinoma in rats. In salted, pickled, hot-smoked and fried fish, nitrosamine formation is considerable. Relatively high concentrations of nitrosamines have been reported in many fermented fish products. Significant association has been reported between intake of salted/smoked fish and certain cancer types.

Biogenic amines for assessment of quality

The content of biogenic amines can be considered as a quality index or a chemical indicator to determine the condition of the raw material, as the accumulation of biogenic amines is related to the activity of contaminating bacteria. After its formation as a result of bacterial activity, they become resistant to thermal treatment which affects the quality of the raw material. Use of more than one single biogenic amine is preferred to overcome the possible variations in the concentration of more than one amine.

Mietz and Karmas (1977) proposed a Chemical Quality Index (QI) based on the concentration of biogenic amines to estimate the degree of freshness of Tuna.

Quality index (QI) = (Histamine+ Putrescine + Cadaverine)/(1+ Spermidine+ Spermine)

It was suggested that the product with QI value below 1 is a first quality raw material and those with QI value of above 10 is poor quality. Veciana-Nóguez *et al.* (1997) proposed a Biogenic Amine Index (BAI) based on the sum of histamine, cadaverine, putrescine and tyramine levels. The index considered values below 50 mg/kg as indicative of good quality food. Baixas-Nogueras *et al.* (2005) proposed a BAI limit of acceptability in a range of 15–20 mg/kg for hake.

Biogenic amine index (BAI) = (Histamine + Putrescine + Cadaverine + Tyramine)

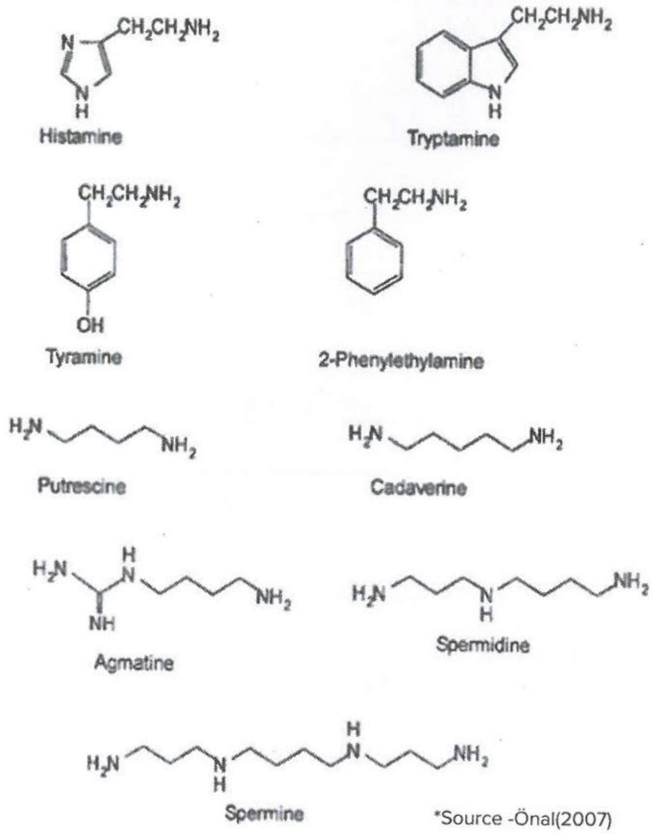

Fig. 1. Structures of biogenic amines

Conclusion

The presence of histamine and other biogenic amines in foods especially seafood is necessary from a toxicological point of view as well as from a quality point of view. With respect to the possible health hazards associated, the biogenic amines could be used as an important quality factor. Maintenance of time and temperature of storage of fish after harvesting is the most important remedy to prevent the formation of biogenic amines during processing and storage of fish.

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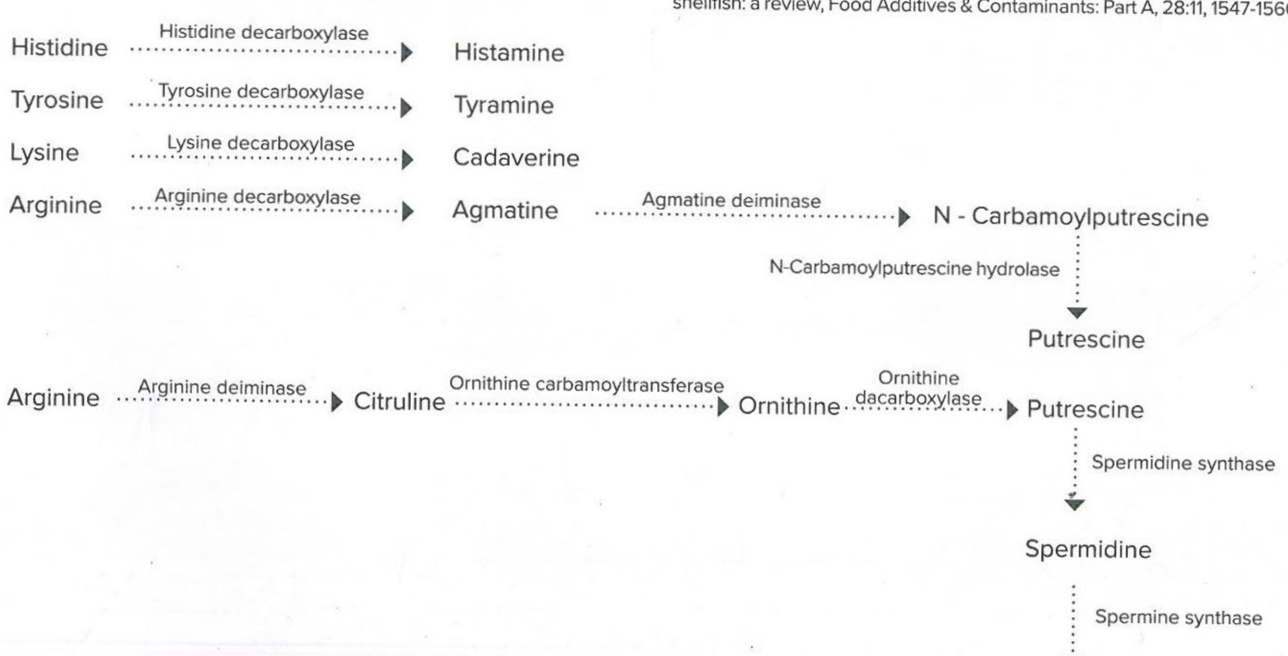

Fig. 2. Formation of different biogenic amines

Table. 1. Fish involved in histamine poisoning in various countries over last decade

Species	Country	Histamine (mg/Kg)	References
Mackerel	Romania, 2008	n.a.	Lionte (2010)
Fish cube	Taiwan, 2007	> 400	Chen *et al.* (2010)
Tuna	Israel, 2005–2007	n.a.	Lavon *et al.* (2008)
Tuna	USA, 2006	>500	Centres for Disease, Control and Prevention, (CDC) (2007)
Dried milkfish	Taiwan, 2006	616	Tsai *et al.* (2007)
Tuna	Taiwan, 2006	1608	Chen *et al.* (2008)
VP cold-smoked tuna	Denmark, 2004	>7000	Emborg *et al.* (2005)
Yellowtail	South Africa, 2004	n.a.	Auerswald *et al.* (2006)
Billfish	Taiwan, 2004	>1500	Tsai *et al.* (2007)
Swordfish	Taiwan, 2004	859–2937	Chang *et al.* (2008)
Escolar fish	USA, 2003	2000–3800	Feldman *et al.* (2005)
Saury	Japan, 2003	320	Miki *et al.* (2005)
Dried sardine	Japan, 2002	>1700	Kanki *et al.* (2004)
Canned mackerel	Taiwan, 2001	500–1539	Tsai *et al.* (2005)
Garfish	Denmark, 2001	1000–2000	Dalgaard *et al.* (2006)

*Source Prester (2011)