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Prevention of Biogenic Amine Formation using Phytochemicals: A Natural Preservatives for Fish and Seafood

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SUMMARY

Biogenic amines are among the hazardous metabolites produced by microbial growth and metabolism during fish rotting. Biogenic amine production has been reduced by either improving handling and processing procedures or adding food additives within limits established by the regulatory authorities. However, there has been a rise in the search for such compounds due to consumer desire to eliminate synthetic chemicals in foods due to their possible toxicity and increased interest in natural antimicrobial compounds. To extend the shelf life and enhance the sensory qualities of food items, a number of bioactive phytochemicals are employed as food components. Therefore, using plant extracts alone or in conjunction with food preservation methods might be a useful alternative strategy to enhance the quality and safety of fish and shellfish without negatively impacting humans. The knowledge on plant-based natural antimicrobials will be summarized in this article, along with information on their diverse uses in fish and seafood products and their modes of action in preventing bacterial growth and the formation of biogenic amines.

INTRODUCTION

Fish and seafood commodities deteriorate more quickly than other muscle foods since they are highly perishable items. The primary cause of seafood deterioration is microbial growth and metabolism, which results in the development of toxic compounds such as biogenic amines. The raw material, processing methods, handling and storage conditions, microorganisms, and the kinds of enzymes produced by the microbes in the seafood have a role in the formation of biogenic amines (Houicher et al., 2021). Because of their involvement in food poisoning, these hazardous metabolites have frequently been controlled in fish and shellfish products. The biogenic amines are primarily created by microbial enzymes decarboxylating certain free amino acids. Many chemical food additives are added to seafood items to postpone the generation of biogenic amines by reducing bacterial growth or decarboxylase enzyme activity. Although many governments have allowed these ubiquitous chemical additives, the possible health risks associated with these synthetic compounds in foodstuffs have triggered the urge to replace them with natural products. However, these substitutes must still guarantee food safety and meet customer preferences. To prevent the production of biogenic amines in fish and marine products, bio preservatives such as plant extracts, bacteriocins, chitosan, and enzymes have also been employed alone or in conjunction with other preservation techniques (Arisekar et al., 2022a; Houicher et al., 2021).

Bacterial growth and amine formation

Fresh fish and fish products generally deteriorate due to either microbial growth or bacterial enzymes and their metabolism of the fish. Storage time and temperature are crucial factors influencing microorganism development, including synthesizing the amino acid decarboxylase enzyme involved in the formation of biogenic amines (Fig. 1) (Xie et al., 2015). The concentrations of biogenic amines increase when storage time and/or temperature are prolonged. Several Gram-negative and Gram-positive bacteria are involved in the production of biogenic amines. *Morganella morganii* has the highest histidine decarboxylase activity, followed by *Klebsiella pneumoniae*, *Hafnia alvei*, and several strains of *Enterobacter aerogenes* and *E. cloacae*. *Morganella psychrotolerans* and *Photobacterium phosphoreum* are psychrotolerant bacteria that produce a large amount of histamine. Histamine-producing bacteria in fermented fish have also been discovered as Vibrio spp., Staphylococcus spp., and Pseudomonas spp. However, Gram-positive bacteria are usually involved in tyrosine decarboxylase activity (Houicher et al., 2021).

Phytochemicals and their antimicrobial effects

The main sources of antimicrobial chemicals include essential oils and extracts from the plant's leaves, flowers, flower buds, and other sections. These active chemicals are phenolics, terpenes, aliphatic alcohols, aldehydes, ketones, acids, and isoflavonoids, and their usage as antimicrobial agents would benefit health and

food preservation. There are two types of phenolic compounds: phenolic acids and flavonoids. The phenolic acids are primarily benzoic or cinnamic acid derivatives, whereas the flavonoids are primarily anthocyanins and tannins. Several studies have demonstrated that phenolic compounds, such as thymol, cinnamic aldehyde, and eugenol, are efficient at controlling and/or inhibiting the development of bacteria with a broad antimicrobial spectrum (Tako et al., 2020; Arisekar et al., 2022b). Furthermore, phenolic compounds including p-hydroxybenzoic, p-coumaric acids, caffeic, vanillic, syringic, protocatechuic, quercetin, and oleuropein were shown to inhibit the growth of *Klebsiella pneumoniae*, *E. coli*, *Bacillus cereus*, *Aspergillus parasiticus*, and *Aspergillus flavus*.

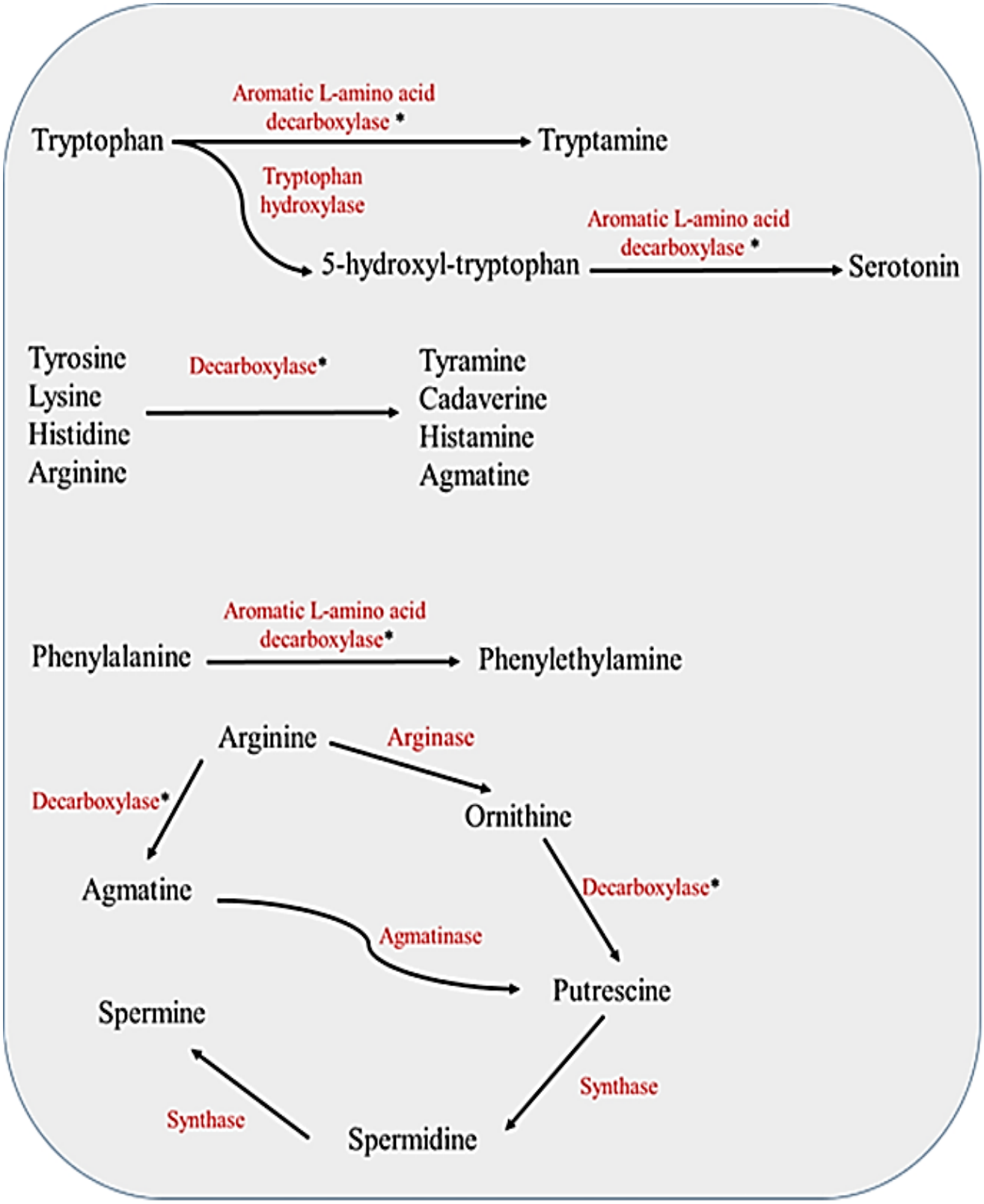

Fig.1. Biogenic Amine formation Mechanism in Fish and Seafood

Natural phenolic compounds can suppress the development of Gram-negative and Gram-positive foodborne bacteria. These compounds show variable antibacterial activity against foodborne pathogens, implying that they have a high potential for usage as natural preservatives during long-term preservation. Terpenes are the second most common antibacterial molecule and the most abundant natural product found in many essential oils (Houicher et al., 2021; Tako et al., 2020). Monoterpenes (two units), sesquiterpenes (three units), diterpenes (4 units), sesterterpenes (5 units), triterpenes (6 units), and tetraterpenes (8 units) are the isoprenoid units that make up their structure. Many terpenes have been shown to have antimicrobial activity against a wide range of pathogens, including Gram-negative and Gram-positive bacteria and fungus. Various diterpenes isolated from Salvia species showed antibacterial activity against many organisms, including *E. faecalis, B. subtilis, S. aureus, S. epidermis, E. coli,* and *P. mirabilis*. Sesquiterpene drimanes have also demonstrated significant antibacterial and antifungal action. Furthermore, terpenes such as carvone, linalool, 1,8-cineol, -3-carene, spathulenol, -pinene, -myrcene, and germacrene have shown antifungal efficacy against a variety of pathogenic fungi (Houicher et al., 2021). However, the use of essential oils as preservatives in food is frequently restricted due to flavor considerations.

Mode of antimicrobial action of phytochemicals

Biogenic amines are produced by the amino acid decarboxylase enzymes found naturally in seafood. Natural antimicrobials can be utilized to reduce or inhibit spoilage and pathogenic microorganisms involved in the generation of biogenic amines in fish. However, their mechanism of action is not completely understood due to differences in the chemical composition and structure of these molecules. Lipophilic characteristics and combinations of active chemicals, for example, may promote the efficacy of essential oils (Houicher et al., 2021). Lipophilic chemicals can impair membrane integrity and cause microbial mortality by inhibiting several enzymatic processes, primarily protein translocation, electron transport, and phosphorylation.

Terpene efficacy is also controlled by the location of the -OH group, which serves as a proton exchanger and can cause cell death when in the correct position. Other phenolic compounds' antibacterial action is also determined by their hydroxyl groups (-OH), the amount of double bonds, and the size of the added alkenyl or alkyl group, which can interact with the bacterial membrane, disrupting it and causing leaking of cellular contents, which can lead to cell death. These groups can also affect microorganism cell metabolism by attaching to the active site of enzymes (Houicher et al., 2021). It is explained that the putative antibacterial effect of phenolic acids is connected to hyper-acidification at the bacterial cytoplasmic membrane caused by phenolic acid dissociation, which may modify cell membrane function, increase permeability, and impact ATP generation. Additionally, several studies have demonstrated the potency of flavonoid molecules as antibacterial agents.

The primary antibacterial mechanisms of flavonoids include inhibition of DNA and RNA synthesis, suppression of energy metabolism, inhibition of cytoplasmic membrane function, and change of membrane permeability (Xie et al., 2015). The mass and structure of the ortho-phenolic hydroxyl groups in tannins play a major role in determining their biological activity. Alkaloids can also exert their effects differently, including the suppression of cell division, respiratory inhibition caused by the binding of bacterial enzymes, disruption of cell membranes, and inactivation of virulence genes.

CONCLUSION

The formation of biogenic amines in seafood is primarily influenced by amino acid precursors and the presence of bacteria and pathogens that produce amino acid decarboxylase enzymes. The best handling and processing practices are required to manage these toxic amines. Still, other options may be utilized and are gaining popularity, such as including certain food additives at or below permitted levels. Without having negative impacts on human health and possibly having positive benefits, natural antimicrobials derived from plants alone or in conjunction with other preservation methods might be a useful alternative strategy to improve seafood quality and meet market needs. Prior to their use in therapeutics, these natural antimicrobials must first undergo a thorough assessment of their toxicity and safety.

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