Review Article

www.dergipark.org.tr/en/pub/mediterranean

MEDITERRANEAN
AGRICULTURAL SCIENCES
(2024) 37(1): 27-31
DOI: 10.29136/mediterranean.1380634

Influence of plants and spices on the formation of biogenic amines in meat

Mustafa Hamza Mawlood AL BAYATI[1, 2], Mehmet Fatih CENGIZ[1]

[1]Akdeniz University, Faculty of Agriculture, Department of Agricultural Biotechnology, 07070, Antalya, Türkiye
[2]University of Sulaimani, College of Agricultural Engineering Sciences, Department of Animal Sciences, 46001, Sulaimani, Iraq

Corresponding author: M. F. Cengiz, e-mail: fcengiz@akdeniz.edu.tr
Author(s) e-mail: mustafa.mawlood@univsul.edu.iq

ARTICLE INFO

Received: October 24, 2023
Received in revised form: January 11, 2024
Accepted: January 12, 2024

***Keywords*:**

Biogenic amines
Food safety
Inhibition
Meat
Plant extracts

ABSTRACT

Biogenic amines (BAs) consist of organic nitrogenous compounds produced by the amino acid's decarboxylation. They are present in various foods, such as meat products, and are associated with several health hazards. In meat, BAs are produced by the action of microorganisms that can decarboxylate amino acids. BAs can also be produced in meat naturally by enzymatic pathways. Tyramine, histamine, cadaverine, and putrescine are BAs frequently found in meat products. BAs are frequently found in fish depending on the species and time-temperature control, but can also be present in meat, particularly in canned, cured and fermented meat products. BAs are associated with various health disorders and toxicological effects including cardiovascular, respiratory and gastrointestinal system problems. Numerous factors influence the BAs generation in meat products. Factors such a handling, storage temperature, and processing procedures are essential for minimizing the risk of BAs formation to ensure food safety. Plant extracts and spices, play a multifaceted role in regulating BAs developments in diverse food items. Plant extracts containing phenolic/polyphenols, terpenoids and alkaloids have exhibited antimicrobial properties that can hinder the growth of microorganisms responsible for producing amines, consequently reducing BAs formation. Also, spices frequently contain compounds that impede the enzymatic conversion of precursor amino acids into biogenic amines.

1. Introduction

Biogenic amines (BAs) are naturally appearing nitrogen-containing compounds present in foods and beverages, particularly in fermented products. The classification of these compounds is determined by both their chemical composition and the quantity of amine groups present within their molecular structure. They can also be classified based on their origin or synthesis, which includes endogenous and exogenous sources. Endogenous sources can be further divided into dietary and non-dietary sources, while exogenous sources can be microbial or plant/animal in origin (Linares et al. 2011; Ruiz-Capillas and Herrero 2019).

BAs serve essential functions in both eukaryotic and prokaryotic cells. They have an important role and act as precursors for the synthesis of nucleic acids, alkaloids, proteins, and hormones, and function as neurotransmitters in the nervous system. Spermidine and putrescine are required for important biological functions, such as DNA and protein synthesis, and modulating RNA. In prokaryotic cells, BA production is related to defense mechanisms against acidic stress, generation of energy, and osmotic and oxidative stress responses (Premont et al. 2001; Santos 1996).

BAs are synthesized in food by bacterial decarboxylation of amino acids, particularly under certain conditions such as high temperature and humidity. Excessive consumption of BAs can lead to health issues, and the accumulation of BAs in products is an important concern for food safety and quality. The production of BAs is generally affected by various conditions and factors, such as type of meat, processing conditions, and storage temperature (Naila et al. 2010). Many microorganisms have the ability to produce BAs, and proper hygiene and sanitation practices (Wójcik et al. 2021), controlling temperature and pH during processing, and using microbial starter cultures can decrease BAs accumulation in meat (Gardini et al. 2016).

The formation of BAs is directly dependent on microorganisms with decarboxylase activity (Bardócz 1995). Various factors, such as pH, water activity, and temperature can affect the formation of BAs. The microbial load and diversity of bacteria can also impact BAs formation in food (Jairath et al. 2015). Moreover, the formation of BAs is contingent on the existence of microorganisms that produce amino acid decarboxylase and the accessibility of free amino acids, which serve as essential precursors (Ruiz-Capillas and Moral 2001).

Using specific starter cultures (Landete et al. 2007), lowering pH during fermentation (Gardini et al. 2016), reducing salt concentration, and adding food additives and preservatives are effective strategies for reducing BAs levels in fermented foods (Kongpun and Suwansakornkul 2000). Processing technologies such as high-pressure processing, irradiation, vacuum packaging, and smoking have also been shown to reduce BAs levels in food products (Naila et al. 2010).

Plant extracts have a significant impact on microbial growth and the formation of BAs. These substances can either inhibit or

promote microbial growth, depending on their composition. Plant extracts, such as thyme essential oil (EO), green tea extract, rosemary extracts, sage and tea have been successful in inhibiting the spoilage bacteria growth and reducing the accumulation of BAs in various food products (Bozkurt 2006; Cai et al. 2015; Huang et al. 2021; Lu et al. 2015; Özogul et al. 2015). Plant extracts and essential oils have also been found to decrease BAs formation, improving the safety of products (Wang et al. 2021).

Spices such as red pepper, ginger, garlic, clove, cinnamon, and others have been shown to influence the levels of BAs in food products. Red pepper's capsaicin can reduce BAs in sausages (Hirasa 1998), while cinnamon have inhibitory effects on BAs production (Shakila et al. 1996). These spices can enhance food safety by limiting the growth of BAs-producing bacteria and reducing amine levels in various dishes, including fermented sausages and anchovy products (Lu et al. 2015).

The aim of this review is to find out the effect of some food additives, plant extracts, and spice extracts on the formation of BAs in food products and especially meat products. Also, this review aims to shed light on the conditions that favor the formation of BAs, as well as the permissible limits for their presence in food products in general.

2. Classification of Biogenic Amines

BAs can be categorized according to their chemical structure (Fig. 1). Aromatic compounds, such as phenylethylamine and tyramine, aliphatic compounds, such as cadaverine, spermidine, spermine, and putrescine, and heterocyclic compounds, such as histamine and tryptamine, are among the classifications (Ruiz-Capillas and Jiménez-Colmenero 2005; Smith 1981). Furthermore, it is possible to categorize them based on the number of amine groups they contain, which includes monoamines (like tyramine and phenylethylamine), diamines (such as putrescine and cadaverine), and polyamines (including spermine and spermidine). According to certain researchers, polyamines such as spermine and spermidine should not be regarded as BAs because they are generated through a condensation process following decarboxylation (Linares et al. 2011).

BAs can also be grouped according to their origin or synthesis. BAs can be endogenous, produced by living organisms, or exogenous, produced by microbial activities in foods. Endogenous BAs are synthesized by living organisms during normal metabolism or in response to various stimuli, such as stress, infection, or injury. Exogenous BAs are produced by microbial activities in foods, such as fermentation or decay (Linares et al. 2011; Prester 2011; Santos 1996).

3. Influential Factors in the Formation of Bas

Several factors impact the formation of BAs, including composition of meat (such as protein, free amino acids, fat content, etc.), pH, and raw material source, and also, the existence of free amino acids (FAAs) is directly related to proteolysis since they provide a substrate for BAs production (Fig 2). A majority of the microorganisms present in meat during storage and treatment increase precursor concentrations through proteolytic reactions. Two key elements are required to form BAs in products: free amino acids, which serve as the basic precursors, and microorganisms that possess amino acid decarboxylases. The presence of a suitable environment that promotes the growth of these microorganisms is also essential (Ruiz-Capillas and Jiménez-Colmenero 2005).

Studies have shown that BAs can be affected by the type of meat source. A few studies have suggested that packed meat products containing only pork (e.g., cooked and cured ham) tend to have a lower level of histamine and tyramine formation than derivatives containing pork and beef (chorizo, salchichon, salami, or Bologna sausages), which tend to have higher levels of tyramine formation (Vidal et al. 1990; Wortberg and Woller 1982).

Temperature is another critical factor that can influence the production of BAs in food (Suzzi and Gardini 2003). Bacterial growth and enzyme activity are temperature-dependent, and 20°C to 37°C is the optimal temperature range for BAs formation (Karovičová and Kohajdová 2005). However, different bacterial species have different temperature requirements for BA

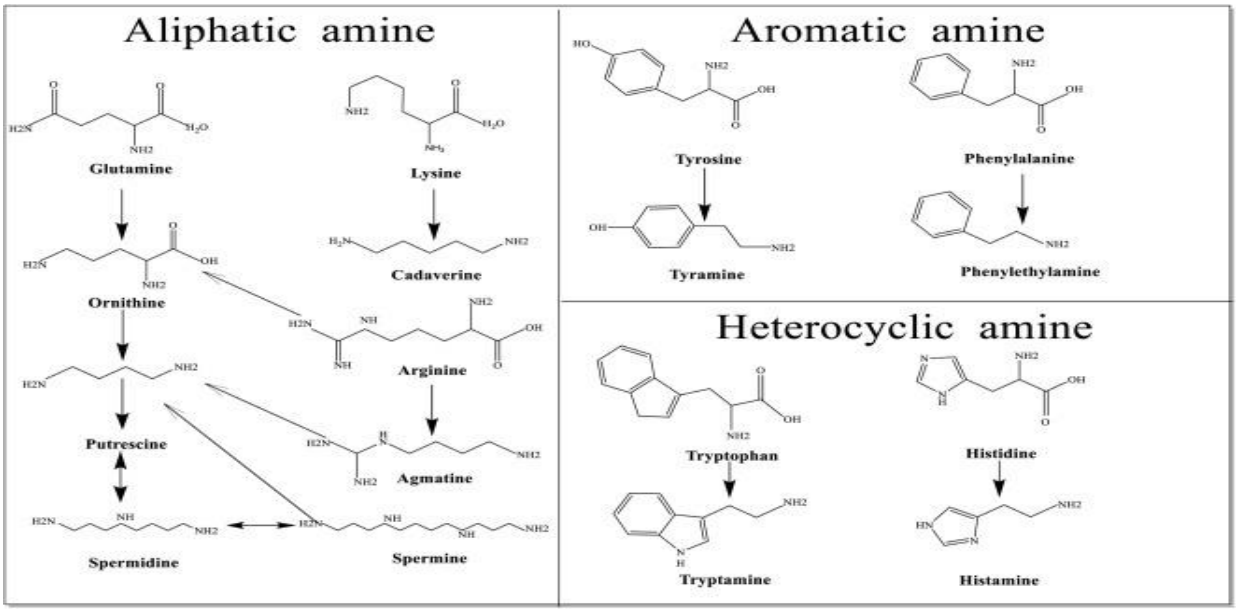

Figure 1. The precursors of BAs and their structures (Li and Lu 2020).

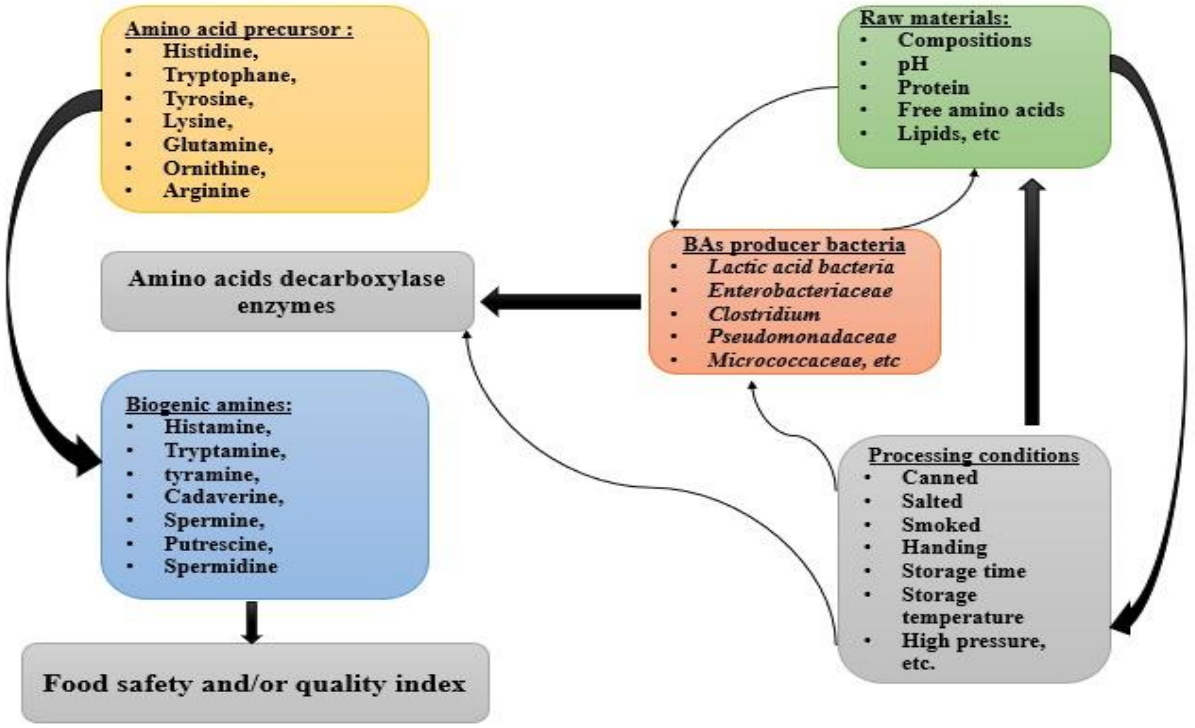

Figure 2. Effect of different factors on BAs formation (Ruiz-Capillas and Herrero 2019).

formation, and some bacteria can produce BAs at lower temperatures (Halász et al. 1994). Microbial development can also be slowed down by freezing fish between -18 and -30°C, but certain enzymatic and nonenzymatic processes and reactions may still occur (Karoui et al. 2017; Sampels 2015; Stonehouse and Evans 2015).

Due to the fact that they are amines precursors and serve as microbial development substrates, FAAs play a crucial part in the production of BAs in meat and meat products. Concentrations rise in tandem with proteolytic activities occurring during treatment and storage, primarily because of the numerous bacteria present. However, it has not been feasible to demonstrate a clear correlation between free amino acids concentrations and the production of the equivalent BAs in meat, such as fish (Eerola et al. 1996; Ruiz-Capillas and Moral 2001).

The pH balance has a substantial influence on the level of BAs due to two mechanisms that affect their production. Acidity inhibits the growth of microorganisms by affecting their growth (Jairath et al. 2015; Maijala et al. 1993). As a method of defense against acidic media, bacteria produce more decarboxylase when the pH drops because low pH encourages them to do so (Cid et al. 2008). BAs are produced as pH decreases due to increased decarboxylase activity. The decarboxylation of amino acids requires a pH above 4.5, and bacterial species such as Enterobacteriaceae and Pseudomonas can produce BAs at pH values between 5.0 to 9.0. In contrast, lactic acid bacteria require lower pH values for BA formation, between 4.5 to 6.5 (Halász et al. 1994). They underscored that inducing a swift and substantial drop in the pH of sausages can be an effective measure to inhibit the proliferation of amine-positive microorganisms, particularly the Enterobacteriaceae family, thereby safeguarding meat products from the formation of BAs (Bover-Cid et al. 2006).

4. Plant and Spices Extracts to Control Biogenic Amines

Plant and spices extracts have a significant impact on microbial growth and the formation of biomolecules. They can inhibit or promote microbial growth, depending on the specific compounds they contain. Additionally, they play a role in providing essential amino acids and stimulating their production. Understanding these effects is vital for optimizing nutrition strategies and has applications in various fields. Some reduction techniques of BAs are explained in the titles below.

4.1. Plant Extracts and Bioactive Compounds

Özogul et al. (2015) conducted a study to examine the effect of various levels of carvacrol on the BAs production by different pathogenic bacteria. The study encompassed a range of bacteria, including *Pseudomonas aeruginosa*, *Salmonella paratyphi A*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *E. faecalis*, *E. coli*, *A. hydrophila*, and *Listeria monocytogenes*. The findings revealed that all the bacteria tested had the ability to decarboxylate multiple amino acids, and the concentration of carvacrol, as well as the bacterial species, influenced the reduction in BAs formation.

Also, the use of green tea extract in Turkish dry-fermented sausage resulted in a decrease in the levels of tyramine, putrescine, and histamine as compared to the control (Bozkurt 2006). The impact of thyme essential oils on the accumulation of biogenic BAs was investigated in traditional horse meat sausages in Xinjiang. The inclusion of thyme essential oil resulted in a reduction in BAs levels (specifically, tyramine, putrescine, cadaverine, and histamine) (Křížek et al. 2018). When 5% garlic extract was added to fermented anchovies, the quantity of BAs was decreased by around 8.7% (Mah et al. 2009).

Recently, the growing demand for natural products and the shift away from synthetic additives in the food industry has led to an upsurge in the use of essential oils as natural flavor and aroma enhancers. Essential oils such as clove, which contain eugenol, possess antibacterial properties that can delay the accumulation of BAs in mackerel caused by *E. aerogenes* (Nandanie and Sakaguchi 1993). Additionally, the utilization of a blend of thymol, lemon extract, and grapefruit seed extract in conjunction with modified atmosphere packaging (MAP) successfully prevented the presence of amines in blue fish burgers (Del Nobile et al. 2009).

Furthermore, thyme essential oil decreased the overall bacterial count and particularly the Gram-negative Enterobacteriaceae family (Huang et al. 2021). Plant extracts were successful in stopping the proliferation of spoilage bacteria and also hindered the buildup of BAs (Cai et al. 2015; Lu et al. 2015). The level of BAs reduction was dependent on both the concentration of the essential oil and the type of bacteria present (Özogul et al. 2015). The primary bioactive antimicrobial agents present in thyme extracts that were effective in preventing BAs formation in sausages were carvacrol and thymol (Burt 2004). The use of rosemary extracts and sage tea was found to significantly inhibit histamine formation in sardines' muscles (Özogul et al. 2011). In a previous study, it was observed that the formation of BAs was inhibited by the antibacterial activity of plant extracts. For example, tea polyphenols were effective in reducing biosynthesis by inhibiting the growth of bacteria responsible for biosynthetic amine production (Fan et al. 2015).

4.2. Spices Extracts

Spices are aromatic plant substances that are used to flavor and color foods. They have been found to have an impact on the BAs accumulation in food. A study by Komprda et al. (2004) findings indicated that the significant red pepper content, in combination with the use of starter cultures, led to a reduced BAs content in dry fermented sausages. Red pepper, owing to its capsaicin content, is recognized for its ability to inhibit the proliferation of specific bacterial strains (Hirasa 1998). The impact of different spices, including cinnamon, clove, ginger, red pepper, on diminishing the levels of BAs in myeolchi-jeot, a traditional Korean salted and fermented anchovy preparation, was examined. Ginger extract was observed to decrease the presence of putrescine, while red pepper extract was effective in lowering cadaverine accumulation (Mah et al. 2009). Other studies have also showed that cinnamon and clove can reduce production histamine by *M. morganii* by up to 95% (Shakila et al. 1996). The inhibition of tyramine formation was observed with the addition of spice extracts such as cinnamon, clove, and anise (Shakila et al. 1996). A study showed Red drum filets (*Sciaenops ocellatus*) that were treated with 4 ml L^{-1} of spearmint, clove, and cumin oils had a low content of BAs, particularly histamine, putrescine, and cadaverine (Cai et al. 2015). A study was conducted to investigate the impact of ginger, cinnamon, and anise essential oils on the level of BAs in fermented sausage. The findings showed that the addition of 0.3% ginger, 0.3% anise, and 0.3% cinnamon essential oils resulted in reductions of total BAs by 28.58%, 34.87%, and 21.63%, respectively. These results suggest that tea polyphenol and plant essential oils, particularly anise essential oil, can be utilized to decrease the BAs formation and inhibit the growth of spoilage bacteria in fermented sausage, which can ultimately enhance its safety (Wang et al. 2021). In addition, plant extracts such as cinnamon, cloves, ginger, and fennel were found to be effective in inhibiting the growth of BAs-producing bacteria, thereby reducing levels of BAs in fermented sausages (Lu et al. 2015).

5. Conclusion

In conclusion, plant extracts have a significant impact on microbial growth and BAs accumulation in food. They can either promote or inhibit microbial growth depending on their composition and provide essential amino acids crucial for overall health and protein synthesis. Determination of microbiological compositions and amino acid contents in the samples is a critical step in understanding the formation of BAs. Reducing BAs in food is essential for food safety and quality. New extraction techniques and reducing methods to obtain high effective active ingredients from plant materials such as thyme, clove, anise, green tea and spices should be studied further in the future.

Acknowledgment

The authors thank to Akdeniz University, The Scientific Research Projects Coordination Unit (FBA-2023-6206) for financial support of this research project.

References

Bardócz S (1995) Polyamines in food and their consequences for food quality and human health. Trends in Food Science & Technology 6: 341-346.

Bover-Cid S, Miguelez-Arrizado MJ, Moratalla LLL, Carou MCV (2006) Freezing of meat raw materials affects tyramine and diamine accumulation in spontaneously fermented sausages. Meat Science 72: 62-68.

Bozkurt H (2006) Utilization of natural antioxidants: Green tea extract and Thymbra spicata oil in Turkish dry-fermented sausage. Meat Science 73: 442-450.

Burt S (2004) Essential oils: their antibacterial properties and potential applications in foods—a review. International Journal of Food Microbiology 94: 223-253.

Cai L, Cao A, Li Y, Song Z, Leng L, Li J (2015) The effects of essential oil treatment on the biogenic amines inhibition and quality preservation of red drum (*Sciaenops ocellatus*) fillets. Food Control 56: 1-8.

Cid SB, Miguélez-Arrizado MJ, Becker B, Holzapfel WH, Vidal-Carou MC (2008) Amino acid decarboxylation by Lactobacillus curvatus CTC273 affected by the pH and glucose availability. Food microbiology 25: 269-277.

Del Nobile MA, Corbo MR, Speranza B, Sinigaglia M, Conte A, Caroprese M (2009) Combined effect of MAP and active compounds on fresh blue fish burger. International Journal of Food Microbiology 135: 281-287.

Eerola S, Maijala R, SAGUÉS AXR, Salminen M, Hirvi T (1996) Biogenic amines in dry sausages as affected by starter culture and contaminant amine-positive Lactobacillus. Journal of Food Science 61: 1243-1246.

Fan W, Yi Y, Zhang Y, Diao P (2015) Effect of an antioxidant from bamboo leaves combined with tea polyphenol on biogenic amine accumulation and lipid oxidation in pork sausages. Food Science and Biotechnology 24: 421-426.

Gardini F, Özogul Y, Suzzi G, Tabanelli G, Özogul F (2016) Technological factors affecting biogenic amine content in foods: A review. Frontiers in Microbiology 7: 1218.

Halász A, Barath A, Simon-Sarkadi L, Holzapfel W (1994) Biogenic amines and their production by microorganisms in food. Trends in food science & technology 5: 42-49.

Hirasa K (1998) Antimicrobial and antioxidant properties of spices. Spice Science and Technology.

Huang L, Wang Y, Li R, Wang Q, Dong J, Wang J, Lu S (2021) Thyme essential oil and sausage diameter effects on biogenic amine formation and microbiological load in smoked horse meat sausage. Food Bioscience 40:100885.

Jairath G, Singh PK, Dabur RS, Rani M, Chaudhari M (2015) Biogenic amines in meat and meat products and its public health significance: A review. Journal of Food Science and Technology 52: 6835-6846.

Karoui R, Hassoun A, Ethuin P (2017) Front face fluorescence spectroscopy enables rapid differentiation of fresh and frozen-thawed sea bass (*Dicentrarchus labrax*) fillets. Journal of Food Engineering 202: 89-98.

Karovičová J, Kohajdová Z (2005) Biogenic amines in food. Chemical papers 59: 70-79.

Komprda T, Smělá D, Pechová P, Kalhotka L, Štencl J, Klejdus B (2004) Effect of starter culture, spice mix and storage time and temperature on biogenic amine content of dry fermented sausages. Meat Science 67: 607-616.

Kongpun O, Suwansakornkul P (2000) Histamine formation during salting of Spanish mackerel (Scomberomorus commerson). Journal of Aquatic Food Product Technology 9: 21-30.

Křížek M, Dadáková E, Vácha F, Pelikánová T, Matějková K (2018). The effects of two essential oil and UV-light irradiation treatments on the formation of biogenic amines in vacuum packed fillets of carp (Cyprinus carpio). LWT, 95, 268-273.

Landete J, Ferrer S, Pardo I (2007) Biogenic amine production by lactic acid bacteria, acetic bacteria and yeast isolated from wine. Food Control 18: 1569-1574.

Li B, Lu S (2020) The importance of amine-degrading enzymes on the biogenic amine degradation in fermented foods: A review. Process Biochemistry 99: 331-339.

Linares DM, Martín M, Ladero V, Alvarez MA, Fernández M (2011) Biogenic amines in dairy products. Critical Reviews in Food Science and Nutrition51: 691-703.

Lu S, Ji H, Wang Q, Li B, Li K, Xu C, Jiang C (2015) The effects of starter cultures and plant extracts on the biogenic amine accumulation in traditional Chinese smoked horsemeat sausages. Food Control 50: 869-875.

Mah J-H, Kim YJ, Hwang H-J (2009) Inhibitory effects of garlic and other spices on biogenic amine production in Myeolchi-jeot, Korean salted and fermented anchovy product. Food Control 20: 449-454.

Maijala RL, Eerola SH, Aho MA, Hirn JA (1993) The effect of GDL-induced pH decrease on the formation of biogenic amines in meat. Journal of Food Protection 56: 125-129.

Naila A, Flint S, Fletcher G, Bremer P, Meerdink G (2010) Control of biogenic amines in food—existing and emerging approaches. Journal of Food Science 75: R139-R150.

Nandanie CW, Sakaguchi M (1993) Combined effects of cloves with potassium sorbate and sodium benzoate on the growth and biogenic amine production of Enterobacter aerogenes. Bioscience, Biotechnology, and Biochemistry 57: 678-679.

Özogul F, Kuley E, Kenar M (2011) Effects of rosemary and sage tea extract on biogenic amines formation of sardine (Sardina pilchardus) fillets. International Journal of Food Science & Technology 46: 761-766.

Özogul F, Kacar Ç, Hamed I (2015) Inhibition effects of carvacrol on biogenic amines formation by common food-borne pathogens in histidine decarboxylase broth. LWT-Food Science and Technology 64: 50-55.

Premont RT, Gainetdinov RR, Caron MG (2001) Following the trace of elusive amines. Proceedings of the National Academy of Sciences 98: 9474-9475.

Prester L (2011) Biogenic amines in fish, fish products and shellfish: a review. Food Additives & Contaminants: Part A 28: 1547-1560.

Ruiz-Capillas C, Moral A (2001) Sensory and Nutritive Qualities of Food-Production of Biogenic Amines and Their Potential Use as Quality Control Indices for Hake (Merluccius merluccius, L.) Stored in Ice. Journal of Food Science 66: 1030-1032.

Ruiz-Capillas C, Jiménez-Colmenero F (2005) Biogenic amines in meat and meat products. Critical Reviews in food Scince and Nutrition 44: 489-599.

Ruiz-Capillas C, Herrero AM (2019) Impact of biogenic amines on food quality and safety. Foods 8: 62.

Sampels S (2015) The effects of storage and preservation technologies on the quality of fish products: A review. Journal of Food Processing and Preservation 39: 1206-1215.

Santos MS (1996) Biogenic amines: their importance in foods. International Journal of Food Microbiology 29: 213-231.

Shakila RJ, Vasundhara T, Vijaya Rao D (1996) Inhibitory effect of spices on in vitro histamine production and histidine decarboxylase activity of Morganella morganii and on the biogenic amine formation in mackerel stored at 30 C. Zeitschrift für Lebensmittel-Untersuchung und Forschung 203: 71-76.

Smith T (1981) Amines in food. Food Chemistry 6: 169-200.

Stonehouse G, Evans J (2015) The use of supercooling for fresh foods: A review. Journal of Food Engineering 148: 74-79.

Suzzi G, Gardini F (2003) Biogenic amines in dry fermented sausages: a review. International Journal of Food Microbiology 88: 41-54.

Vidal M, Izquierdo M, Martín M, Mariné A (1990) Histamina y tiramina en derivados cárnicos. Revista de Agroquimica Y Tecnologia de Alimentos 30: 102-108.

Wang J, Zhang X, Li X, Yu Z, Hu J, Zhu Y (2021) Effects of plant extracts on biogenic amine accumulation, bacterial abundance and diversity in fermented sausage. CyTA-Journal of Food 19: 771-781.

Wójcik W, Łukasiewicz M, Puppel K (2021) Biogenic amines: formation, action and toxicity–a review. Journal of the Science of Food and Agriculture 101: 2634-2640.

Wortberg W, Woller R (1982) Quality and freshness of meat and meat products as related to their content of biogenic amines.[According to a lecture]. Fleischwirtschaft.