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MiniReview
The effects of food processing on biogenic amines formation

Chong, C. Y., *Abu Bakar, F., Russly, A. R., Jamilah, B. and Mahyudin, N. A.

Faculty of Food Science and Technology, University Putra Malaysia, Serdang 43400, Selangor, Malaysia

Abstract: Biological amines are nitrogenous compounds that occur naturally in wide variety of food. Histamine, putrescine, cadavarine, tyramine, spermine, spermidine, tryptamine and β-phenylethylamine are the biogenic amines that are normally present in foods. Although the biogenic amines play some important physiological functions but high level of amines can cause toxicological effects. High amount of amines can be produced by bacteria during amino acids decarboxylation and have been identified as one of the important agent causing seafood intoxication. Temperature is the major factor for controlling the biogenic amines formation in food. The effects of other alternatives are also discussed including salting, packaging, irradiation, high pressure processing and the use of starter culture. A variety of techniques can be combined together to control the microbial growth and enzyme activity during processing and storage for better shelf life extension and food safety.

Keywords: Biogenic amines, histamine, food processing, food safety

Introduction

Biogenic amines (BA) are the compounds in which one, two or three hydrogen of ammonia are replaced by alkyl or aryl groups (Shalaby, 1996). Figure 1 shows the chemical structure of several major biogenic amines. Putrescine, cadaverine, spermine and spermidine have aliphatic structure whereas tyramine and phenylethylamine containing aromatic structure. Heterocyclic structures are found in histamine and tryptamine (Santos, 1996). They can also be classified into monoamines (phenylethylamine and tyramine), diamines (cadaverine and putrescine) or polyamines (spermidine and spermine) based on the number of amine groups (Spano *et al*., 2010).

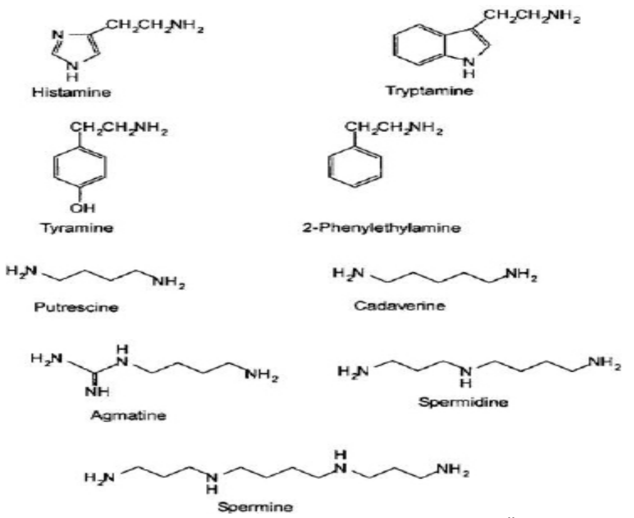

Figure 1. shows the structures of biogenic amines (Önal, 2007).

Biogenic amines are natural compounds which can be produced during the normal metabolism of living cells (ten Brink *et al*., 1990). It is also present in food such as fish, wine, cheese, dairy product, beer, meat and vegetable. Histamine, tryptamine, β-phenylethylamine and tyramine have important physiological roles in humans (Shalaby, 1996). During food spoilage, microorganism can produce high concentration of biogenic amines by decarboxylating the free amino acids. The concentrations of biogenic amines have been suggested as indices for bacterial contamination in food (Rezaei *et al*., 2007).

The occurrences of biogenic amines in foods (ten Brink *et al*., 1990; Shalaby, 1996; Santos, 1996). fish (Rawles *et al*., 1996) and dry fermented sausages (Suzzi and Gardini, 2003) have been reviewed. There is little literature on the effects of different food processing on the production of biogenic amines. The objective of this paper is to review briefly the effects of food processing on biogenic amines formation.

Outbreak and epidemiology

Biogenic amines intoxication is always related with intake of fish belongs to the *Scombroid* family. The consumption of high amount of biogenic amines in food can result in histamine poisoning and tyramine toxicity. Histamine poisoning is the most toxic and common form of poisoning. Histamine intoxication, is also termed Scombroid poisoning is an important food borne disease over the world. Outbreaks are common in the United States, Canada, Japan and other countries with a high consumption of fish (Behling and Taylor, 1982).

In the United States, seafood ranked third among various foods which caused food poisoning during 1983-1992. Scombroid poisoning is the most

*Corresponding author.
Email: *fatim@food.upm.edu.my*

important causative agent following the consumption of mahi-mahi, tuna, mackerel, bluefish, sardines, amberjack and abalone. The major cause of scombroid poisoning is temperature abuse (Lipp and Rose, 1997). Wallace *et al*. (1999) reviewed food borne disease data gathered by the New York State Department of Health (NYSDOH) between 1980 and 1994. Among 148 seafood-associated outbreaks, scombrotoxin was one of the most common agents, responsible for 44% sea food associated disease outbreak.

In the USA, 69 outbreaks of scombrotoxin poisoning involving 297 cases were reported to CDC's Food Disease Outbreak surveillance system between 1993 and 1997 (Olsen *et al*., 2000). From 1998 to 2002, around 118 outbreaks of scombrotoxin poisoning involving 463 cases were reported (Lynch *et al*., 2006). In Canada, the most common seafood-associated diseases is scombroid poisoning from improperly stored fish, but Paralytic shellfish poisoning (PSP) and ciguatera poisoning have the most serious consequences (Todd, 1997). In United Kingdom, PHLS Communicable Disease Surveillance Centre reported 1425 outbreaks of Infectious Intestinal Disease (IID) from 1992 to 1999 (Gillespie *et al*., 2001). According to this report, 10% were related with the fish and shellfish. The consumption of spoiled tuna (47%) was the most important cause for scombrotoxic fish poisoning. It was followed by mollusks contaminated with viral pathogen (36%) and crustaceans contaminated by salmonella or viral pathogens (11%).

Histamine poisoning

Scombroid fish poisoning is related with the intake of fish from *Scombroid* family such as tuna, mackerel and bonito (McLauchlin *et al*., 2006). However, certain non-scombroid fish are also implicated in histamine poisoning including mahi-mahi, bluefish and sardines (Taylor *et al*., 1989). FDA (2009) identify some potential species of fish related to histamine poisoning hazards including amberjack, anchovy, bluefish, bonito, oilfish, herring, jack, jobfish, mackerel, mahi-mahi, marlin, sardine, saury, shad, trevally and tuna.

Histamine fish poisoning produce one or more of the following symptoms including reddening on the face, neck and upper chest, vomiting, sweating, nausea, abdominal cramps, headache, diarrhea, dizziness, palpitations and flushing (McLauchlin *et al*., 2006). After ingestion of the food, the incubation periods range from a few minutes to a few hours (Becker *et al*., 2001). Histamine fish poisoning is frequently misdiagnosed due to its typical symptoms mimic those of allergy (Attaran and Probst, 2002).

The presence of secondary amines including putrescine and cadaverine contribute to synergistic effect and enhancing the histamine toxicity in food poisoning (Taylor, 1983). Amines are also a possible mutagenic precursor, react with nitrites forming nitrosamines which is carcinogenic (Shalaby, 1996). Healthy people are able to metabolize the dietary histamine rapidly. However, the accumulation of histamine exceeding the capacity of histamine degradation can results in histamine toxicity. Clinical symptoms are more serious in people consuming drug that can retard the enzyme that metabolizes the histamine in intestine (Stratton *et al*., 1991). Consumption of alcohol and certain drugs such as antihypertensive, antidepressants, antihypotonics, antiarrhythmics and other drugs are able to inhibit the diamine oxidase and increasing the susceptibility of people to histamine intoxication (Maintz and Novak, 2007).

The histamine detoxification systems in human comprised of diamine oxidase (DAO) and histamine N-methyl transferase. DAO plays the major role in histamine catabolism (Hungerford, 2010). Amine oxidases catalyze the oxidative deamination of biogenic amines producing the aldehyde, ammonia and hydrogen peroxide (Longu *et al*., 2005). Diamino oxidase (DAO) catalyze the oxidative deamination of histamine and histamine-N-methyl transferase (HNMT) catalyze the ring methylation of histamine (Maintz *et al*., 2006). DAO has been suggested for degrading histamine extracellularly whereas histamine N-methyltransferase can only metabolize histamine intracellularly (Maintz and Novak, 2007). The treatment for histamine toxicity involves the use of antihistamines (Attaran and Probst, 2002).

Effects of various foods processing on biogenic amines formation

The control of biogenic amines formation mainly focused on the controlling the growth of biogenic amines forming bacteria. It is because the histamine is heat stable (ten Brink *et al*., 1990; Santos, 1996; Kurt and Zorba, 2009) and is not detectable organoleptically by even trained panelists (Tapingkae *et al*., 2010). Once formed, histamine is difficult to destroy by using methods including freezing, cooking, retorting, or smoking (Etkind *et al*., 1987). However, there are some methods are able to degrade the histamine including the gamma irradiation (Kim *et al*., 2004) and application of diamine oxidase bacteria to degrade the histamine (Dapkevicius *et al*., 2000).

Storage temperature is the most important factor contributing to biogenic amines formation. The effects of temperature abuse on biogenic amines formation have been studied extensively. High amount of amines can be produced under high temperature storage reported by many authors (Du *et al*., 2002; Rodtong *et al*., 2005; Kim *et al*., 2002; Wei *et al*., 1990). 25°C was optimum for histamine production by *Morganella morgani* in the artificially contaminated muscles of mackerel, albacore, and mahi-mahi (Kim *et al*., 2002). Histamine amount increased drastically after six hours at 25°C. Kim *et al*. (2002) detected a high level of histamine of 4610 ppm in mackerel after 24 hours of storage; 3430 ppm in albacore; and 3340 ppm in mahi-mahi. Temperature of 4°C retarded the *M. morganii* growth in all species up to 14 days.

Economou *et al*. (2007) assessed the effect of temperature abuse on histamine formation in tuna muscle stored at different temperature. For storage temperature 0–2°C, 258.3 ppm histamine was detected in fresh tuna loins abused at 30°C for 2 hours daily for 12 days. This value was higher than that of the control sample of 33.5 ppm. High histamine concentration of 1962 ppm was found in tuna stored at 6–7°C after 12 days of temperature abuse storage. Icing temperature was found to retard the histamine formation. Du *et al*. (2002) only found 18 ppm of histamine in tuna after 9 days storage at 0°C whereas 68.8 ppm and 564 ppm histamine were detected in tuna stored at 4°C and 10°C. Similarly, Rodtong *et al*. (2005) only detected 19 ppm of histamine in Indian anchovy (*Stolephorus indicus*) after 15 days at ice storage.

Salting

Roseiro *et al*. (2006) studied the higher final NaCl concentrations in dry fermented pork sausage to evaluate the effects on biogenic amines levels. The author reported that the 6% salt content reduced the total biogenic amines levels significantly compared to 3% salt content. The usual formulation for the same product ranges from 4% to 4.5%. The higher salt content showed the reductions by 83%, 43%, 28% and 98% for cadaverine, putrescine, tyramine and phenylethylamine level respectively. Different salt content could be attributed to the variation of microflora composition and leading to the differences in biogenic amines formation. In this study, 6% salt concentration had lower Enterobacteriaceae, Enterococci and total aerobic psychrotrophic counts compared to 3% salt concentration. Enterobacteriaceae is responsible for the histidine decarboxylase activity to produce histamine (Bover-Cid *et al*., 2009). In salt-fermented soybean paste, higher salt content (12%) had the lower biogenic amines level compared to lower salt condition (6% and 8% salt) (Kim *et al*., 2005a). Similarly, some studies found the high salt content can control the biogenic amines formation in Feta cheese (Valsamaki *et al*., 2000) and in meat batter (Bover-Cid *et al*., 2009).

Rodtong *et al*. (2005) identified prolific histamine producers from spoiled Indian anchovy (*Stolephorus indicus*) as *M. morganii*, *Proteus vulgaris*, and *Enterobacter aerogenes*. At 5% NaCl, these three strains were still able to produce high histamine concentration in medium. However, all isolates did not produce histamine at ≥10% NaCl. Lakshmanan *et al*. (2002) investigated the changes of the amine forming microorganisms in salt-dried sardines (*Sardinella gibbosa*). The salt content of final products ranged from 10 to 16%. The author found that only cadaverine and putrescine were produced by the bacteria isolated and did not found histamine formers during salt-drying process. The author concluded that the growth of amine forming microflora was inhibited with over 10% NaCl. However, Kongpun (2000) observed that the histamine content increased with the increase of salt content in Spanish Mackerel and achieving the highest concentration when 13-15% salt content was recorded. The author explained that it may be due to the increase of total viable count and histamine forming bacteria count with the increase of salt content.

Packaging

Modified atmosphere packaging is a popular preservation method involving the changing of gas composition surrounding the food product and packaging with barrier film. Oxygen, nitrogen and carbon dioxide are usually used in this technique and carbon dioxide is the major gas with bacteriastatic and fungistatic properties. The inclusion of carbon dioxide may inhibit the growth and increase the lag phase of microorganism with amino acid decarboxylase.

There are some studies reporting the successful inhibition of biogenic amines using modified atmosphere packaging in fish (Ozogul *et al*., 2002a; Özogul *et al*., 2002b ; Emborg *et al*., 2005; Ozogul and Ozogul, 2006) and chicken meat (Balamatsia *et al*., 2006; Patsias *et al*., 2006). The modified atmosphere packaging has a better inhibitory effect compared to vacumm packaging (Ozogul *et al*., 2002a; Emborg *et al*., 2005; Ozogul and Ozogul, 2006; Alak *et al*., 2010). Emborg *et al*. (2005) studied the effect of vacuum packaging and modified packaging on biogenic amine formation at 2°C and 10°C in tuna muscle inoculated with psychrotolerant bacteria. Histamine achieved toxic level in chilled vacuum packaging tuna steaks at 2°C. But modified packaging with 40% CO_2/60%

O_2 was reported to inhibit the histamine formation. The author suggested vacumm packaged tuna may have caused the histamine intoxication during the last decade.

Ozogul and Ozogul (2006) found the modified atmosphere packaging (60% CO_2 and 40% N_2) was most effective in retarding the production of amines in sardine compared to vacuum packaging and normal air storage. The same author, Ozogul *et al*. (2002a) showed the histamine amount in herring reached 396 ppm in air, 284 ppm in vacumm packaging and 197 ppm in modified atmosphere packaging (60% CO_2 and 40% N_2) after 16 days stored at 2°C. Similarly, modified atmosphere packaging (60% CO_2 and 40% N_2) was effective in inhibiting the production of amines in herring compared to that stored in air (Özogul *et al*., 2002b).

However, Dalgaard *et al*. (2006) found the modified atmosphere packaging (40% CO_2 and 60% N_2) did not differed significantly from air storage in reducing the histamine production in chilled fresh garfish at 0 and 5°C. Similarly, a modified atmosphere with gas composition of 60% CO_2, 25% N_2 and 15% O_2 and gas composition of 40% CO_2, 40% N_2 and 20% O_2 were not effective in reducing the amines production in hake compared to air storage (Ruiz-Capillas and Moral, 2001). But the author showed that the higher O_2 level did retard the amines formation. Gallas *et al*. (2010) also showed that the higher oxygen (75% O_2, 25% CO_2) had significant lower biogenic amine concentration in chicken meat compared to modified atmosphere of 75% N_2 and 25% CO_2.

Chitosan was studied on the use of food edible film due to its antimicrobial properties (Jeon *et al*., 2002). Recently, chitosan film packaging was found to have the best histamine inhibitory effect in Atlantic bonito fillet and it was followed by modified atmosphere packaging (100% CO_2), vacumm packaging and cling film packaging (Alak *et al*., 2010). The fillet packaged with chitosan film and modified packaging had significant lower histamine concentration and enterobacteriaceae count. Enterobacteriaceae was known as a major bacteria group for histamine production.

Irradiation

Irradiation is one of the important food preservation techniques. Food irradiation involves the exposure of food to ionizing radiations such as gamma rays, high energy electrons and X-rays (Arvanitoyannis *et al*., 2009). The ionising radiation inactivates the microorganism by damaging the nucleic acid of cells (Farkas, 2006). Besides the microbial inactivation, the food irradiation is also able to induce the radiolytic degradation of biogenic amines. More than 50 countries have adopted irradiation (Rabie *et al*., 2010).

Irradiation was found to reduce biogenic amines content in aqueous solutions (Kim *et al*., 2004), in fish (Mendes *et al*., 2000; Mendes *et al*., 2005; Mbarki *et al*., 2008), in Chinese Rugao ham (Wei *et al*., 2009), in low salt-fermented soybean paste (Kim *et al*., 2005a) and in ground beef and pork (Min *et al*., 2007). Kim *et al*. (2004) investigated the irradiation effects on amine standards dissolved in distilled water. The author demonstrated that the radiolytic degradation of biogenic amines decreased the biogenic amine significantly in a dose-dependent manner. In this study, irradiation broke down putrescine and spermine completely at 5 kGy. 10 kGy and 15 kGy were found to breakdown spermidine and histamine respectively.

In fish, irradiation significantly retarded the production of histamine, tyramine, cadaverine and putrescine in blue jack mackerel with 1 to 3 kGy (Mendes *et al*., 2000). Mendes *et al*. (2005) showed that histamine was only detected in the control compared to irradiated sample in horse mackerel (*Trachurus trachurus*) after 23 days of ice storage. The author reported even lower level (1 kGy) of irradiation was effective to reduce the amines contents significantly. Similarly, Mbarki *et al*. (2008) reported gamma irradiation retarded the histamine production significantly ($p \leq 0.05$) in Bonito (*Sarda sarda*) with doses ranging from 0 to 7.5 kGy during chilled storage. The author showed the decrease was correlated with the increased dose (R^2=0.97). The author suggested the irradiation dose below 4 kGy was sufficient to preserve bonito quality during chilled storage.

In ripened sausages, irradiation reduced the total biogenic amines concentrations by 40%, 47% and 68% with the dosage of with 2, 4 and 6 kGy during storage (Rabie *et al*., 2010). In Chinese Rugao ham, γ-irradiation was also reported to reduce the volatile N-nitrosamines, and residual nitrite in dry-cured ham (Wei *et al*., 2009). Nitrite can react with putrescine and cadaverine to produce carcinogenic nitrosamines and may also cause hemoglobinaemia (Kurt and Zorba, 2009).

However, Kim *et al*. (2003) found no significant difference in biogenic amines concentration between irradiated samples and control after irradiation. Irradiation was also reported to increase concentration of phenylethylamine in pepperoni (Kim *et al*., 2005b), spermidine, cadaverine, tryptamine and phenylethylamine in Chinese Rugao ham (Wei *et al*., 2009). It could be explained by the radicals produced from irradiation may alter the protein physical chemical properties and hence increase the concentration of certain biogenic amines (Rabie *et al*., 2010). Although the irradiation is effective in controlling biogenic amines formation but it may poses some adverse effects on the aspects of food nutrition and organoleptic properties. Mbarki *et al*. (2008) found the poly-unsaturated fatty acid was reduced significantly and irradiation induced maximum lipid oxidation rates with doses of 6 and 7.5 kGy.

High pressure processing

Recently high pressure processing has become an alternative method to preserve the food. The food is subjected to high hydrostatic pressure (usually among 100 and 1000 MPa) for shelf life extension (Bárcenas *et al*., 2010). The application of the non-thermal technology has the advantages of maintaining sensory and nutritional properties of foods compared to traditional heat treatment. This technology is being applied in the meat (Omer *et al*., 2010), vegetable (Colle *et al*., 2010) and seafood processing (Li *et al*., 2009). Microorganisms are inactivated when the present of factors causing the changes of cell structure or physiological functions (Lado and Yousef, 2002). High pressure processing inactivates microorganisms by damaging membranes, denaturing the enzymes and changing the cell morphology (Murchie *et al*., 2005).

The different levels of pressure and treatment time in high pressure processing influence the biogenic amines content. In some cases, higher pressure treatment was not effective to retard biogenic amines formation. Paarup *et al*. (2002) studied the effects of high pressure processing (15 min at ambient temperature and stored at 4°C) on biogenic amines in vacuum-packed squid mantles. For histamine, pressure of 200 MPa and 300 MPa did not show the retarding effect, its level was higher than that of control and 150 MPa. But 400 MPa was found to retard histamine production. Paarup *et al*. (2002) reported that the tyramine levels in sample of 300 and 400 MPa were higher than that of the 150 and 200 MPa and control.

Latorre-Moratalla *et al*. (2007) reported that pressure of 200 MPa (10 min at 17°C) strongly inhibit putrescine and cadavarine production in meat batter but no inhibitory effect was found on tyramine accumulation. Another study on vacuum-packaged frankfurther conducted by Ruiz-Capillas *et al*. (2007) showing that 400 MPa (10 min at 30°C) was effective to delay the tyramine, putrescine and cadavarine formation after 62 days of chilled storage at 2°C as compared to control lot. Novella-Rodriguez *et al.* (2002a) reported 50 MPa for 72 h produced the highest amine concentrations and three times higher tyramine concentration as compared to untreated goat cheese. By contrast, the amine content of sample treated with higher pressure for short time (400 MPa for 5 min) was similar to control lot. There was study did not found the difference on biogenic amines formation in milk between pressure treatment (500 MPa for 15 min, 20°C) and heat pressurization (Novella-Rodríguez *et al*., 2002b). The effects of high pressure processing on biogenic amines formation need more investigation.

Starter culture

In fermented food production, a starter culture is added to the raw material to accelerate the fermentation process and to obtain the better shelf life, desirable characteristics such as texture and sensory profile (Leroy and De Vuyst, 2004). The mixture of strains of lactic acid bacteria, *staphylococci* and *micrococci* genus are usually used as commercial starter cultures (Hugas and Monfort, 1997). *Staphylococcus* or *micrococcus* spp. and lactic acid bacteria are commonly applied in fermented sausages due to their lipolytic and proteolytic properties (Gücükoğlu *et al*., 2010). The equilibrium between amines formed and degraded amines influence the biogenic amines level in food (Gardini *et al*., 2002). Therefore, during the fermentation process, the biogenic amines formation can be controlled by using the starter cultures that are less effective in decarboxylating the amino acids to produce biogenic amines. The other approach is to use the starter cultures with amine oxidase to degrade the biogenic amines.

Various studies were done on the biogenic amines degradation by different bacteria. Mah and Hwang (2009) found that *S. xylosus* degraded 38.0% of the histamine and 4.4% of the tyramine in a phosphate buffer. Later *S. xylosus* was used as starter culture and applied to the ripening of a salted and fermented anchovy, and decrease total biogenic amines concentration by 16.0% as compared to control. Leuschner *et al*. (1998) observed that *Micrococcus* strain showed the highest tyramine oxidase activity and *Lactobacillus plantarum* had only low efficiency in degrading histamine and tyramine *in vitro*. However, Fadda *et al*. (2001) findings disagreed with Leuschner *et al*. (1998) result and found 2 strains of *L. casei* showing the greatest tyramine oxidase activity (93 and 98% degradation) and 60 and 69% degradation for 2 strains of *L. plantarum* after 96 hours of incubation in buffer system. Dapkevicius *et al*. (2000) found 4 isolate of *L. sakei* and 1 isolate of *L. curvatus* were able to degrade 20–56% of the histamine within 30 hour in a model systems. Recently, Zaman *et al*. (2010a) isolated the *Bacillus amyloliquefaciens* and *Staphylococcus carnosus* from fish sauce with histamine degradation activity up to 59.9% and 29.1% respectively in buffer system. These cultures were used as starter culture in fish sauce fermentation, *Staphylococcus carnosus* FS19 and *Bacillus amyloliquefaciens* FS05 was found to reduce the histamine concentration by 27.7% and 15.4% as compared to control, respectively (Zaman *et al*., 2010b).

Besides, there are studies reported that the use of starter culture is effective in inhibiting biogenic amines formation in fermented meat sausage (Gençcelep *et al*., 2007; Gücükoğlu *et al*., 2010), pork sausage (Lu *et al*., 2010; Coloretti *et al*., 2008), carp sausages (Hu *et al*., 2007) and fish sauce (Zaman *et al*., 2010b). Mixed starter culture of *Lactobacillus farciminis* and *Staphylococcus saprophyticus* were inoculated in fermented sausages and significantly reduced the levels of histamine, putrescine, cadaverine and tyramine compared to *Pediococcus pentosaceus* and *Staphylococcus xylosus* (Lu *et al*., 2010). In this study, *Lactobacillus farciminis* and *Staphylococcus saprophyticus* were found to inhibit *Staphylococcus sciuri*, *Enterococcus faecalis*, *Enterobacter aerogenes*, *Lactobacillus sakei*, *Pseudomonas* sp. and *Micrococcus luteus*. *Enterobacteriaceae*, *Clostridium*, *Lactobacillus*, *Streptococcus*, *Micrococcus*, and *Pseudomonas* species possess the amino acid decarboxylase to produce the biogenic amines (Shalaby, 1996). Many enterobacteriaceae and pseudomonas are able to produce histamine, cadavarine and putrescine. Some micrococcaceae and lactic acid bacteria can produce considerable amount of putrescine, histamine and tyramine (Hu *et al*., 2007).

The mixture of starter culture of *Lactobacillus plantarum* together with *Kocuria varians* was effective in reducing the total biogenic amines concentration compared with *Lactobacillus plantarum* alone and control in low-acid salami (Coloretti *et al*., 2008). Two different starter cultures using mixture of *Lactobacillus sakei* and *Staphylococcus carnosus* and mixture of *Pediococcus acidilactici*, *Staphylococcus xylosus* and *Lactobacillus curvatus* were effective to reduce the amounts of putrescine, cadaverine and tyramine significantly compared to control in Turkish dry-fermented sausage (Gençcelep *et al*., 2007). Gücükoğlu *et al*. (2010) reported that the three different starter culture using *L. sake*, *S. xylosus*, *L. plantarum*, *S. carnosus*, and *L. curvatus* were able to reduce the biogenic amines formation compared to control in Turkish fermented sausages. In another study of silver carp sausages, three group mixed starter cultures involving *Lactobacillus plantarum*, *Staphylococcus xylosus*, *Pediococcus pentosaceus* and *Lactobacillus casei* subsp. *Casei* were able to reduce the histamine, putrescine, cadavarine and tyramine significantly after 2 days of fermentation. In this study, the use of starter culture reduced the histamine by 90–95% in sausage compared to the control (Hu *et al*., 2007).

During chilled and room temperature storage, Komprda *et al*. (2001) found the total biogenic amines of sausage using starter culture B (*L. sakei*, *S. carnosus*, *Pediococcus pentosaceus*) was significantly higher than of starter culture A (*L. sakei*, *S. carnosus*, *S. xylosus*) at the end of the study. However, the total biogenic amines content during ripening in dry fermented sausage did not differ significantly between these two starter cultures. Komprda *et al*. (2001) suggested the different biogenic amines formation during the storage was due to the different starter culture and microflora present in sausage.

Although the use of starter culture showed a positive results in degrading or controlling the biogenic amines formation but are not necessarily effective under real manufacturing process. In fermented products, starter culture is the most important factor in influencing biogenic amines formation (Komprda *et al*., 2009). The other chemico-physical factors including raw material, pH, aW, ripening temperature, storage temperature, sausage diameter and additives used (Komprda *et al*., 2009). These parameters should be investigated further to determine the optimum fermentation process and least biogenic amines formation.

Conclusion

Histamine poisoning is important food borne disease and international trade issue. It can be easily misdiagnosed and not all the incidents go reported. Foods are susceptible to contamination by biogenic amines producing microorganisms during post harvest handling. High level of biogenic amines can be avoided by using good quality raw material, applying good hygienic food handling and avoiding temperature abuse during handling, delivery and storage. More studies needed to be done on the effects of irradiation and high pressure processing on biogenic amines formation and on food quality. The combination of these preservative factors (hurdle) in influencing the microbial stability, the organoleptic and nutritional quality of foods needs more investigation.

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