

Monitoring the content of biogenic amines in red wines subjected to malolactic fermentation

Ionel Popescu-Mitroi*¹, Dana Gina Radu¹, Claudia Mureşan¹, Andreea Lupitu², Dana Copolovici¹ and Lucian Copolovici^{1,2}

¹“Aurel Vlaicu” University of Arad, Faculty of Food Engineering, Tourism and Environmental Protection, Arad 310330, Romania

²“Aurel Vlaicu” University of Arad, Institute of Research Development Innovation in Technical and Natural Sciences, Arad 310330, Romania

*Corresponding author: ionel89@hotmail.com

Abstract

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Biogenic amines are produced by yeast and lactic bacteria during alcohol and malolactic fermentation processes by the decarboxylation of amino acids. Wines contain different quantities of biogenic amines, depending on the concentration of free amino acids in the wine, the type of bacteria present, grape variety and vineyard, temperature, pH, and hygiene conditions during the technological process. In this paper, biogenic amines (tyramine, histamine, cadaverine and putrescine) were determined for 5 types of dry red wines from the 2017 Miniş vineyard harvest (Arad County, Romania), 2 of the wines with malolactic fermentation in progress (Merlot, Fetească neagră), and 3 of the wines with finalised malolactic fermentation (Cabernet Sauvignon, Pinot noir, and Cadarcă). The determination of biogenic amines was performed by high-performance liquid chromatography (HPLC) using the orthophthaldialdehyde/2-mercaptoethanol (OPA/MCE) derivatisation method.

The results obtained show that the wine samples with non-finalised malolactic fermentation do not contain putrescine and cadaverine, and the contents of tyramine and histamine are low. In contrast, wine samples with finalised malolactic fermentation show much higher concentrations of biogenic amines, the content in tyramine reaching 0.97 ppm. In all samples, tyramine contents exceed histamine levels. The descending order of the biogenic amine concentrations found in the red wines analysed is tyramine > histamine > cadaverine > putrescine.

Keywords: red wines; malolactic fermentation; biogenic amines; HPLC; OPA derivatization

Introduction

The monitoring of biogenic amines in malolactically fermented wines is a relevant study from the point of view of consumer protection and safety.

Biogenic amines are low molecular weight organic bases formed by biological processes in all living organisms. Biogenic amines are formed from amino acids under the action of decarboxylase enzymes present in plant and animal tis-

sues, including those secreted by microorganisms (yeasts, but mainly bacteria) (Guerrini et al., 2002).

Some authors reported that amines were formed at the end of the alcoholic fermentation, while, most authors underlined an increased amine production at the end of malolactic fermentation; finally, other studies found no significant increase in amine production at the end of alcoholic fermentation or malolactic fermentation (Restuccia et al., 2018; Guo et al., 2015).

The abundance of amines after malolactic fermentation is strictly related to the microflora, but also to the amino acid concentration of wines after alcoholic fermentation. The latter depend on the composition of must or wine, which in turn depends on the grape variety, on the one hand, and the metabolism of yeasts, on the other hand (Souffleros et al., 1998).

As lactic bacteria develop in wines after yeasts, the yeasts have already changed the composition of the original must by using some amino acids and the secretion of others during alcoholic fermentation. Moreover, if the wines are kept in contact with the yeasts, lactic bacteria will have a substrate richer in amino acids, which they subject to decarboxylation. This explains the high level of amines in some wines stored on the yeast sediment (Coton et al., 1998; Rollan et al., 1995). Another reason is the variable decarboxylation capacity of lactic bacteria, especially dependent on pH. The higher the pH, the more biogenic amines are produced, as confirmed by our study. White wines, which are generally more acidic, have lower concentrations in biogenic amines compared to red wines (Gerbaux & Monany, 2000). The Gerbaux study (2000) showed that the most active growth phase is between the 4th and the 8th month after the end of the malolactic fermentation, which shows that the administration of sulphur dioxide is not capable of stopping all the bacterial biochemical reactions (Lonvaud-Funel, 2001).

For a long time, oenologists considered that only the lactic bacteria belonging to the genus *Pediococcus* were responsible for histamine production. However, lately, *Oenococcus oeni* strains capable of decarboxylating histidine have also been detected (Lonvaud-Funel and Joyeux, 1994; Rosi et al., 2009).

For a particular microorganism, histamine production is increased under adverse growth conditions, such as the lack of fermentable substances such as sugars and malic acid or the presence of ethyl alcohol. This suggests that the decarboxylation of histidine can be used as an additional mechanism for generating energy in cells that are deprived of other substrates. This explains why histamine concentration increases even after malolactic fermentation, when most energy sources have been metabolised. The phenomenon is amplified if the maceration or storage of wine on the yeast is prolonged, as more and more histidine is available for decarboxylation (Lonvaud-Funel, 2001).

The biogenic amines content of wines is very variable, with some samples even having tens of mg/l before bottling (Carrie & Fuster, 2002).

Histamine and tyramine are potent allergens, causing cramps, diarrhoea, headaches, vomiting, hives, therefore they need to be monitored along with other biogenic amines that worsen the sensory characteristics of red wines (putres-

cine and cadaverine) where the contents tend to increase, especially during malolactic fermentation, but also during aging.

The most frequently reported technique for biogenic amines analysis in wine, as well as in other food samples (Tašev et al., 2017) is liquid chromatography (LC) coupled to UV-Vis or fluorimetric detection (Sentellas et al., 2016), with pre- or post-column chemical derivatization using different derivatization reagents: dansyl chloride (Dns-Cl) (Tašev et al., 2016; Manetta et al., 2016), ophthalaldehyde (OPA) (Arrieta and Prats-Moya, 2012; Kelly et al., 2010; Vidal-Carou et al., 2003), dansyl chloride (Dabs-Cl) (Romero et al., 2000), benzoyl chloride (Bnz-Cl) (Ozdestan & Üren, 2009), fluorenylmethylchloroformate (FMOC) (Bauza et al., 1995), 1,2-naphthoquinone-4-sulphonate (NQS) (Hlabangana et al., 2006), and 6-aminoquinolyl-N-hydroxysuccinimidyl carbamate (AQC) (Hernández-Orte et al., 2006). In addition, biogenic amines can be determined by capillary electrophoresis (CE) (Herrero et al., 2014), gas chromatography (GC) (Fernandes and Ferreira, 2000), and enzymatic methods (Lange & Wittmann, 2002).

In this paper, the determination of biogenic amines was made for 5 types of wine from the 2017 Miniș vineyard harvest (Arad County, Romania), 2 of the wines with the malolactic fermentation in progress (Merlot, Fetească neagră), and 3 of the wines with finalised malolactic fermentation (Cabernet Sauvignon, Pinot noir and Cadarcă).

Material and Methods

The determination of biogenic amines was performed by high-performance liquid chromatography (HPLC) using the orthophthalaldehyde/2-mercaptoethanol (OPA/MCE) derivatisation method, described by other authors as well (Kalkan et al., 2006; Marques et al., 2007; Pereira Monteiro & Bertrand, 1994; Pripis-Nicolau et al., 2001).

Derivatisation agents (orthophthalaldehyde, 2-mercaptoethanol) and pure standards of the following biogenic amines, purchased from Sigma Aldrich Germany were used: histamine (PubChem CID: 774), tyramine (PubChem CID: 5610), cadaverine (PubChem CID: 273) and putrescine (PubChem CID: 1045).

Wine processing

The grapes were harvested at relative contents in sugars above 220 g/l, thereby explaining the high alcohol concentrations of the obtained wines. Sulphitation was carried out with aqueous solutions of 5% sulphur dioxide after crushing and destemming, up to 30 mg/l. The maceration-fermentation of wines took place in ROTO tanks under controlled

conditions (inoculation with FERMACTIVE D containing *Saccharomyces oviformis* at a dose of 20 g/hl) at 26–28°C, applying a 15-minute spin cycle every 3 hours. Phase separation (free run grape juice/marc) took place after 48 hours of maceration-fermentation at density 1013 kg/m³. After combining the free run grape juice with the crusher must, the fermentation continued for 15 days. Malolactic fermentation was carried out under controlled conditions at 22°C (inoculation with INOFLORE R containing *Oenococcus oeni* at 1 g/hl). The wines were analysed at an interphase point, at 10 days after the start of the malolactic fermentation.

Preparation of biogenic amines standards

Pure standards of tyramine, histamine, cadaverine and putrescine were used in this paper, purchased from Sigma Aldrich Germany. Standard solutions of biogenic amines were prepared by dissolving 2 mg of pure standard in 2 ml of 0.1 M HCl solution. To prepare the mixture of standards, 0.5 ml of each standard was taken, and after homogenisation the pH was adjusted to 9 with 0.1 M HCl, then the contents was diluted and brought up to the mark with distilled water in a 25 ml flask.

Preparation of derivatisation reagent

We used the method proposed by Uren and Karababa (2003) for the preparation of the derivatisation solutions. Initially, the borate buffer solution was prepared by dissolving 2.47 g of boric acid in 20 ml of distilled water. The pH was adjusted to 9 with 1M NaOH, then the contents were diluted and brought up to the mark with distilled water in a 100 mL flask. Next, 200 mg of o-phthaldialdehyde was dissolved in 9 ml of methanol. We added 1 ml of borate buffer solution and 160 µl of 2-mercaptoethanol (under the mark). The obtained solution (OPA reagent) was stored in the refrigerator until use.

Derivatization of standards

To 800 µL of methanol, 50 µL of standard mixture of biogenic amines and 950 µL of distilled water were added. Following the addition of 200 µL of OPA reagent, the mixture was filtered through a 0.20-mm pore size filter and 1 mL of filtrate were immediately injected on the column.

Derivatization of samples

Samples were derivatized as follows: the pH of 25.0 mL of wine sample was adjusted to 9.0 with 1M NaOH solution and diluted to 30.0 mL with distilled water. To 200 µL of wine sample, 800 µL of methanol and 800 µL of distilled water were added. After the addition of 200 µL of OPA reagent, the mixture was filtered through a 0.20 mm pore size filter and 1 mL of the solution were immediately injected on the column.

Chromatographic analysis

Cadaverine, histamine, putrescine and tyramine were determined by using an UHPLC method. Briefly, a high performance liquid chromatograph (Nexera X2, Shimadzu, Tokyo, Japan) equipped with a diode array detector (M30A, Shimadzu, Tokyo, Japan) and a Nucleosil 100-3-C18 reversed-phase column (4.0 mm i.d. × 125 mm column length, 3 µm particle size, Macherey-Nagel GmbH, Duren, Germany) was used. The column temperature was maintained at 20°C and the flow rate at 1 ml min⁻¹. The solvents used for the chromatographic elution consisted of ultra-pure water with 0.1% TFA (A) and acetonitrile (B). The chromatographic elution program used was as follows: 95% A and 5% B that was changed linear gradient to 40% B for 3 min, followed by a linear gradient to 85% B in 20 min, followed by 90% B in 23 min, and then 50% B in 28 min. Thereafter, the eluent was changed to the initial composition of 95% A and 5% B linear gradient for 5 min. The measurements have been done between 200–400 nm wavelengths.

Results and Discussion

The wines analysed at the start of the malolactic fermentation have generous concentrations of alcohol (12.3–14.3% vol.), do not exhibit organoleptic and microbiological defects, having a moderate sulphitation (total SO₂: 22–29 mg/l), allowing malolactic fermentation to occur under normal conditions without deviation to fermentation accidents, disease or defects. The total acidity of wines ranges from 3.52 g/l in Cabernet Sauvignon to 4.31 g/l in Cadarcă, being closely correlated with malic acid concentrations and pH values (Table 1).

Table 1. Physical-chemical characteristics of wines at the start of malolactic fermentation

Types of wines	Alcohol, % vol.	Total acidity, g/l	Malic acid, g/l	pH	Total SO ₂ , mg/l
1. Cabernet Sauvignon	13.7	3.52	1.1	3.64	22
2. Pinot noir	13.1	3.57	1.1	3.63	23
3. Merlot	14.3	4.16	1.2	3.39	25
4. Fetească neagră	14.1	4.21	1.2	3.38	28
5. Cadarcă	12.3	4.31	1.3	3.27	29

By paper chromatography, separated organic acids appear in the form of yellow spots on a blue background with the following position: tartaric acid close to the starting line, malic acid in the centre, lactic acid at the top (Figure 1).

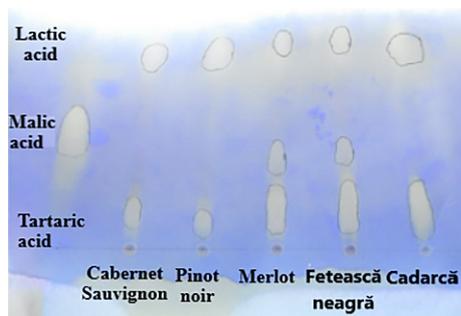


Fig. 1. Separation of organic acids from wine by means of Michaud's paper chromatography (10 days after the start of the malolactic fermentation)

Figure 1 shows that 10 days after the start of the malolactic fermentation, the Cabernet Sauvignon, Pinot noir and Cadarcă wines have completed this process, while the Merlot and Fetească neagră wines exhibit malolactic fermentation in progress. This “non-synchronisation” is normal and is due to different concentrations of substrate (malic acid) that is degraded by malolactic fermentation. Also, physiological factors influence this “non-synchronisation” because the Merlot and Fetească neagră wines have higher alcohol concentrations (14.1–14.3% vol) that inhibit the activity of lactic bacteria. The other parameters (temperature, sulphur dioxide, lactic acid bacteria density) are not able to modify the dynamics of malolactic fermentation since the wines were kept at the same temperature (22°C), were sulphitated with similar sulphur dioxide doses (22–29 mg/l total SO₂)

and were subjected to the same inoculation protocol with the same lactic acid preparation (NOFLORE R).

UHPLC analysis

In the wine samples it has been found four different biogenic amines (tyramine, histamine, putrescine and cadaverine). The typical chromatogram which has shown the separation of all four amines is presented in Figure 2. For all biogenic amines has been employed calibration curves and different analytic figures have been calculated (Table 2).

Table 3 shows the concentrations of biogenic amines (tyramine, histamine, putrescine and cadaverine) determined for 5 dry red wines (Cabernet Sauvignon, Pinot noir, Merlot, Fetească neagră, Cadarcă). Three sets of determinations were performed for each sample and the accuracy of the results included in the table takes into account the standard deviation.

The data presented in Table 3 in connection with figure a show that wine samples with non-finalised malolactic fermentation (Merlot and Fetească neagră) do not contain putrescine and cadaverine, and the contents of tyramine and histamine are modest, the average being between 0.78–0.84 ppm for tyramine and 0.04–0.38 ppm for histamine. These tyramine and histamine contents are due to yeasts, which act during the alcoholic fermentation and which have a rather complex enzyme content also including decarboxylating enzymes involved in the decarboxylation of amino acids present in the must (tyrosine and histidine).

The data presented in Table 3 show that wine samples with finalised malolactic fermentation (Cabernet Sauvignon, Pinot noir, Cadarcă) have much more consistent concentrations of biogenic amines, the average content in tyramine being 0.94 ppm. These increases in the concentration of tyramine during malolactic fermentation are certainly due to malolactic bacteria, which secrete tyrosine

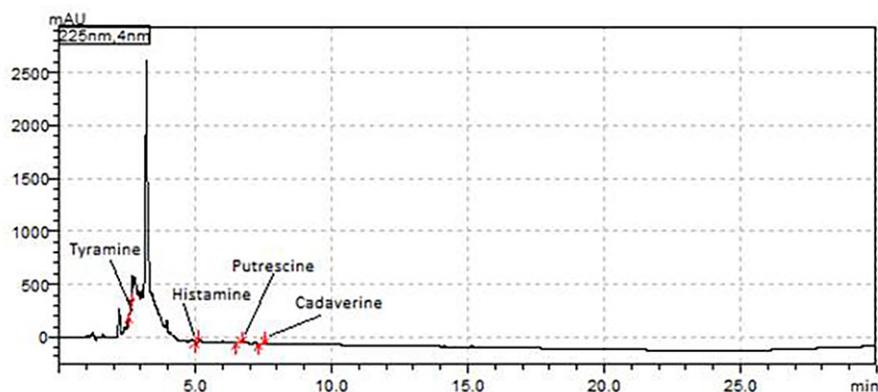


Fig. 2. Chromatogram of sample Pinot noir of biogenic amines

Table 2. Analytical figures for all biogenic amines which have been found in the wine samples

Analyte	Calibration curve equation	Correlation coefficient	Detection limit, $\mu\text{g L}^{-1}$	Quantification limit, $\mu\text{g L}^{-1}$
1. Tyramine	$y = 97917x + 10106$	0.9995	3.3	10.1
2. Histamine	$y = 84946x - 17000$	0.9970	1.1	3.2
3. Putrescine	$y = 30308x + 47700$	0.9990	7.7	23.2
4. Cadaverine	$y = 4827x - 5620$	0.9955	6.4	19.4

Table 3. Concentration of biogenic amines in samples of wines

Time of retention, min	2.68	5.07	6.60	7.43
Biogenic amines, $\mu\text{g/L}$ samples	Tyramine	Histamine	Putrescine	Cadaverine
1. Cabernet Sauvignon	949.70±22.15	60.7±12.80	1.55±0.01	10.8±0.1
2. Pinot noir	561.15±1.1	41.5±0.9	2.66±0.02	12.9±0.1
3. Merlot	841.75±98.05	389.95±78.15	n.d.	n.d.
4. Fetească neagră	789.5±109.8	42.45±2.65	n.d.	n.d.
5. Cadarcă	786.35±47.85	353.72±63.78	n.d.	n.d.

n.d – not detected

decarboxylase (TDC), which converts tyrosine to tyramine. In the Cabernet Sauvignon and Pinot noir wine samples, the putrescin and cadaverine biogenic amines are also present in reduced quantities (0.001–0.002 ppm putrescine and 0.01 ppm cadaverine). Fortunately, these quantities are not able to worsen the organoleptic (taste, odour) characteristics of the samples. It is worth noting that the Cadarcă wine sample, which has completed malolactic fermentation, contains no cadaverine and putrescine, and the contents of tyramine and histamine are not at all worrying (tyramine 0.78 ppm and histamine 0.35 ppm). Of all the wine samples analysed, this wine sample seems to have evolved best during the malolactic fermentation. This should be also correlated with the physical-chemical characteristics of the wine: moderate alcohol concentration (12.3%), pH of 3.27, total SO_2 of 29 mg/l, all these features being conducive to the development of malolactic bacteria selected from the preparation INOFLORE R and the development of malolactic fermentation in good conditions. Of all analysed wine samples, the Cadarcă sample had the highest total acidity and the highest malic acid content; however, these conditions did not adversely affect the development of the malolactic fermentation, as expected. On the other hand, there is a correlation between pH and the quantity of biogenic amines in wines: the Cadarcă wine sample has the lowest pH and the quantity of biogenic amines is reduced; the Cabernet Sauvignon wine sample has the highest pH and the highest quantity of biogenic amines. It seems that the malolactic fermentation was rather encumbered by the

high alcohol content in the Merlot and Fetească neagră wine samples (14.1–14.3%).

Conclusions

The determination of biogenic amines in wine is an important study from the point of view of consumer protection. Based on the results obtained, we can draw the following conclusions:

- the results of this study show that increases in biogenic amine content occur especially during malolactic fermentation. The results show that wine samples with non-finalised malolactic fermentation do not contain putrescine and cadaverine, and the levels of tyramine and histamine are lower. Conversely, wine samples with finalised malolactic fermentation have much more consistent concentrations of biogenic amines, the content in tyramine reaching 0.97 ppm.
- in all samples, tyramine content exceeds histamine levels, although other studies show that histamine is predominant in red wines. The decreasing order of biogenic amine concentrations found in the red wines analysed is tyramine > histamine > cadaverine > putrescine.
- the higher the pH, the higher the quantity of biogenic amines; the Cabernet Sauvignon sample has the highest pH and is the richest in biogenic amines.
- cadaverine and putrescine were not detected in 3 of the 5 analysed wines; in wines where there are quantities of

putrescine and cadaverine, the production of histamine is slightly lower.

- the variable quantities of amines in the five analysed wines can be explained both by the different dynamics of the malolactic fermentation, influenced by the alcohol concentration and pH, but also by the different composition in free amino acids (the quantities of tyrosine in wines are superior to those of histidine)

Some countries have established recommendations for histamine (2–10 mg/l), levels of biogenic amines below 10 mg/ml seem to be acceptable. For example, Switzerland allows 10 mg/l, Germany 2 mg/l, the Netherlands 3 mg/l, Finland and Belgium 5 mg/l, and France 8 mg/l. In the future, it would be advisable for Romania as well that the content of biogenic amines in wines, in general, and that of histamine, in particular, be regulated by law, in order to obtain quality wines that meet consumer innocuity requirements.

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References

- Arrieta, M. P. & Prats-Moya, M. S. (2012). Free amino acids and biogenic amines in Alicante Monastrell wines. *Food Chem.*, 135, 1511-1519.
- Bauza, T., Blaise, A., Daumas, F. & Cabanis, J. C. (1995). Determination of biogenic amines and their precursor amino acids in wines of the Vallee du Rhone by high-performance liquid chromatography with precolumn derivatization and fluorimetric detection. *J. Chromatogr. A.*, 707, 373-379.
- Carrie', C. & Fuster, A. (2002). Comparison of commercial preparations of lactic acid bacteria with direct inoculation in order to manage the malolactic fermentation at Merlot. (Comparasion de préparations commerciales des bactéries lactiques à ensenencements direct en vue de gérer la fermentation malolactique du Merlot.) *Revue des Oenologues*, 103, 16-18.
- Coton, E., Rollan, G. C., Bertrand, A. & Lonvaud-Funel, A. (1998). Histamine – producing lactic acid bacteria in wines; early detection, frequency and distribution. *Am. J. Enol. Vitic.*, 49, 199-204.
- Fernandes, J. O. & Ferreira, M. A. (2000). Combined ion-pair extraction and gas chromatography-mass spectrometry for the simultaneous determination of diamines, polyamines and aromatic amines in port wine and grape juice. *J. Chromatogr. A.*, 886, 183-195.
- Gerbaux, V. & Monany, C. (2000). Biogenic amines in Bourgogne wines Content, origin and control in wines. (Les amines biogenes dans le vins de Bourgogne Teneurs, origine et maîtrise dans le vins.) *Revue Francaise d'Oenologie*, 25-28.
- Guerrini, S., Mangani, S., Granchi, L. & Vincenzi, M. (2002). Biogenic amine production by *Oenococcus oeni*. *Current Microbiology*, 44, 374-378.
- Guo, Y. Y., Yang, Y. P., Peng, Q. & Han, Y. (2015). Biogenic amines in wine. A review. *Int. J. Food Sci. Technol.*, 50, 1523-1532.
- Hernández-Orte, P., Peña-Gallego, A., Ibarz, M. J., Cacho, J. & Ferreira, V. (2006). Determination of the biogenic amines in musts and wines before and after malolactic fermentation using 6-aminoquinoly1-N hydroxysuccinimidyl carbamate as the derivatizing agent. *J. Chromatogr. A.*, 1129, 160-164.
- Herrero, M., García-Cañas, V., Simo, C. & Cifuentes, A. (2014). Recent advances in the application of capillary electrophoresis methods for food analysis and foodomics. *Electrophoresis*, 35, 147-169.
- Hlabangana, L., Hernandez-Cassou, S. & Saurina, J. (2006). Determination of biogenic amines in wines by ion-pair liquid chromatography and post-column derivatization with 1,2-naphthoquinone-4-sulphonate. *J. Chromatogr. A.*, 1130, 130-136.
- Kalkan, H. Y., Üren, A. & Yücel, U. (2007). Evaluation of biogenic amines in organic and non-organic wines by HPLC-OPA derivatization. *Food Technol. Biotechnol.*, 45 (1), 62-68.
- Kelly, M. T., Blaise, A. & Larroque, M. (2010). Rapid automated high performance liquid chromatography method for simultaneous determination of amino acids and biogenic amines in wine, fruit and honey. *J. Chromatogr. A.*, 1217, 7385-7392.
- Lange, J. & Wittmann, C. (2002). Enzyme sensor array for the determination of biogenic amines in food samples. *Anal. Bioanal. Chem.*, 372, 276-283.
- Lonvaud-Funel, A. (2001) Biogenic amines in wines: role of lactic acid bacteria. *FEMS Microbiology Letters*, 9-13.
- Lonvaud-Funel, A. & Joyeux, A. (1994). Histamine production by wine lactic acid bacteria: isolation of a histamine-producing strain of *Leuconostoc oenos*. *J. Appl. Bacteriol.*, 77, 401-407.
- Manetta, A. C., Di Giuseppe, L., Tofalo, R., Martuscelli, M., Schirone, M., Giammarco, M. & Suzzi, G. (2016). Evaluation of biogenic amines in wine: determination by an improved HPLC-PDA method. *Food Control*, 62, 351-356.
- Marques, A. P., Leita, M. C. & San Roma, M. V. (2008). Biogenic amines in wines: Influence of oenological factors. *Food Chemistry*, 107, 853-860.
- Ozdestan, O. & Üren, A. (2009). A method for benzoyl chloride derivatization of biogenic amines for high performance liquid chromatography. *Talanta*, 78, 1321-1326.
- Pereira Monteiro, M. J. & Bertrand, A. (1994). Validation of an assay method. Application to the analysis of biogenic amines in wine. (Validation d'une methode de dosage. Application à l'analyse des amines biogenes du vin.) *Bulletin de l'O.I.V.*, 765-766, 917-962.
- Pripis-Nicolau, L., De Revel, G., Marchand, S., Beloqui, A. A. & Bertrand, A. (2001). Automated HPLC method for the measurement of free amino acids including cysteine in musts and wines; first application. *Journal of the Science of Food and Agriculture*, 81, 731-738.

- Restuccia, D., Loizzo, M. R. & Spizzirri, U. G.** (2018). Accumulation of biogenic amines in wine: role of alcoholic and malolactic fermentation. *Fermentation*, 4(1). doi:10.3390/fermentation4010006. <https://www.mdpi.com/2311-5637/4/1/6>
- Rollan, G. C., Coton, E. & Lonvaud-Funel, A.** (1995). Histidine decarboxylase activity of *Leuconostoc oenos* 9204. *Food Microbiology*, 12, 455-461.
- Romero, R., Gázquez, D., Bagur, M. G. & Sánchez-Vinas, M.** (2000). Optimization of chromatographic parameters for the determination of biogenic amines in wines by reversed-phase high-performance liquid chromatography. *J. Chromatogr. A*, 871, 75-83.
- Rosi, I., Nannelli, F. & Giovani, G.** (2009) Biogenic amine production by *Oenococcus oeni* during malolactic fermentation of wines obtained using different strains of *Saccharomyces cerevisiae*. *Food Science and Technology*, 42, 525-530.
- Sentellas, S., Nuñez, Ó. & Saurina, J.** (2016). Recent advances in the determination of biogenic amines in food samples by (U)HPLC. *J. Agric. Food Chem.*, 64, 7667-7678.
- Soufleros, E., Barrios, M. L. & Bertrand, A.** (1998). Correlation between the content of biogenic amines and other wine compounds. *Am. J. Enol Vitic.*, 49, 266-278.
- Tašev, K., Ivanova-Petropulos, V. & Stefova, M.** (2016). Optimization and validation of a derivatization method for analysis of biogenic amines in wines using RP-HPLC-DAD. *Maced. J. Chem. En.*, 35, 19-28.
- Tašev, K., Ivanova-Petropulos, V. & Stefova, M.** (2017). Ultra-performance liquid chromatography-triple quadruple mass spectrometry (UPLC-TQ/MS) for evaluation of biogenic amines in wine. *Food Anal. Methods*, 10, 4038-4048.
- Üren, A. & Karababa, Z.** (2003). Determination of biogenic amines by an high-performance liquid chromatography method with pre-column o-phthaldialdehyde derivatization. MSc Thesis Ege University Food Engineering Department İzmir Turkey.
- Vidal-Carou, M. C., Lahoz-Portoles, F., Bover-Cid, S. & Marine-Font, A.** (2003). Ion-pair high-performance liquid chromatographic determination of biogenic amines and polyamines in wine and other alcoholic beverages. *J. Chromatogr. A*, 98, 235-241.

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