

Reduction of biogenic amines in fermented fish sauces by using Lactic acid bacteria

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Received: February 2018

Accepted: July 2018

Abstract

Fish sauce is a fermented product which is used mainly in south Asian countries. Fish sauce contains many vitamins and minerals, and all essential amino acids and is especially high in lysine. Despite the positive nutritional characteristic, these products contain biogenic amines as unhealthy compounds. Biogenic amines are secondary metabolites which formed by microbial decarboxylation of respective amino acids or by amino acid transaminase activity on aldehydes and ketones, and categorized as bases with low molecular weight. These compounds are one of the prevalent issues regard to consumption of sea-foods, especially the cured and fermented products. Among the various compounds of biogenic amines, histamine, tyramine, putrescine, and cadaverine, are used for computing quality and biogenic amine indices for raw/processed sea-foods. Biogenic amines are a major causative agent of food borne diseases hence, their identification, and applying procedures corresponding to their decrement are significantly important in food industry. Many of the bacterial species are able to decrease biogenic amines in fish sauces. The application of bacteria possessing the biogenic amines degrading enzymes or starter cultures are novel techniques explored for reducing biogenic amines concentration in fermented fish products.

Keywords: Biogenic amines, Fish, Sauces, Bacteria, Fermentation

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Introduction

Fish sauce, a salty brown liquid with mild fishy flavor, is a fermented product which consumed since ancient times such as "Garum" made by romans from viscera and blood of mackerel," Garos " prepared in Greece made from the liver of *Scomber colias*, and also "Botargue" and "Ootarides" which produced in Italy and Southern Greece (Boziaris, 2014). Now a days in Southeast Asia especially in Thailand fish sauce production has annually extended deeper in to international markets. More over these kinds of products are also popular in Malaysia (Budu), Philippines (Patis), Indonesia (Ketjap-ikan), Japan (Ishiru), and China (Yeesu), respectively. As a general recipe for preparing this product is to store salted whole small fish in underground earthenware for 9 to 12 months in order to complete the fermentation and hydrolysis procedure. Fermented fish sauce can be consumed as condiment or in some cases as a main dish regard to its nutritional value, having significant proportion of amino acids, especially high in lysine, being a good source for obtaining vitamins, especially B12 and also various minerals such as sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), and phosphorus (P). On the other hand fish sauce has some consumption limitations because of salt concentration, biogenic amines which produced during the fermentation period and also the bacterial flora. Biogenic amines are basic nitrogenous composition producing in meat and fish

products, mostly due to the amino acid decarboxylation activities of some microbes (Boziaris, 2014). Consumption of these products could lead to scombroid poisoning in consumers (Tsai *et al.*, 2006). Eight major amines i.e. histamine, tyramine, putrescine, cadaverine, tryptamine, phenylethylamine, spermine and spermidine were recognized in fish sauce, and paste products. However histamine, putrescine and cadaverine are the most abundant compounds, respectively (Zaman *et al.*, 2010). Using cold storage can be used as an inhibitory process for histamine formation during fermentation period (FDA, 2011). It is assumed that the source of histamine in most fish sauces, was from Gram-negative bacteria being prevailing within fish during the early stages of processing; by the presence of free amino acids, decarboxylase activity of Gram-negative bacteria (Petaja *et al.*, 2000). Lactic acid bacteria are being applied in many fish sauces; however studies (Munoz-Atienza *et al.*, 2011) showed that lactic acid bacteria do not produce histamine or other biogenic amines. Moreover many authors revealed the regulation potential of histamine synthesis in fermented products by addition of halophilic lactic acid bacteria, as starter culture (Pierina *et al.*, 2012). This article reviews the potential of Lactic acid bacteria in reducing the content of biogenic amines in fermented fish sauce.

Biogenic amines in processed sea food

Formation of biogenic amines is possible during processes such as

brining, salting, smoking, drying, fermenting, and pickling until the product is fully shelf-stable. Using refrigeration can be prevented histamine formation during these Processing operations (FDA, 2011). Samples of fermented fish products (fish sauce, fish paste, and shrimp paste) were analyzed for histamine content (Tsai *et al.*, 2006), which was 394, 263, and 382mg/kg, respectively. More than 500mg/kg of histamine in three fish sauces, two fish pastes, and two shrimp paste products are reported. Moreover 7.4% of the tested samples contained >1000mg/kg. The mean amount of diverse BAs in target samples was reported less than 90mg/kg. Rihaakuru (one kind of fish paste), which is an important flavouring in the Maldives, have high amount of BAs, was originated from raw tuna, being exposed to temperature abuse. Histamine was identified at the high concentration in twenty-eight samples of Rihaakuru were analyzed for some BAs (5487mg/kg) (Naila *et al.*, 2011). Tryptamine was not detected in most of the samples (only three samples contained <5mg/kg) and phenylethylamine only occurred at low levels (<25mg/kg). The authors supposed that the histamine found in Rihaakuru samples was most likely to have originated from Gram-negative bacteria growing in the fish before processing or within the fish during the early steps of manufacture. There are other processed seafood which have been investigated for BAs content. In

southern China, three fish products are widely consumed: salted and fermented fish, canned fish, and packaged fish. Zhai *et al.* (2012) examined 49 fish products from the China market. The maximum total BAs content of lightly cured horse mackerel was 484.42mg/kg compared to 167.86mg/kg or less for the other salted and fermented fish products. In the Spanish mackerel sample, histamine was detected within the range of 15.74–28.70mg/kg, whereas the maximum histamine level was 26.95mg/kg in canned anchovies, 22.38mg/kg in canned sardines and less than 10mg/kg in all other canned samples tested (Zhai *et al.*, 2012). Mah *et al.* (2002) found high levels of histamine (155–579mg/kg) in fermented fish products made from anchovies, whereas Hwang *et al.* (2010) reported large amounts of histamine in dried fish products (63.1–479.0mg/kg). Anchovies prepared from fish of the *Engraulis encrasicolus* species, and are one of the traditional fish sauces in some Mediterranean countries. Pons-Sánchez-Cascado *et al.* (2005a) reported in salt-ripened anchovies tyramine has the most amount of biogenic amines with values up to 90mg/kg, whereas histamine did not exceed 20mg/kg. Then, the same authors analyzed samples of vinegar-marinated anchovies and reported higher values for tyramine than histamine (7.81 and 0.54mg/kg, respectively) in 14 days of refrigerated storage (Pons-Sánchez-Cascado *et al.*, 2005b). The condition for formation

BAs may be match with fermentation process condition like accessibility of free amino acids, the attendance of decarboxylase-positive microorganisms and conditions causing bacterial growth, decarboxylase synthesis, and decarboxylase activity (Petäjä *et al.*, 2000). The result cleared certain fish sauce products, especially that produced from sardine and mackerel, mostly have large amount of histamine, almost 1000mg/l or greater (Tsai *et al.*, 2006; Kuda and Miyawaki, 2010), as a result of the histidine decarboxylase of *Tetragenococcus* spp., a halophilic lactic acid bacterium. However, most studies (Thapa *et al.*, 2006; Muñoz-Atienza *et al.*, 2011) showed that in fermented fish products LAB produced no histamine or other BAs. Kuda *et al.* (2012) said that addition of some halophilic LAB, like a starter culture, can regulate histamine accumulation in salted and fermented fish products of nukazuke (salted and fermented fish with rice bran). 13 strains of 200 isolates from nukazuke fish, have ability for producing histamine at levels more than 200µg/ml but 130 isolates produced no histamine. Moreover, 22 of the tested strains cleared to suppress histamine production (Kuda *et al.*, 2012).

Microorganisms related to biogenic amines production

A lot of bacterial species are capable to convert histidine to histamine.

Enterobacteriaceae are generally considered as a primary cause of histamine production in scombroid fish. *Morganella morganii*, *Klebsiella pneumoniae* and *Hafnia alvei* are the strongest histamine producers (EFSA, 2011). Other bacterial species able to producing histamine include *Morganella psychrotolerans*, *Photobacterium phosphoreum*, *Photobacterium psychrotolerans* (Ozogul and Ozogul, 2006), *Clostridium* spp, *Vibrio alginolyticus*, *Acinetobacter lowffi*, *Plesiomonas shigelloides*, *Pseudomonas putida*, *Pseudomonas fluorescens*, *Aeromonas* spp. (Yatsunami and Echigo 1993; Hwang *et al.*, 2010). Some intestinal bacterial species able to producing histamine include *Proteus vulgaris*, *Proteus mirabilis*, *Enterobacter aerogenes*, *Enterobacter cloacae*, *Serratia fonticola*, *Serratia liquefaciens* and *Citrobacter freundii* (Tsai *et al.*, 2005; Kung *et al.*, 2009). *Staphylococcus* spp., *Vibrio* spp, and *Pseudomonas* spp were found as histamine producing bacteria in fermented fish by Yatsunami and Echigo (1993). Fifteen histamine producing bacteria were isolated from tuna dumpling products by Kung *et al.* (2010). These are *Raoultella ornithinolytica* (four strains), *Enterobacter. aerogenes* (two strains), *Abaylyi* (one strain) for prolific histamine formers and *Pantoeasp* (one strain), *Serratia. marcescens* (one starin), *Bacillus. megaterium* (one starin), *Klebsiella. oxytoca* (two strains)

and *Klebsiella. Pneumoniae* (one strain). Kung *et al.* (2009) recognize *Hafnia.alvei* as a weak histamine former, *Raoultella. planticola* and *Raoultella.ornithinolytica* as prolific histamine formers with the ability to produce >500 ppm histamine in tuna sandwiches. Hwang *et al.* (2010) introduced *Staphylococcus piscifermentans*, *Bacillus spp*, and *Bacillus subtilis* as weak histamine producer in tuna candy products. *Bacillus*, *Citrobacter*, *Clostridium*, *Klebsiella*, *Escherichia*, *Proteus*, *Pseudomonas*, *Salmonella*, *Schigella*, *Photobacterium*, *Lactobacillus*, *Pediococcus*, *Streptococcus* are capable of decarboxylating one or more amino acids (Brink *et al.*, 1990). Lee *et al.* (2015a) identified ten histamine forming bacterial strains from milk fish having an ability to produce 373–1261 ppm of histamine in trypticase soy broth supplemented with 1% L-histidine. The microorganisms identified were *Enterobacteraerogenes* (4 strains), *Ecloacae* (1 strain), *Morganellamorganii* (2 strains), *Serratia marcescens* (1 strain), *Hafnia alvei* (1 strain) and *Raoultella orithinolytica* (1 strain). Kung *et al.* (2015) cleared that *Staphylococcus xylosus*, a halotolerant bacterium of dried frying fish products had a consistent ability to form more than 300 ppm of histamine at 3% sodium chloride concentration. In fermented seafood, *Staphylococcus* and *Tetragenococcus spp* produce histamine (Yatsunami and Echigo, 1993). *Bacillus*

coagulans and *Bacillus megaterium* were identified as weak histamine producer in fermented fish products by Tsai *et al.* (2006). The main phenylethylamine producers are tyrosine decarboxylating bacteria and its production is related to tyramine formation. According to Hu *et al.* (2012), the growth of mesophilic and psychrophilic bacteria in blue cod and octopus positively associated with the formation of amines such as putrescine, cadaverine, histamine and tyramine during chill storage.

Biogenic Amines intolerance

Histamine intolerance (HIT) due to high sensitivity to histamine is a metabolic disorder which varies between individuals because of the level of diamine oxidase activity, reduction of histamine catabolism rate and metabolic disorders (Maintz and Novak 2007; Hungerford 2010). Moreover some sort of therapeutics i.e. antidepressants and tuberculostatics act as diamine oxidase inhibitors (Prester, 2011); and ulcerative colitis, Crohn's disease, colorectal neoplasm (Petersen *et al.*, 2002), atopic eczema (Maintz *et al.*, 2006) are effective on hypersensitivity of patients to histamine. Although the symptoms could be controlled through keeping on a free- histamine diet or by substitution of DAO (Prester, 2011).

The same problem is detected for consuming tyramine rich food stuffs in sensitive patients due to genetic or tyramine catabolism disorders; which

maybe sever in those cases who take antidepressant and anti-parkinsonian drugs (McCabe-Sellers *et al.*, 2006).

As these food sensitivities become more common over the last decades, therefore producers especially fermented and fisheries industry try to control the level of biogenic amines in products.

Measuring Biogenic amines in foods

Regard to the importance of controlling the levels of biogenic amines in ingredients and processed foods, various analytical methods have been introduced as a part of food control processes. Generally these methods are classified into biological and analytical methods. In biological method which was the first method of AOAC for determining the histamine, it is measured as the amount of histamine that induces response in histamine sensitive organ like guinea ileum (Biji *et al.*, 2016).

Chromatographic methods are generally used for quantification measurements of biogenic amines especially in seafood; such as gas chromatography, thin layer chromatography, high performance liquid chromatography and paper electrophoresis (Biji *et al.*, 2016). As a convenient method test kits based on selective antibody and immunoassay reactions also used for histamine determination (Hungerford and Wu, 2012)

Biogenic amines degradation by microorganism

Many bacteria have been shown to convert primary amines via an oxidative deamination step into products that can be utilized either as a source of carbon and/or energy and as a source of nitrogen, or both (Hacisalihoglu *et al.*, 1997; Levering *et al.*, 1981). The potential role of microorganisms in food fermentation with amino acids oxidases and dehydrogenases activity has been investigated to prevent or reduce the accumulation of biogenic amines in foods. These findings are useful for the application of microbial degradation of biogenic amines (Dapkevicius *et al.*, 2000; Siddiqui *et al.*, 2000; Bozkurt and Erkmen, 2002; Gardini *et al.*, 2002). Kongkiattikajorn (2015) reported that biogenic amines formation (cadaverine, putrescine, histamine, tryptamine, phenylethylamine, and tyramine) was significantly lower in *som-fug* (Thai traditional fermented fish sausage) fermented with starter culture (Table 1). Accumulation of these biogenic amines in *som-fug* could reduce significantly by the incubation with of *L. sakei* KM5474 and *L. plantarum* KM1450. Starter culture *L. plantarum* KM1450 had the highest ability in decreasing biogenic amines accumulation in *som-fug* compared with starter culture *L. sakei* KM5474.

Table 1: Microorganisms reduce biogenic amines in marine products.

Type of product	Type of microorganisms	Researchs and date of publishing
<i>som-fug</i>	<i>L. sakei</i> KM5474 and <i>L. plantarum</i> KM1450	Kongkiattikajorn, 2015
sausage	<i>Lactobacillus sakei</i> CTC494 and <i>L. curvatus</i> CTC371	Bover-Cid <i>et al.</i> .(2000)
fish pastes	<i>Lactic acid bacteria</i> species	Maria <i>et al.</i> , 2000

Moreover mixed starter cultures of *L. sakei* KM5474 and *L. plantarum* KM1450 indicated the highest potential in reducing the amount of biogenic amines. Bover-Cid *et al.* (2000) cleared that the amount of biogenic amines during sausage fermentation and storage at 4 and 19°C reduced by the effect of *Lactobacillus sakei* CTC494, a negative amino acid–decarboxylase starter culture. The addition of starter culture resulted in a decrease on the biogenic amines formation, depending on the strain inoculated. A great reduction in tyramine content was achieved when *L. sakei* CTC494 was inoculated, whereas *L. curvatus* CTC371 only attenuated tyramine accumulation compared with the control batch. The production of putrescine and cadaverine were significantly limited by both starter cultures, and they had inhibition effect on tryptamine and phenylethylamine formation by the wild microbial flora. Maria *et al.* (2000) showed that some bacteria, among which some *Lactic acid bacteria* species, are able to degrade biogenic amines by means of amino oxidases. This could be of interest for fish silage production, to control biogenic amines build-up in this

product. Seventy-seven *Lactic acid bacteria* cultures isolated from fish pastes submitted to natural fermentation at two temperatures (15 and 22°C) and selected combinations of these isolates were examined for histamine, tyramine, cadaverine and putrescine production. Degradation occurred at all temperatures tested (15, 22 and 30°C), but not at pH 4.5. The application of bacteria possessing the biogenic amines degrading enzymes or starter cultures are novel techniques explored for reducing biogenic amines concentration in fermented fish products. Using a proper selected starter culture in sausages production was advised to produce safer product with low contents of biogenic amines.

Conclusion

Seafood products are important from nutritional and economical points of view, however formation of secondary metabolites, biogenic amines, may limited their consumption regard to be a causative agents of illness and physiological disorders. Many regulatory standards are set as the limitation levels of biogenic amines presence in food products. In this regard, prevention methods such as

applying microorganism starter culture are used to keep the level of biogenic amines lower than the announced acceptable standards.

References

- Biji, K. B., Ravishankar, C.N., Venkateswarlu, R., Mohan, C.O. and Srinivasa Gopal, T.K., 2016.** Biogenic amines in seafood: A Review. *Journal of food science technology*, 35(5), 2210-2218. <https://doi.org/10.1007/s13197-016-2224-x>
- Bover-Cid, S., Hugas, M., Izquierdo-Pulido, M. and Vidal-Carou, MC., 2000.** Reduction of biogenic amine formation using a negative amino acid-decarboxylase starter culture for fermentation of Fuet sausages. *Journal of Food Protection*, 63, 237-43. <https://doi.org/10.4315/0362-028X-63.2.237>.
- Boziaris, I.S., 2014.** Seafood processing: Technology, Quality and Safety, First edition, John Wiley and Sons, Ltd. <https://doi.org/10.1002/9781118346174>.
- Bozkurt, H. and Erkmen, O., 2002.** Effects of starter cultures and additives on the quality of Turkish style sausage sucuk. *Meat Science*, 61, 149-156. [https://doi.org/10.1016/S0309-1740\(01\)00176-0](https://doi.org/10.1016/S0309-1740(01)00176-0)
- Brink, B., Damink, C., Joosten, H. and Veldjh, J., 1990.** Occurrence and formation of biologically active amines in foods. *International Journal of Food Microbiology*, 11, 73-84. [https://doi.org/10.1016/0168-1605\(90\)90040-C](https://doi.org/10.1016/0168-1605(90)90040-C)
- Dapkevicius, M.L.N.E., Nout, M.J.R., Rombouts, F.M., Houbon, J.H. and Wymenga, W., 2000.** Biogenic amine formation and degradation by potential fish silage starter microorganisms. *International Journal of Food Microbiology*, 57, 107-114. [https://doi.org/10.1016/S0168-1605\(00\)00238-5](https://doi.org/10.1016/S0168-1605(00)00238-5)
- EFSA (European Food Safety Authority), 2011.** Scientific opinion on risk based control of biogenic amine formation in fermented foods. *EFSA J*, 9(10), 2393. <https://doi.org/10.2903/j.efsa.2011.2393>
- FDA (Food and Drug Administration), 2011** Fish and Fishery Products Hazards and Controls Guidance, 4th edn. Department of Health and Human Services, Food and Drug Administration, Center for Food Safety and Applied Nutrition, Washington DC.
- Gardini, F., Martuscelli, M., Crudele, M.A., Paparella, A. and Suzzi, G., 2002.** Use of *Staphylococcus xylosum* as a starter culture in dried sausages: effect on the biogenic amine content. *Meat Science*, 61, 275-283. [https://doi.org/10.1016/S0309-1740\(01\)00193-0](https://doi.org/10.1016/S0309-1740(01)00193-0)
- Hacisalihoglu, A., Jongejan, J. A. and Duine, J.A., 1997.** Distribution of amine oxidases and amine

- dehydrogenases in bacteria grown on primary amines and characterization of the amine oxidase from *Klebsiella oxytoca*. *Microbiology*, 143, 505–512. <https://doi.org/10.1099/00221287-143-2-505>
- Hu, Y., Huang, Z., Li, J. and Yang, H., 2012.** Concentrations of biogenic amines in fish, squid and octopus and their changes during storage. *Food Chemistry*, 135, 2604–2611. <https://doi.org/10.1016/j.foodchem.2012.06.121>
- Hungerford, J.H., 2010.** Scombroid poisoning: a review. *Toxicon*, 56, 231–243.
- Hwang, C., Lee, Y., Huang, Y., Lin, C., Shiau, C., Hwang D. and Tsai Y., 2010.** Biogenic amines content, histamine-forming bacteria and adulteration of bonito in tuna candy products. *Food Control*, 21, 845–850. <https://doi.org/10.4315/0362-028X.JFP-12-061>
- Hungerford, J., and Wu, W.H., 2012.** Comparison study of three rapid test kits for histamine in fish: bioscientific max signal enzymatic assay, neogen veratox ELISA, and the neogen reveal histamine screening test. *Food Control*, 25, 448–457. <https://doi.org/10.1016/j.foodcont.2011.11.007>
- Kongkiattakajorn, J., 2015.** Potential of starter culture to reduce biogenic amines accumulation in som-fug, a Thai traditional fermented fish sausage. *Journal of Ethnic Foods*, 4, 186–194. <https://doi.org/10.1016/j.jef.2015.11.005>
- Kuda, T., and Miyawaki, M., 2010.** Reduction of histamine in fish sauces by rice bran nuka. *Food control*, 21, 1322–1326. <https://doi.org/10.1016/j.foodcont.2010.04.003>
- Kuda, T., Izawa, Y., Ishii, S., Takahashi, H., Torido, Y., and Kimura, B., 2012.** Suppressive effect of *Tetragenococcus halophilus*, isolated from fish-nukazuke, on histamine accumulation in salted and fermented fish. *Food Chemistry*, 130, 569–574. <https://doi.org/10.1016/j.foodchem.2011.07.074>
- Kung, H., Wang, T., Huang, Y., Lin, C., Wu, W., Lin, C. and Tsai, Y., 2009.** Isolation and identification of histamine-forming bacteria in tuna sandwiches. *Food Control*, 20, 1013–1017. <https://doi.org/10.1016/j.foodcont.2008.12.001>
- Kung, H., Lee, Y., Huang, Y., Lin, W., Lin, C., Chenb, W. and Tsai, Y., 2010.** Biogenic amines content, histamine-forming bacteria, and adulteration of pork and poultry in tuna dumpling product. *Food Control*, 21, 977–982. <https://doi.org/10.4315/0362-028X.JFP-12-061>
- Kung, H.F., Huang, C.Y., Lin, C.M., Liaw, L.H., Lee, Y.C. and Tsai, Y.H., 2015.** The histamine content of dried flying fish products in Taiwan and the isolation of

- halotolerant histamine-forming bacteria. *Journal of food and drug analysis China*, 23, 335–342. <https://doi.org/10.1016/j.jfda.2014.10.009>
- Lee, Y.C., Lin, C.S., Liu, F.L., Huang, T.C. and Tsai, Y.H., 2015a.** Degradation of histamine by *Bacillus polymyxa* isolated from salted fish products. *Journal of food and drug analysis China*, 23, 836–844. <https://doi.org/10.1016/j.jfda.2015.02.003>
- Levering, P.R., van Dijken, J.P., Veenhuis, M. and Harder, W., 1981.** *Arthrobacter* P1, a fast growing versatile methylotroph with amine oxidase as a key enzyme in the metabolism of methylated amines. *Archives of Microbiology*, 129, 72–80. <https://doi.org/10.1007/BF00417184>
- Mah, J.H., Han, H.K., Oh, Y.J., Kim, M.G., and Hwang, H.J., 2002.** Biogenic amines in Jeotkals, Korean salted and fermented fish products. *Food Chemistry*, 79, 239–243. [https://doi.org/10.1016/S0308-8146\(02\)00150-4](https://doi.org/10.1016/S0308-8146(02)00150-4)
- Maintz, L., Benfadal, S., Allam, J.P., Hagemann, T., Fimmers R. and Novak N., 2006.** Evidence for a reduced histamine degradation capacity in a subgroup of patients with atopic eczema. *The Journal of Allergy and Clinical Immunology*, 117, 116–1112. <https://doi.org/10.1016/j.jaci.2005.11.041>
- Maintz, L. and Novak N., 2007.** Histamine and histamine intolerance. *The American Journal of Clinical Nutrition*, 85, 1185–1196. <https://doi.org/10.1036/1097-8542.BR10229141>
- Maria, L.N., Enes Dapkevicius, M.J., Robert, Nout, Frank, M., Rombouts Jacques, H. and Houben W.W., 2000.** Biogenic amine formation and degradation by potential fish silage starter microorganisms. *International Journal of Food Microbiology*, 57, 107–114. [https://doi.org/10.1016/S0168-1605\(00\)00238-5](https://doi.org/10.1016/S0168-1605(00)00238-5)
- McCabe-Sellers B., Staggs C.G. and Bogle M.L., 2006.** Tyramine in foods and monoamine oxidase inhibitor drugs: a crossroad where medicine, nutrition, pharmacy, and food industry converge. *Journal of Food Composition and Analysis*. 19, S58–S65. <https://doi.org/10.1016/j.jfca.2005.12.008>
- Muñoz-Atienza, E., Landeta, G., delas Rivas, B., Gómez-Sala, B., Muñoz, R., Hernández, P.E., Cintas, L.M., and Herranz, C., 2011.** Phenotypic and genetic evaluations of biogenic amine production by lactic acid bacteria isolated from fish and fish products. *International Journal Food Microbiology*, 146, 212–216. <https://doi.org/10.1016/j.ijfoodmicro.2011.02.024>

- Naila, A., Flint, S., Fletcher, G.C., Bremer, P.J., and Meerdink, G., 2011.** Biogenic amines and potential histamine-forming bacteria in rihaakuru (a cooked fish paste). *Food Chemistry*, 128, 479–484. <https://doi.org/10.1016/j.foodchem.2011.03.057>
- Ozogul, F., and Ozogul, Y., 2006.** Biogenic amine content and biogenic amine quality indices of sardines (*Sardina pilchardus*) stored in modified atmosphere packaging and vacuum packaging. *Food Chemistry*, 99, 574–578. <https://doi.org/10.1016/j.foodchem.2005.08.029>
- Petäjä, E., Eerola, S. and Petäjä, P., 2000.** Biogenic amines in cold-smoked fish fermented with lactic acid bacteria. *Europe Food Research Technology*, 210, 280–285. <https://doi.org/10.1007/s002179900097>
- Petersen, J., Raithel, M. and Schwelberger, HG., 2002.** Histamine N-methyl-transferase and diamine oxidase gene polymorphisms in patients with inflammatory and neoplastic intestinal diseases. *Inflammation Research*, 51, 91–92. <https://doi.org/10.1007/PL00022464>
- Pierina, V., Schirone, M., Tofalo, R. and Suzzi, G., 2012.** Biogenic amines in raw and processed seafood. *Frontiers in Microbiology/Food Microbiology*. 3, 1-10. <https://doi.org/10.3389/fmicb.2012.00188>
- Pons-Sánchez-Cascado, S., Veciana-Nogués, M.T., Bover-Cid, S., Mariné-Font, A. and Vidal-Carou, M.C., 2005a.** Volatile and biogenic amines, microbiological counts, and bacterial amino acid decarboxylase activity throughout the salt-ripening process of anchovies (*Engraulis encrasicolus*). *Journal Food Protection*, 68, 1683–1689. <https://doi.org/10.4315/0362-028X-68.8.1683>
- Pons-Sánchez-Cascado, S., Vidal-Carou, M.C., Mariné-Font, A. and Veciana-Nogués, M.T., 2005b.** Influence of the freshness grade of raw fish on the formation of volatile and biogenic amines during the manufacture and storage of vinegar-marinated anchovies. *Journal Agriculture Food Chemistry*, 53, 8586–8592. <https://doi.org/10.1021/jf050867m>
- Prester, I., 2011.** Biogenic amines in fish, fish products and shellfish: a review. *Food additives and contaminants: Part A*. 28(11), 1547-1560. <https://doi.org/10.1080/19440049.2011.600728>
- Siddiqui, J.A., Shoeb, S.M., Takayama, S., Shimizu, E. and Yorifuji, T., 2000.** “Purification and characterization of histamine dehydrogenase from *Nocardioides simplex* IFO 12069”. *FEMS Microbiology Letters*, 15, 183–187. [https://doi.org/10.1016/S0378-1097\(00\)00277-9](https://doi.org/10.1016/S0378-1097(00)00277-9)

- Thapa, N., Pal, J. and Tamang, J.P., 2006.** Phenotypic identification and technological properties of lactic acid bacteria isolated from traditionally processed fish products of the Eastern Himalayas. *International Journal Food Science*, 107, 33–38. <https://doi.org/10.1016/j.ijfoodmicro.2005.08.009>
- Tsai, Y.H., Lin, C.Y., Chang, S.C., Chen, H.C., Kung, H.F. and Wei C.I., 2005.** Occurrence of histamine and histamine-forming bacteria in salted mackerel in Taiwan. *Food Microbiology*, 22, 461–467. <https://doi.org/10.1016/j.fm.2004.11.003>
- Tsai, Y.H., Lin, C.Y., Chien, L.T., Lee, T.M., Wei, C.I. and Hwang, D.F., 2006.** Histamine contents of fermented fish products in Taiwan and isolation of histamine forming bacteria. *Food Chemistry*, 98, 64–70. <https://doi.org/10.1016/j.foodchem.2005.04.036>
- Yatsunami, K. and Echigo, T., 1993.** Studies on halotolerant and halophilic histamine forming bacteria. III. Changes in the number of halotolerant histamine forming bacteria and contents of nonvolatile amines in sardine meat with addition of NaCl. *Bulletin of the Japanese Society for the Science of Fish*, 59,123–127. <https://doi.org/10.2331/suisan.59.123>
- Zaman M.Z., Bakar F.A., Selamat J. and Bakar, J., 2010.** Occurrence of biogenic amines and amines degrading bacteria in fish sauce. *Czech Journal Food Science*, 28(5), 440–449. <https://doi.org/10.17221/312/2009-CJFS>
- Zhai, H., Yang, X., Li, L., Xia, G., Cen, J., Huang, H. and Hao, S., 2012.** Biogenic amines in commercial fish and fish products sold in southern china. *Food Control*, 25, 303–308. <https://doi.org/10.1016/j.foodcont.2011.10.057>