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Histamine reduction by Maillard reaction with glucose

Wei Jiang [a], Xiaoxia He [b], Huicheng Yang [c], Xingwei Xiang [c], Shiwei Hu [a], Shijie Li [a], Yu Liu [a, *]

[a] Laboratory of Seafood Processing, Institute of Innovative and Application, Zhejiang Ocean University, Zhoushan, Zhejiang, 316022, China
[b] Qingdao Entry-Exit Inspection and Quarantine Bureau, Qingdao, Shandong, 266002, China
[c] Zhejiang Marine Development Research Institute, Zhoushan, Zhejiang, 316022, China

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Glucose (PubChem CID: 5793)
Ampicillin (PubChem CID: 6249)
Methanol (PubChem CID: 887)
Dansyl chloride (PubChem CID: 11801)
Streptomycin (PubChem CID: 19649)
Sodium chloride (PubChem CID: 5234)
Dimethyl sulfoxide (PubChem CID: 679)

ABSTRACT

Histamine, well known as a toxic biogenic amine, is found in a variety of foods. Reducing its concentration and toxicity is desirable. In this study, the glucose/histamine Maillard reaction was proposed as a novel tool for histamine control. Effects of temperature, heating time, initial pH value, NaCl concentration, initial histamine concentration and initial glucose concentration on percentage removal of histamine in the glucose/histamine Maillard reaction model were investigated. The results showed that histamine reduction was affected by these variables, and could be almost eliminated under appropriate conditions. Fluorescence intensity and ultraviolet–visible spectroscopy analyses were used to characterize the glucose/histamine Maillard reaction. Cytotoxicity assay revealed that the glucose/histamine Maillard reaction significantly reduced the toxicity of histamine ($P < 0.05$). Furthermore, histamine concentrations in canned tuna samples were significantly reduced by thermal treatment with glucose ($P < 0.05$). This study demonstrates that the glucose/histamine Maillard reaction is a promising method for histamine control.

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1. Introduction

Histamine, (2-(4-imidazolyl) ethylamine), is a biogenic amine produced from the decarboxylation of amino acid histidine by bacterial or tissue enzyme. As shown in Fig. 1, histamine is a heterocyclic monoamine chemical. High content of histamine is widely found in various foods, especially in fermented foods (Koral et al., 2013; Nei, Nakamura, Ishihara, Kimura, & Satomi, 2017; Pradenas, Galarce-Bustos, Henríquez-Aedo, Mundaca-Uribe, & Aranda, 2016; Todoroki et al., 2014). Taking foods with high levels of histamine can cause histamine poisoning, which is also known as scombroid poisoning worldwide. It can not only cause a mild illness with symptoms including dizziness, headache, hypotension, oral burning and sweating, but also bring about life-threatening (Feng, Teuber, & Gershwin, 2016).

The risk of histamine poisoning has attracted worldwide attention. Reducing histamine concentration and toxicity in foods is desirable. Briefly, histamine reduction can be achieved by two means, namely preventing the formation of histamine and consuming the existed histamine. For instance, high hydrostatic pressure (Křížek, Matějková, Vácha, & Dadáková, 2014), irradiation (Aflaki, Ghoulipour, Saemian, Shiebani, & Tahergorabi, 2015) and modified atmosphere packing (Rodrigues et al., 2016) are employed to inhibit the growth of microorganisms and thus suppress the formation of histamine. However, these techniques are not applicable for fermented foods where the growth of microorganisms is

* Corresponding author.
E-mail address: liuyu1987@zjou.edu.cn (Y. Liu).

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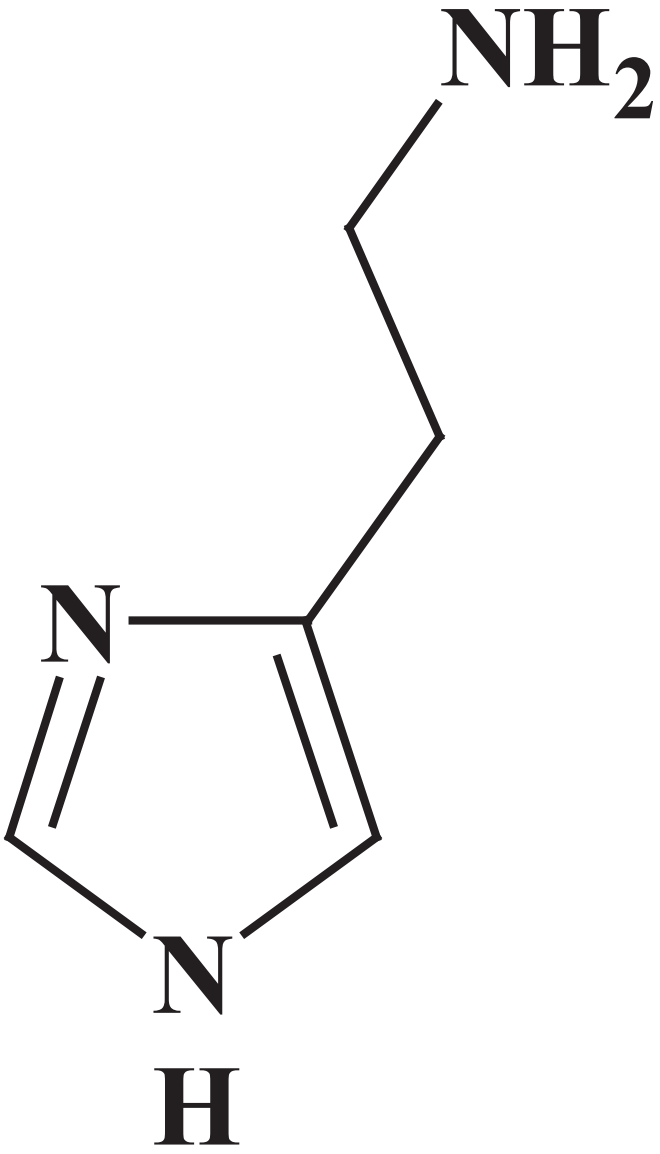

Fig. 1. Structure of histamine.

very important. Furthermore, the existing histamine cannot be consumed by these methods. Thus, some other researchers isolated histamine degrading strains as functional starter cultures (Xu, Liu, Xu, Wang, & Jiang, 2016) or applied amine oxidase (Naila et al., 2012) for the degradation of histamine. However, the amine oxidase is expensive at present, and professional equipment/staff are required for the application of histamine degrading strains. Hence, a more feasible method is required for histamine control in foods.

Maillard reaction, also known as non-enzymatic browning reaction, is a complex chemical reaction between carbonyl groups of reducing sugars and free amino groups of amino acids, peptides, proteins or some other nitrogen containing compounds. Maillard reaction plays an important role in food industry and occurs during thermal processing or food storage. According to the compounds generated during Maillard reaction, the reaction process is divided into early, intermediate and final stages (Nursten, 2005). Among them, the intermediate and final stages can be characterized by fluorescence intensity and ultraviolet–visible absorption. Maillard reaction is affected by a variety of variables, such as temperature, reaction time, pH, substrate concentration, substrate type, and water activity (Caballero, Finglas, & Toldrá, 2016). It can be used as an important tool for acquiring valuable Maillard reaction products (MRPs) (Kanzler, Haase, Schestkowa, & Kroh, 2016; Lee et al., 2016). Moreover, the Maillard reaction of glucose/fumonisin B_1 was used to the reduction of mycotoxin-fumonisin B_1 (Lu et al., 2002), implying that Maillard reaction might be applied to the reduction of harmful chemicals with amino groups. Considering that histamine has a free amino group (Fig. 1), it may be consumed by Maillard reaction theoretically. Nevertheless, the Maillard reaction between sugar and histamine has not been studied previously.

This study investigated the effects of temperature, initial pH value, NaCl concentration, initial glucose concentration and initial histamine concentration on histamine reduction in a glucose/histamine Maillard reaction model. The intermediate and final stages of this reaction were characterized by fluorescence intensity and ultraviolet–visible spectroscopy. Cytotoxicity of histamine, glucose, glucose/histamine mixture, and glucose/histamine MRPs was compared. Moreover, the reduction of histamine content in canned tuna by the glucose/histamine Maillard reaction was assessed preliminarily. The aim was to evaluate the possibility of applying the glucose/histamine Maillard reaction to reduce histamine level and detoxification of it.

2. Materials and methods

2.1. Chemicals

Histamine, dansyl chloride and dimethyl sulfoxide were provided by Sigma-Aldrich, Inc. (St. Louis, MO, USA). Glucose was provided by Solarbio Inc. (Beijing, China). Methanol (HPLC grade) was provided by Merck (Darmstadt, Germany). Ultrapure water was prepared by Milli-Q (Millipore, Billerica, MA, USA). Roswell Park Memorial Institute (RPMI) 1640 medium, fetal bovine serum, streptomycin sulphate, ampicillin, trypsin, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) were provided by Gibco (Invitrogen Co., Burlington, ON, Canada).

2.2. Glucose/histamine maillard reaction model

Glucose/histamine Maillard reaction was conducted in 16 mm × 155 mm glass screw tubes capped with tight screw-caps. Unless otherwise stated, the incubations contained 50 mM potassium phosphate, pH 8.0, 40 mM glucose, and 2.5 mM histamine in a total volume of 5.0 mL without the addition of NaCl. The tubes were incubated at designed temperatures in a Digital Dry Bath (Jinxin, JX100-4, Shanghai, China). To ensure that the reaction was stopped at the appropriate time point, the tubes were cooled in a mixture of ice and water for 30 min.

2.3. Factors affecting percentage removal of histamine in the glucose/histamine maillard reaction model

Effect of temperatures (60, 70, 80, 90, 100 and 110 °C) on percentage removal of histamine was investigated by the reaction of 40 mM glucose and 2.5 mM histamine at pH 8.0 for 12 h without the addition of NaCl. Samples were taken at 0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 6, 8, 10 and 12 h. Effects of initial pH values (5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0 and 12.0), NaCl concentrations (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 6.0, 8.0, 10.0 and 12.0%, w/v), initial glucose concentrations (5, 10, 20, 40, 60, 80, 160 and 320 mM) and initial histamine concentrations (0.5, 1.0, 2.5, 5.0, 10.0 and 20.0 mM) on percentage removal of histamine were investigated by changing one parameter at a time in the reaction of 40 mM glucose and 2.5 mM histamine at 100 °C and pH 8.0 for 5 h without the addition of NaCl. Samples were taken at 0.5, 1, 3 and 5 h.

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