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Microbial Toxins and Related Contamination in the Food Industry

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Chapter 1
Histamine in Fish and Fishery Products

Salvatore Parisi, Caterina Barone, Giorgia Caruso, Antonino Santi Delia, Gabriella Caruso and Pasqualina Laganà

Abstract The consumption of certain fish products containing high levels of histamine (and other biogenic amines) can result in an acute illness with allergy-like symptoms called scombroid syndrome. Fish accumulate toxic levels of histamine when their high level of histidine in muscle tissues is coupled with a proliferation of bacteria rich in the enzyme histidine decarboxylase. Other vasoactive amines—cadaverine, putrescine, etc.—may inhibit detoxification mechanisms that reduce the intestinal absorption of histamine. Moreover, histidine can be transformed by means of another metabolic pathway leading to accumulation in fish muscle of urocanic acid. Recently, interest has been extended to mesophilic and psychrotolerant bacteria. Histamine accumulation is traditionally correlated to microbially contaminated fish and poor storage conditions. In addition, the high thermal stability has to be considered. At present, different methods are available for the analytical determination of histamine ranging from the AOAC fluorometric method to HPLC, ELISA and rapid stick methods.

Keywords ELISA · Histamine · Histidine decarboxylase · HPLC · Mesophilic microorganism · Psychrotolerant bacterium · Refrigeration · Scombroid syndrome

Abbreviations

ELISA	Enzyme-Linked Immunosorbent Assay
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
HACCP	Hazard Analysis and Critical Control Points
HPLC	High-Performance Liquid Chromatography
WHO	World Health Organization

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1.1 Histamine in Fish and Fishery Products: An Introduction

Scombroid fish poisoning, also named histamine poisoning, is one of the most challenging food safety problems in the seafood industry (Hungerford 2010). The consumption of mishandled fish belonging to the families of *Scombridae*, namely tuna and mackerel, *Clupeidae (*sardines and herrings) and *Engraulidae* (anchovies), may result in an acute illness with allergy-like or *Salmonella-like* infection symptoms (Lehane and Olley 2000). This 'scombroid syndrome' occurs if these foods contain high levels of histamine—2-(4-imidazolyl) ethylamine or 4-(2-aminoethyl) imidazole—and other vasoactive (biogenic) amines.

Normally, histamine can be important when related amounts are ≥50 mg/100 g of microbially contaminated fish. In detail, unsatisfactory raw fish usually show more than 50 ppm of histamine (toxic values should be between 100 and 500 ppm), while normal levels should not exceed 10–50 ppm (Chamberlain 2001). On the other side, urocanic acid—an imidazole compound derived from histidine in contaminated products—may be also considered when speaking of scombroid poisoning effects (Lehane and Olley 2000).

Basically, the accumulation of histamine and other decomposition compounds is observed in many fish types, including *Scombridae*. From the biochemical viewpoint, histamine is obtained in scombroid fish (*albacore, bonito*, skipjack, Spanish mackerel, saury, etc.) by means of the enzymatic conversion of free and abundant histidine in muscle tissues (Cattaneo 2011; Lehane and Olley 2000; Rawles et al. 1996; Ruiz-Capillas and Moral 2004; Taylor 1986; Tortorella et al. 2014). However, the abundant presence of free histidine is reported in many fish products, including also (Antoine et al. 1999; Chang et al. 2008; Hungerford 2010; Taylor 1986):

- Anchovies (Engraulis spp.)
- Herring (Clupea spp.)
- Pilchards (Sardina pilchardus)
- Mahi-mahi (Coryphaena spp.)
- Sardines (Sardinella spp.)
- Swordfish (Xiphias gladius).

Actually, histamine poisoning has been reported in relation to non-fish products such as Gouda, Swiss, Gruyere, Cheddar and Cheshire cheeses (Chambers and Staruszkiewicz 1978; Doeglas et al. 1967; Kahana and Todd 1981; Taylor 1986). However, these situations appear circumscribed to a few situations: apparently, cheeses might be considered as a potential problem when speaking of unusual ageing (Taylor 1986). Moreover, other fermented products—*Sauerkraut*, wines—or partially demolished foods (in relation to the protein fraction) such as Italian *pepperoni* and *salami* may contain occasionally high histamine levels (Dierick et al. 1974; Mayer and Pause 1972; Ough 1971; Taylor 1986; Taylor et al. 1978). Anyway, the most part of observed and reported histamine poisoning episodes is correlated with the consumption of raw fish and finished seafood products (Hungerford 2010).

It has to be considered that the bacterial and enzymatic production of histamine from histidine is strictly correlated with storage temperatures: normally, thermal values should always remain below 4 °C (Hastein et al. 2006; Tsironi et al. 2008). On the other hand, this process may occur in all stages of the food chain (Cattaneo 2014; Kanki et al. 2004). In detail, the production of histamine can be easily be observed in skipjack and big-eye tuna fish at 22 °C after 24–48 h, while this phenomenon may be remarkably delayed at 10 and 4 °C. However, the amount of detectable histamine may be notable after 3 days under refrigerated storage (Silva et al. 1998).

The Food and Drug Administration (FDA) has published a detailed guideline in relation to retail food establishments (scombroid products). According to this document (FDA 2011), raw fish should have internal temperatures below or equal to 10 °C (if fish has been delivered 12 or more hours after death) or 4.4 °C (if fish has been delivered 24 or more hours after death). Anyway, temperatures should be evaluated after receipt (FDA 2011). Certainly, storage at 0 °C can determine the end of histamine production (Chamberlain 2001) but existing levels are not eliminated.

Recently, it has been recognised that the production of histamine from high levels-histamine fish can be assessed when temperatures are higher than 25 °C for 6 h or more (FAO/WHO 2012). On these bases, the recommended amount of histamine in fish products has been defined to be lower than 15 mg/kg on the condition that good hygienic practices and 'Hazard analysis and critical control points' (HACCP)—based strategies have been implemented. The Codex Alimentarius Commission has defined two different levels (100 and 200 mg/kg) in relation to the commercial acceptability and possible food safety problems of fish products respectively (Cattaneo 2014).

These values have a slightly different meaning in the European Union in relation to the Regulation (EC) No. 2073/2005 and subsequent amendments. In detail, nine samples have to be considered and four conditions are possible when speaking of normal fish products:

(a) All results have to be lower than 100 mg/kg. Fish products are fully acceptable
(b) One or two results only are found between 100 and 200 mg/kg while remaining samples are below 100 mg/kg. Fish products are fully acceptable
(c) One or more samples exceed 200 mg/kg. Fish products have to be recalled or withdrawn from the market
(d) More than two samples are found between 100 and 200 mg/kg. Fish products have to be recalled or withdrawn from the market.

These norms are valuable for unsalted fish products. Should salted fish be sampled (nine products), four conditions are possible when speaking of normal fish products (FAO/WHO 2012):

(e) All results have to be 200 mg/kg. Fish products are fully acceptable
(f) One or two results only are found between 200 and 400 mg/kg while remaining samples are below 200 mg/kg. Fish products are fully acceptable

(g) One or more samples exceed 400 mg/kg. Fish products have to be recalled or withdrawn from the market
(h) More than two samples are found between 200 and 400 mg/kg. Fish products have to be recalled or withdrawn from the market.

Interestingly, histamine levels in foods do not appear to be influenced by normal processing treatments such as cooking and smoking. Actually, these processes kill histamine producers but the existing amounts of histamine remain unchanged (Cattaneo 2014). In addition, cold storage cannot reduce the real incidence or diminish possible poisoning episodes when raw fish is partially compromised (FDA 2011).

1.2 Chemistry and Production of Histamine: Importance of Other Biogenic Amines

Actually, histamine is not produced in degraded fish only. In fact, a low amount of histamine is also naturally produced by human beings because of the decarboxylation of histidine (FAO/WHO 2012).

With exclusive reference to fish products, toxic levels of histamine are accumulated when their high level of histidine in muscle tissues is coupled with a proliferation of bacteria rich in the enzyme histidine decarboxylase (Alini et al. 2006). Histamine exerts its negative effects on specific receptors known as H_1 and H_2 receptors located on human cell membranes. H_1 receptors are implicated in allergic reactions with dilation of peripheral blood vessels (rash, namely of the lips and surrounding area, urticaria, headache), while H_2 receptors are responsible for gut motility (diarrhoea, cramps, vomiting). The onset of symptoms either without or with small amounts of histamine implicates other causes or contributory causes of intoxication.

Other vasoactive amines such as cadaverine and putrescine may inhibit detoxification mechanisms that reduce intestinal absorption of histamine by means of catabolic enzymes like histaminase (FAO/WHO 2012). These biogenic amines are produced by means of microbial spoilage and fermentation from amino acids; the precursor is ornithine (FAO/WHO 2012). The role of these molecules is not clear at present: potentially, putrescine and cadaverine might be considered as histamine potentiators (Taylor and Lieber 1979). On the other hand, the real role of these biogenic amines in scombroid poisoning episodes is not clear (FAO/WHO 2012). The same thing can be affirmed when speaking of tyramine, a monoamine molecule formed from tyrosine (Leuschner and Hammes 1999; Prester 2011; Taylor and Lieber 1979). Other notable biogenic amines with some food safety importance are tryptamine, spermine, spermidine and β-phenylethylamine (Shalaby 1996). In relation to the present section, the importance of these amines is reduced because they can be found in many foods including also dairy and meat products, nuts, chocolate, etc. (Emborg 2007).