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Analytical strategies for the determination of biogenic amines in dairy products

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Abstract

Biogenic amines (BA) are mainly produced by the decarboxylation of amino acids by enzymes from microorganisms that emerge during food fermentation or due to incorrectly applied preservation processes. The presence of these compounds in food can lead to a series of negative effects on human health. To prevent the ingestion of high amounts of BA, their concentration in certain foods needs to be controlled. Although maximum legal levels have not yet been established for dairy products, potential adverse effects have given rise to a substantial number of analytical and microbiological studies: they report concentrations ranging from a few mg/kg to several g/kg. This article provides an overview of the analytical methods for the determination of biogenic amines in

Abbreviations: AB, aminobutyric; AG, agmatine; ALA, β-alanine; AM, amylamine; AQC, 6-aminoquinolyl-N-hydroxysuccinimidylcarbamate; BAs, biogenic amines; BCEC-CL, 2-(11H-benzo[a]-carbazol-11-yl) ethyl chloroformate; BNZ-Cl, benzoyl chloride; BU, butylamine; CAD, cadaverine; CCR, 4′-carbonyl chloride rosamine; CD, conductivity detection; CE, capillary electrophoresis; CO, colamine; CZE, capillary zone electrophoresis; C4D, capacitively coupled contactless conductivity detection; DAO, diamine oxidase; DBS-Cl, dabsyl chloride; DEEMM, ethoxymethyl malonate diethyl ester; DIM, dimethylamine; DLLME, dispersive liquid-liquid microextraction; DNS-Cl, Dansyl chloride; DOP, dopamine; d3-4-MBA-OSu, N-hydroxysuccinimidyl ester of d0/d4-4-methoxybenzoic acid; ELISA, enzyme-linked immunosorbent assay; ET, ethylamine; ETH, Ethanolamine; FIA, flow injection analysis; FITC, fluorescein; FL, fluorescence; FMOC-Cl, 9-fluorenylmethyl chloroformate; GA, glutaraldehyde; GC, gas chromatography; HE, Hexylamine; HCl, Hydrochloric acid; $HClO_4$, perchloric acid; HIM, histamine; H_2SO_4, sulfuric acid; IBCF, isobutyl chloroformate; IEC, ion exchange chromatography; IPAD, Integrated pulsed amperometric detection; IPR, isopropylamine; IS, isoamylamine; ISO, isopentylamine; LIF, laser radiation; LOD, limit of detection; LOQ, limit of quantification; MAE, microwave-assisted extraction; ME, methylamine; MIP, molecularly imprinted polymer; MS, mass spectrometry; MSA, methanesul-fonic acid; NBD-CL, 4-Chloro-7-nitrobenzofurazan; NDA, naphtalene-2,3-dicarboxyaldehyde; NMR, nuclear magnetic resonance spectroscopy; OCT, octopamine; OPA, o-phthalaldehyde; PAD, pulsed amperometric detection; PAO, plasmas amino oxidase; PBS, phosphate-buffered saline; PHE, phenylethylamine; PRO, propylamine; PUT, putrescine; SAMF, 6-Oxy-(N-succinimidyl acetate)−9-(2′-methoxycarbonyl) fluorescein; SPD, spermidine; TAO, trypanosome alternative oxidase; TCA, triclhoroacetic; TEA, triethylamine; TLC, Thin-layer chromatography; TMA, trimethylamine; TTMBB-Su, 1,3,5,7-tetramethyl-8-(N-hydroxysuccinimidyl butyric ester)-difluoroboradiaza-s-indacene; TRY, tryptamine; TYR, tyramine; 3-MBU, 3-methylbutylamine.

dairy products, with particular focus on the most recent and/or most promising advances in this field. We not only provide a summary of analytical techniques but also list the required sample pretreatments. Since high performance liquid chromatography with derivatization is the most widely used method, we describe it in greater detail, including a comparison of derivatizing agents. Further alternative techniques for the determination of BA are likewise described. The use of biosensors for BA in dairy products is emerging, and current results are promising; this paper thus also features a section on the subject. This review can serve as a helpful guideline for choosing the best option to determine BA in dairy products, especially for beginners in the field.

KEYWORDS
analytical methods, biogenic amines, biosensors, dairy products, liquid chromatography

1 | INTRODUCTION

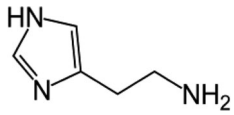
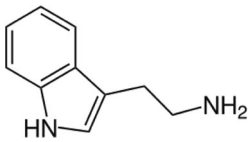
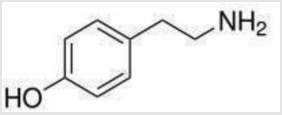
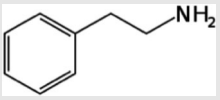
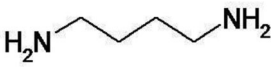
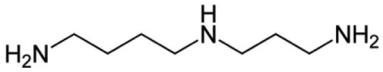
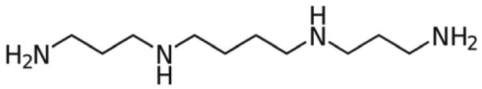
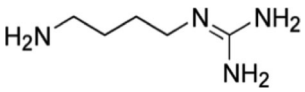
Biogenic amines (BA) are low-molecular weight nitrogenous compounds that emerge through enzymatic decarboxylation of amino acids (Linares et al., 2011; Zhang et al., 2019) or by amination and transamination of aldehydes and ketones (McCabe et al., 2003; Pluta-Kubica et al., 2020). Their chemical structures can be classified as: aliphatic, aromatic, or heterocyclic (Linares et al., 2011; McCabe et al., 2003; Papageorgiou et al., 2018; Spano et al., 2010). Furthermore, according to number of amino groups, they can be classified as monoamines, diamines, or polyamines (Ladero et al., 2017; Spano et al., 2010). An extensive variety of BA is usually present in plants, animals (Farooqui, 2013), and foods (Naila et al., 2010), but the most important BA in certain foods and beverages are histamine, tyramine, putrescine, cadaverine, tryptamine, spermidine, spermine, and phenylethylamine, which are produced by decarboxylation of their respective amino acids (Brito et al., 2014; del Rio et al., 2017; Palermo et al., 2013; Restuccia et al., 2011; Spano et al., 2010), as can be seen in Table 1.

BA act as precursors for the synthesis of hormones, alkaloids, nucleic acids, and proteins; some of them, such as histamine and tyramine, play an important role as neurotransmitters (del Rio et al., 2018). Despite their benefits, multiple negative effects on health derived from food intake with high amounts (ranged from 190 mg/kg to 500 mg/kg for histamine and from 301.8 mg/kg to 500 mg/kg for tyramine) of different amines have been described (del Rio et al., 2017, 2018; Fernández et al., 2006; Ladero et al., 2010; Lehane & Olley, 2000; Linares et al., 2016; McCabe et al., 2003; Ruiz-Capillas & Herrero, 2019; Spano et al., 2010). Synergistic effects among different BA present in food can increase these adverse effects, as is the case of tyramine, which has synergistic cytotoxic effects in combination with histamine (Palomino-Vasco et al., 2019). It should also be noted that BA are precursors to nitrosamines, which have been linked to carcinogenic and mutagenic activity (McCabe et al., 2003; Papageorgiou et al., 2018).

The toxicities of the various biogenic amines, alone or in combination, have for the most part not been established (Paulsen et al., 2017). Most regulations thus focus exclusively on the most dangerous ones, especially on histamine. While legal limits have been established to regulate histamine in certain foods such as fresh fish or enzyme-maturated fish product, allowing up 100 mg/kg and 200 mg/kg, respectively (Commission Regulation No. 2073/2005) (Ladero et al., 2017; UE, 2005), no regulation has been established for dairy products (Moniente et al., 2021). Only recommended maximum levels of histamine have been suggested for dairy products (Rauscher-Gabernig et al., 2009), despite the fact that high amounts of BA have been found in some of them. For example, 1000 to 2500 mg/kg of histamine have been detected in some varieties of cheese, as well as 1500 to 4000 mg/kg of tyramine in cheddar and Camembert cheese (Maintz & Novak, 2007).

BA have been also found in milk submitted to diverse treatments (raw, pasteurized and ultra-high temperature [UHT]) stemming from different animal species (sheep, cow, and goat), as well as in dairy products derived from fermented milk (Benkerroum, 2016; Costa et al., 2018; Ladero et al., 2017), although the levels of BA in the latter are much lower. It would nevertheless be important to control low concentrations of histamine in foods as well, since ingestion of small amounts of histamine can produce disorders in histamine-sensitive patients (Paulsen et al., 2017). Even their determination at very low levels could help to certify histamine-free products.

TABLE 1 Formation of the most important biogenic amines from their precursor amino acids

Precursor substrate	Enzyme	Biogenic amine	Chemical structure
Histidine	Histidine decarboxylase	Histamine 	Heterocyclic amines
Tryptophan	Tryptophan hydroxylase	Tryptamine 	
Tyrosine	Tyrosine descarboxylase	Tyramine 	Aromatic amines
Phenylalanine	Phenylalanine descarboxylase	Phenylethylamine 	
Ornithine	Ornithine descarboxylase	Putrescine 	Aliphatic amines
Lysine	Lysine descarboxylase	Cadaverine 	
Putrescine	Spermidine synthase	Spermidine 	
Spermidine	Spermine synthase	Spermine 	
Arginine	Arginine descarboxylase	Agmatine 	

BA detection requires sensitive, selective analytical methods (Henao-Escobar et al., 2013). In addition, most foods are complex matrices, and some of them have high percentages of proteins and fats that make it difficult to determine BA. To reduce matrix interferences and increase the sensitivity of analytes, sample preparation steps prior to analysis are usually necessary: deproteinization by acids (Andiç et al., 2010, 2011; Bunkova et al., 2013; Contreras et al., 2007; Custódio et al., 2007; Durlu-Özkaya, 2002; Ercan et al., 2019; Fiechter et al., 2013; Flasarová et al., 2016; Gobbi et al., 2019; Korös et al., 2008; Lanciotti et al., 2007; Marijan et al., 2014; J. L. Ordóñez et al., 2016; Samková et al., 2013; Sawilska-Rautenstrauch et al., 2010; Spizzirri et al., 2019; Tittarelli et al., 2019; Toro-Funes et al., 2015), for example, or solid phase extraction (SPE) (Calbiani et al., 2005; J. L. Ordóñez et al., 2016; Spizzirri et al., 2013, 2019).

Multiple analytical methods have been developed for the determination of BA in a wide variety of foods and beverages (Komprda et al., 2008; Marks & Anderson, 2005; Moracanin et al., 2015; Nalazek-Rudnicka & Wasik, 2017; Peña-Gallego et al., 2009; Spizzirri et al., 2013; Yigit & Ersoy, 2003). A series of analytical techniques such as gas chromatography (GC), thin layer chromatography

(TLC), and capillary electrophoresis (CE) have been used (Adımcılar et al., 2018; Draisci et al., 1998; Fernández-García et al., 1999, 2000; Gaya et al., 2005; Karovičová & Kohajdová, 2005; Kvasnička & Voldřich, 2006; Lange & Wittmann, 2002; Pham & Nguyen, 2016; Shalaby et al., 2016; Švarc-Gajic & Stojanovic, 2011) to analyze BA. Nevertheless, due to the low volatility and polarity of these analytes, most of the analytical methods used are based on analysis by liquid chromatography (LC) (Önal et al., 2013), since the derivatization of BAs is commonly applied to improve their determination. Other type of methods based on enzymatic procedures such as enzyme-linked immunosorbent assay (ELISA) have also been used (Aygün et al., 1999; Leszczyocha & Pytasz, 2018), and an increasing number of studies in recent years have determined amines using biosensors (Alonso-Lomillo et al., 2010; Calvo-Pérez et al., 2013; Carelli et al., 2007; Compagnone et al., 2001; Huang et al., 2011; Salleres et al., 2016; Telsnig et al., 2012).

Growing concern about the presence of BA in different foods is reflected in a growing quantity of published papers and reviews (Huang et al., 2011; Mayr & Schieberle, 2012; Papageorgiou et al., 2018; Paulo Vieira et al., 2020; Ramos et al., 2020). Given the variety of matrices in which BA can be found, recent reviews have covered the analytical methods developed for a variety of different foods and beverages (Biji et al., 2016; Guo et al., 2015; Önal, 2007; J. L. Ordóñez et al., 2016; Papageorgiou et al., 2018; Suzzi & Gardini, 2003; Zhang et al., 2019). Consumed in all cultures on a daily basis, dairy products encompass a wide range of products: milk, yogurt, cheese, kefir, butter, and cream, among others. This food group features considerable physicochemical variability with different characteristics of texture (liquid, solid, and gel), viscosity, or composition. Due to the global importance and variability of dairy products, we consider it necessary to review and compare the different strategies used to analyze BA in this group of foods, spotlighting the latest advances in the field.

2 | SAMPLE PRETREATMENT METHODS FOR DAIRY PRODUCTS

The decision of using sample pretreatments is based on the selectivity and sensitivity of the determination step and the physicochemical characteristics of the sample. So, two of the main objectives of sample pretreatment methods are cleaning the sample and preconcentrating the analytes. Sometimes, samples can be analyzed without any treatment and the easiest is applying the "dilute and shoot" method; however, in dairy products, perhaps due to their complexity and to the concentration of BA, it has not been used for the determination these analytes. The high protein content in dairy products implies that most sample pretreatments focus on protein removal; solvent pretreatments have thus been extensively applied for the precipitation of proteins (Gianotti et al., 2008; Gloria et al., 2011; He et al., 2016; Korös et al., 2008; Latorre-Moratalla et al., 2009; Madejska et al., 2018; Molaei et al., 2019; Redruello et al., 2013; Ubaldo et al., 2015).

The application of solid–liquid (S–L) or liquid–liquid (L–L) extraction methods depends on the dairy product's texture, seeking not only to precipitate proteins but also a maximum solubility of BA in the extracting phases. A wide variety of such methods (Andiç et al., 2010; Gaya et al., 2005; Innocente et al., 2007; Lange & Wittmann, 2002; Mayer et al., 2010; Rabie et al., 2011; Shalaby et al., 2016; Standarová et al., 2009; Yigit & Ersoy, 2003) have been used to extract BA from cheeses. Custódio et al. (2007) carried out a remarkable comparison, evaluating hydrochloric, trichloroacetic, perchloric, sulfosalicylic, and acetic acids, borate buffer, methanol, and ethanol as extracting agents of amines in grated Parmesan cheese. The level of amines present in the sample, the type of sample, the concentration and temperature of the extractor, as well as the method used, affected the degree of extraction efficiency. Each one of the studied BAs could be better recovered in a different way, although 1 M HCl was the most adequate solution for most of the amines.

Although solvent extractions are the most common methods for the analysis of BA in different dairy matrices such as milk, cheese, or yogurt (Mohammadi et al., 2017; Molaei et al., 2019; Wu et al., 2015) due to their high performance in removing undesirable compounds (Liu et al., 2018), they have several disadvantages, such as slowness, high amounts of harmful organic solvents, loss of objective analytes (Wu et al., 2015), low repeatability, complexity, laborious emulsion formation (Liu et al., 2018; Saaid et al., 2009), a large sample volume for trace analysis (Huang et al., 2011), and time-consuming procedures (J. L. Ordóñez et al., 2016). To overcome these disadvantages, modifications and improvements have been made based on liquid–liquid extraction (LLE) techniques by using liquid phase microextraction methods such as dispersive liquid–liquid microextraction (DLLME) and salting-out assisted liquid–liquid extraction (SALLE). Ultrasonic-assisted extraction (UAE) and microwave-assisted extraction (MAE) have also been used to avoid these drawbacks.

Some of the advantages of DLLME analysis are high enrichment capacity, simple technique, low consumption of organic solvents, time saving due to short extraction time, low cost, good repeatability, and high sensitivity (Kamankesh et al., 2013; Rezaee et al., 2006; Wu et al., 2015). Mohammadi et al. (2017) used this method in combination with the auxiliary application of MAE for the simultaneous determination of four BA in samples of Iranian Lighvan cheese, and demonstrated that

MAE–DLLME–GC coupled with mass spectrometry (MS) is effective in extracting and determining small amounts of BA in cheese with 20% fat. The analysis procedure was as follows: 1 g of sample was homogenized with 5 ml of 0.1 M HCl and microwaved at 500 MHz for 3 min; after the precipitation of the proteins, BA derivatization and microextraction were carried out simultaneously by adding 25 μl of isobutyl chloroformate (IBCF), 2 g of NaCl, 600 μl of acetonitrile (ACN) (dispersive solvent), and 60 μl of 1-octanol (extractive solvent). Solution was centrifuged at 4000 rpm for 5 min, and 2 μl of the floated phase of 1-octanol was injected directly into the GC–MS. DLLME has also been used a step prior to LC analysis. Wu et al. (2015) studied BA in cheese with UAE–DLLME, but added chloroform and acetone as extraction and dispersing solvents, respectively.

SALLE is used to prepare samples for organic extraction in chromatographic analysis (Tang & Weng, 2013). To increase the distribution ratio of a particular solute, the effect of salt is used by adding an electrolyte to an aqueous solution (Rice et al., 1993). This effect promotes the extraction of molecular species to an organic phase and allows for phase separation between the two solvents (Shishov et al., 2019).

Ramos et al. (2020) recently used SALLE for the determination of BA in seven different types of cheese, including derivatization with dansyl chloride (DNS-Cl) and HPLC coupled to a fluorescence detector (FLD). An extraction of soluble BA was carried out with 1 M HCl prior to the use of SALLE, simultaneously with the derivatization step, and the extract was injected into a liquid chromatography system.

UAE is used to improve extraction efficiency and reduce analysis times, thanks to the effects it produces such as vibration, cavitation, and agitation generated by ultrasonic waves that induce the effective components to enter the solvent (Khaled, 2014; Redruello et al., 2013; Švarc-Gajic & Stojanovic, 2011).

Several authors have used UAE to extract BA in cheese (Fernández et al., 2007; Herrero-Fresno et al., 2012; Krause et al., 1995; Redruello et al., 2013; Švarc-Gajic & Stojanovic, 2011; Zotou & Notou, 2012). Švarc-Gajic and Stojanovic (2011) compared the efficiency of different extraction procedures: they tested three different solvents and carried out a comparison among classical reflux extraction, UAE, and MAE. They concluded that methanol was the best solvent and that UAE was the most efficient procedure.

Further alternative pretreatment techniques have been developed, such as SPE (Calbiani et al., 2005; Gianotti et al., 2008; Gosetti et al., 2007; Restuccia et al., 2011; Spizzirri et al., 2019; Yang et al., 2016) and solid phase microextraction (SPME) (Ali Awan et al., 2008). Advantages provided by these methods include low consumption of extraction solvents, ease of use, and low cost, as well as the possibility of automation and of online coupling with analytical instruments (Pena-Pereira et al., 2012).

Gosetti et al. (2007) compared the recoveries obtained with LLE and SPE. In the SPE method, the BA were extracted from cheese with 0.1 M HCl and the solution was loaded onto the SPE cartridge (C18 sorbent and Strata X were compared and C18 was selected), which was washed with water and eluted with methanol. Better results were obtained with SPE than with LLE, with recovery yields greater than 90% for all amines through SPE. This procedure of extraction with 0.1 M HCl, loading onto C18 cartridges and cleaning with water, is the most common one when SPE is used to determine BA in cheeses (Gianotti et al., 2008; Restuccia et al., 2011); however, other kinds of sorbent material, such as cyanopropyl (CN) cartridges, and other washing steps have also been used (Calbiani et al., 2005).

One of the aforementioned advantages of SPE is the possibility of automatization. Yang et al. (2016) successfully developed a novel method based on online SPE coupled to capillary HPLC for the simultaneous separation and determination of 15 BA in cheese. Using the online SPE purification technique, it was possible to reduce the matrix effect of the samples while simplifying sample pretreatment, reducing manual error, and greatly improving analysis efficiency.

SPE has been also applied to determine BA in milk. Spizzirri et al. (2019) studied BA in reconstituted milk powder and ready-to-use liquid milk using SPE prior to derivatization and LC with ultraviolet (UV) analysis. The SPE cartridges (ENVI-18SpeTubes) were first preconditioned with a water/ammonia solution (70/30% v/v) and then with methanol. The sample was loaded, after which the washing step was performed with water and eluted with methanol.

Ali Awan et al. (2008) demonstrated the advantages of SPME as a technique to extract and derivatize BA for GC analysis. They used trifluoroacetylacetone (TFAA) as derivatizing agent; derivatization and extraction were carried out simultaneously into a SPME vial at 120°C during 20 min. This method was applied for the determination of putrescine and cadaverine in a cheese sample.

3 | ANALYTICAL METHODS FOR DAIRY PRODUCTS

One of the greatest challenges in food analysis remains BA determination, which is of considerable importance for two main reasons: on the one hand, the potential toxicity of BAs and, on the other hand, the possibility of using them as food quality markers.

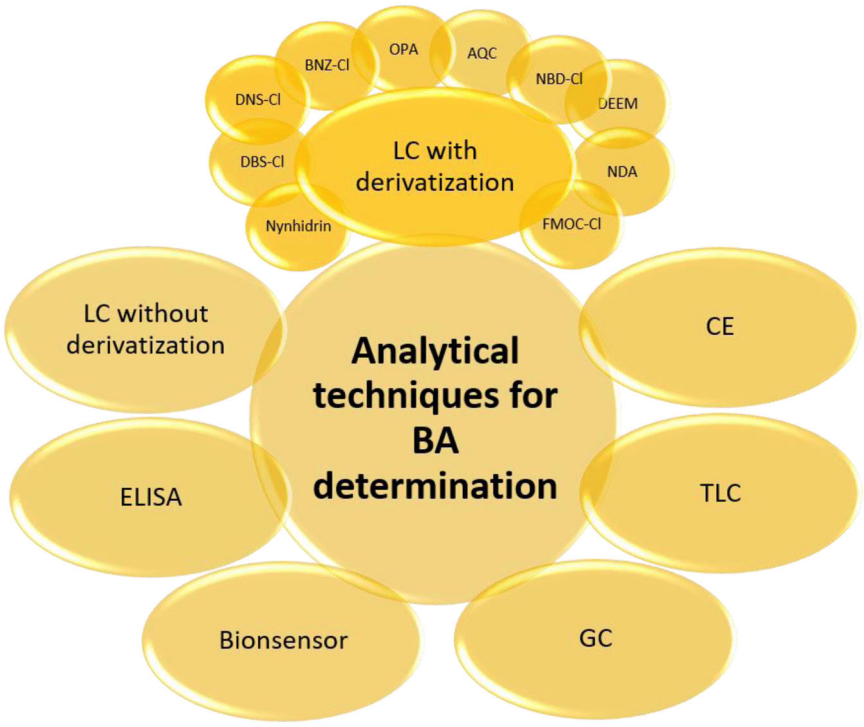


FIGURE 1 The most common analytical techniques used for the determination of biogenic amines.
Abbreviations: AQC, 6-aminoquinolyl-N-hydroxysuccinimidylcarbamate; Bnz-Cl, benzoyl chloride; CE, capillary electrophoresis; Dbs-Cl, dabsyl chloride; DEEMM, ethoxymethyl malonate diethyl ester; Dns-Cl, dansyle chloride; ELISA, enzyme-linked immunosorbent assay; FMOC-Cl, 9-fluorenylmethyloxycarbonyl chloroformate; GC, gas chromatography; LC, liquid chromatography; NBD-CL, 4-Chloro-7-nitrobenzofurazan; NDA, naphtalene-2,3-dicarboxyaldehyde; OPA, o-phthalaldehyde; TLC, thin layer chromatography

One of the difficulties in BA determination is the polarity of these compounds, which makes them have a higher solubility in water than in the organic solvents used for analysis. Other difficulties are: the complexity of the sample; the presence of interfering compounds that cause the spread of chromatographic peaks and the appearance of shoulders; a limited concentration range within which analytes cannot be detected by the analytical detectors; and the absence of intrinsic properties of the BA for most of the usual detectors (Önal et al., 2013; Papageorgiou et al., 2018). To solve these analytical difficulties, analytical methods are generally combined with previous processes of extraction and derivatization prior to separation and detection.

A wide range of methods (Tables 2 and 3) have been developed for the analysis of BA in dairy products with different analytical techniques (Figure 1): TLC, GC, CE, ELISA, chronopotentiometry, and biosensors, whereby LC is the most widespread analytical technique.

3.1 | Analytical methods based on LC with derivatization

Many BA, for example putrescine, cadaverine, spermine, and spermidine, do not absorb in the UV region, while others, such as phenylethylamine, tyramine, and histamine, absorb in a shorter wavelength region (close to 200 nm) where matrix effects can appear (Jain & Verma, 2018; Zhang et al., 2019). Most of them require derivatization due to low volatility and lack of chromophores, and also in order to reduce their polarity with the purpose of improving chromatographic and detectability properties (Önal, 2007).

The derivatization process allows to improve the resolution of the analytes in reverse phase (RP) columns as well. Therefore, most analytical LC methods for the quantification of BA feature a pre- or postcolumn derivatization step (García-Villar et al., 2009). A broad array of derivatizing reagents have been used for the determination of BA in dairy products. The most common derivatization reactions are shown in Figure 2. Reproducibility, stability, and speed are the main reasons for choosing among the different options (Munir & Badri, 2020). The most common derivatizing reactions are the following:

3.1.1 | Derivatization by DNS-Cl reagent

Sulfonyl chlorides work to derivatize primary and secondary amines, and DNS-Cl is the one most widely used. This derivatizing reagent offers a high fluorescence efficiency, especially in organic solvents (Chen, 1967). Fluorescence detection is therefore recommended, although other types of detectors can also be used.

UV-Visible (UV-Vis) detection
In spite of the excellent fluorometric properties of dansylated compounds, most authors choose to use UV-Vis for their detection. The analytical method developed by

TABLE 2 Analytical methods based on separation techniques to determine biogenic amines in dairy products

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, PHE, SPM	RP-HPLC	0.1 M HCl	Dbs-Cl	UV (436 nm)	LOD: 0.12 and 0.52 pmol	Fernández et al. (2007)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	RP-HPLC	0.1 M HCl	Dbs-Cl	UV (436 nm)	–	Valsamaki et al. (2000)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	RP-HPLC	0.1 M HCl 40% TCA	Dbs-Cl	UV (436 nm)	LOD: 0.12 and 0.52 pmol	Krause, et al. (1995)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY, SPD, ET	RP-HPLC	0.2 M $HClO_4$	Dbs-Cl	UV (436 nm)	LOD: 1.5 mg/L	Pinho et al. (2001)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	RP-HPLC	0.2 M $HClO_4$	Dbs-Cl	UV (436 nm)	–	Pinho et al. (2004)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, TRY	HPLC	0.1 M HCl	Dbs-Cl	UV (254 nm)	LOD: 0.25–0.76 pmol LOQ: 0.99–2.9 pmol	Bockhardt et al. (1996)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD , TRY, TBA	RP-HPLC	0.4 M $HClO_4$	Dns-Cl	UV (254 nm)	–	Durlu-Ozkaya (2002)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD	HPLC	0.4 M $HClO_4$	Dns-Cl	UV (254 nm)	LOD: 1–5 mg/kg	Contreras et al. (2007)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	HPLC	0.4 M $HClO_4$	Dns-Cl	UV (254 nm)	–	Andiç et al. (2010)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	HPLC	0.4 M $HClO_4$	Dns-Cl	UV (254 nm)	–	Marijan et al. (2014)
Cheese	HIM, TYR	HPLC	0.4 M $HClO_4$	Dns-Cl	UV (254 nm)	–	Tittarelli et al. (2019)
Cheese	HIM, TYR, PUT, CAD, PHE	HPLC	5% TCA	Dns-Cl	UV (254 nm)	–	Deabes et al. (2013)
Cheeses	HIM, TYR, PUT, CAD, TRY, PHE, SPD, SPM,	RP-HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	LOD: 0.002 μg/cm3 LOQ: 0.010 mg/kg	Bonczar et al. (2018)
Cheese	HIM, TYR, PUT, CAD, TRY, SPD, SPM, PHE	RP- HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	LOD: 0.002 μg/cm3 LOQ: 0.010 mg/kg	Pluta-Kubica et al. (2020)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, SPD, SPM, PHE, TRY	RP-HPLC	0.1 M HCl	Dns-Cl	UV (218 nm)	LOD: 1.3–3.1 mg/kg LOQ: 1.9–4.6 mg/kg	Combarros-Fuertes et al. (2016)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	RP-HPLC-DAD	0.1 M HCl	Dns-Cl	UV (254 nm) FL (ex. 330 nm, em. 500 nm)	LOD: 0.07 mg/kg–0.23 mg/kg LOQ: 0.20 mg/kg–0.70 mg/kg	Zazzu et al. (2019)
Cheese	HIM, TYR, PUT, CAD, SPM, SPD, TRY	RP-HPLC	10 % TCA	Dns-Cl	UV (436 nm)	–	Standarová et al. (2010)
Cheese	HIM	HPLC	TCA	Dns-Cl	DAD	LOD: 3 mg/kg	Gardini et al. (2012)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD	HPLC	0.2 M $HClO_4$	Dns-Cl	DAD	LOD: 1-5 mg/kg	Lanciotti et al. (2007)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY, SPD, SPM, ME, ET, AM, OCT	HPLC	Methanol 0.1 M HCl Online SPE	Dns-Cl	UV-VIS	LOD: 0.05—0.25 mg/L LOQ: 0.15—0.80 mg/L	Yang et al. (2016)
Cheese	HIM, TYR, PUT, CAD, SPM, SPD	HPLC	Acid extraction	Dns-Cl	UV (254 nm)	–	Mercogliano et al. (2010)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	HPLC	0.2 M $HClO_4$	Dns-Cl	UV (254 nm)	–	El Zahar (2014)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	HPLC	0.6 M $HClO_4$	Dns-Cl	UV (254 nm)	–	Flasarová et al. (2016)
Cheese	HIM, TYR, PUT, CAD, TRY, PHE	HPLC	0.4 M $HClO_4$	Dns-Cl	DAD (254 nm)	–	Andiç et al. (2011)
Cheese	HIM, TYR, CAD, PUT, TRY, PHE, SDP, SPM	HPLC	0.2 M $HClO_4$	Dns-Cl	DAD (254 nm)	–	Ordoñez et al. (1997)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, TRY	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	LOD:1–5 mg/kg	Galgano et al. (2001)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, TRY	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)		Moret and Conte (1996/)
Cheese	HIM, TYR, PUT, CAD, PHE	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	LOD: 5 mg/kg for all the amines and 8 mg/kg only for PHE	Schirone et al. (2013)
Milk. cheese and yoghurt	HIM, TYR, PUT, CAD, PHE, SPD, SPM, TBA	HPLC	0.4 M $HClO_4$	Dns-Cl	DAD (254 nm)	–	Min et al. (2004)
Cheese	HIM, TYR, PUT, CAD	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	LOD: 0.3 mg/kg of LOQ: 1 mg/kg	Forzale et al. (2011)
Cheese	ET, TRY, PHE, SPM, PUT	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	–	Martuscelli et al. (2005)
Cheese	HIM, TYR, PUT, CAD	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	–	Gennaro et al. (2003)
Cheese	HIM,TYR, CAD	HPLC	5% TCA	Dns-Cl	UV (254 nm)	–	Ibrahim and Amer (2010)
Cheese	HIM, TYR, CAD, TRY	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm) $_1$ ESI-MS $_2$ APCI-MS $_3$	LOD_1: 14-67 μg/L LOQ_1: 45–229 μg/L LOD_2: 7–58 μg/L LOQ_2: 23–197 μg/L LOD_3:10–54 μg/L LOQ_3: 29–183 μg/L	Mazzucco et al. (2010)
Cheese	HIM, TYR, PUT, CAD, TRY	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	–	Innocente and D'Agostin (2002)
Cheese	HIM, TYR, PUT, CAD, SPD, SPM, TRY	HPLC	0.1 M HCl	Dns-Cl	UV (254 nm)	–	Innocente et al. (2007)
Cheese	HIM, TYR, PUT, CAD, TRY, PHE	HPLC	0.4 M $HClO_4$	Dns-Cl	UV (254 nm)	–	Ercan et al. (2019)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, PUT, TYR, CAD, SPD, SPM, ME, DIM, ET	HPLC	SALLE 1 M HCl	Dns-Cl	FL (ex. 320 nm, em 523 nm) MS/MS	LOD: 0.015 and 1.77 mg/L LOQ: 0.050 and 5.9 mg/L	Ramos et al. (2020)
Cheese	HIM, TYR, PUT, CAD, SPM, SPD, PHE	HPLC	TCA	Dns-Cl	DAD	–	Mascaro et al. (2010)
Cheese	HIM, TYR, PUT, CAD	HPLC	0.1 M HCl	Dns-Cl	FL	LOD: 0.185–0.367 μg/g LOQ: 0.536–1.246 μg/g	Brito et al. (2014)
Cheese	HIM, TYR, PUT, CAD	RP-HPLC	0.2 M HClO4	Dns-Cl	FL (ex. 465 nm, em. 545 nm)	LOD: 0.7 mg/kg–1.3 mg/kg. LOQ: 1.4 mg/kg–2.6 mg/kg	Sawilska-Rautenstrauch et al. (2010)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, TBA	RP-HPLC	HCl	Dns-Cl	FL	LOD: 2–33 mg/kg	Standarová et al. (2009)
Cheese	HIM, TYR, CAD, SPD, SPM, TRY	HPLC	0.1 M HCl SPE	Dns-Cl	MS/MS	LOD: 5.1–35.0 μg/L LOQ: 14.2–101.2 μg/L	Gosetti et al. (2007)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY, SPD, SPM, ETH	HPLC	0.1 M HCl	Dns-Cl	PDA (254 nm)	LOD: 1 μg/L LOQ: 2 μg/L	Esatbeyoglu et al. (2016)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	HPLC	0.1 M HCl	Dns-Cl	FL (ex. 340 nm, em. 520 nm)	–	Manca et al. (2015)
Cheese	HIM	HPLC	0.2 M TCA	Dns-Cl	UV–Vis (215 nm)	LOD: 3.52 mg/kg LOQ: 4.25 mg/kg	Madejska et al. (2018)
Cheese	HIM, TYR, PUT, CAD	HPLC	0.6 M $HClO_4$	Dns-cl	UV (254 nm)	0.24—1.39 mg/kg	Pachlova et al. (2016)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	HPLC	0.1 M HCl	Dns-Cl/OPA	UV (254 nm)	–	Renes et al. (2014)
Milk. yogurt and cheese	HIM, TYR, PUT, CAD, PHE, AG, SPM, SPD, TRY, OCT	HPLC	0.6 N $HClO_4$	OPA	FL (ex. 340 nm, em. 445 nm)	LOD: 0.10 mg/kg	Novella-Rodriguez et al. (2000)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY	HPLC	0.6 N $HClO_4$	OPA	FL (ex. 340 nm, em, 445 nm)	LOD: 0.10 mg/kg	Novella-Rodríguez et al. (2002) b
Cheese. milk. rennet. curd and whey	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY	HPLC	0.6 N $HClO_4$	OPA	FL (ex. 340 nm; em. 445 nm)	LOD: 0.10 mg/kg	Novella-Rodríguez et al. (2002) a
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY, TBA, OCT	HPLC	0.6 N $HClO_4$	OPA	FL (ex. 340 nm, em. 445 nm)	LOD: 0.10 mg/kg	Novella-Rodríguez et al. (2003)
Milk. rennet and brine. curd. whey and cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY, TBA, OCT	HPLC	0.6 N $HClO_4$	OPA	FL (ex. 340 nm, em. 445 nm)	LOD: 0.10 mg/kg	Novella-Rodríguez et al. (2004)
Cheese	HIM, TYR, TRY, PHE	HPLC	5 % TCA	–	UV (215 nm)	LOD: < 10 mg/kg	Van Boekel and Arentsen (1987)
Cheese	HIM, TYR, TRY, PHE	HPLC	5% TCA	–	UV (215 nm)	LOD: < 10 mg/kg	Öner et al. (2006)
Cheese	HIM, TYR, PUT, CAD,PHE, SPM, SPD, AG, TRY	Ion-pair HPLC	0.1 and 1 M HCl Ethanol Methanol 12% sulfosalicylic acid	OPA	FL (ex. 340 nm, em. 445 nm)	LOD: 0.01-0.2 μg/ml	Custóordio et al. (2007)
Milk	HIM, TYR, PUT, CAD, SPD, SPM, TRY, PHE, AGM	HPLC	1.2 g of sulphos-alicylic acid	OPA	FL (ex. 340 nm; em. 445 nm)	LOD: < 0.010 mg/L	Gloria et al. (2011)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY	HPLC	1.5% sulfosalicylic acid	OPA	FL (ex. 340 nm, em. 450 nm)	LOD and LOQ: 0.5 mg/kg	Sampaio et al. (2015)
Milk. yogurt and cheese	PUT, CAD, SPD, SPM, AGM	RP-HPLC	5% TCA	OPA	FL (ex. 340 nm, em.455 nm)	–	Nishimura et al. (2006)
Cheese	HIM, TYR, TRY, AGM, PHE, SPD, SPM	HPLC	1 M $HClO_4$	OPA-ET-FMOC	DAD (190 and 400 nm) FL (ex. 334, ex. 262 nm)		Köros et al. (2008)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, SPM, SPD, AG	HPLC	5% TCA	OPA	MS	LOD: 0.5 mg/kg	Lange et al. (2002)
Fermented milk kefir	HIM, TYR, PUT, CAD, PHE, SPM, SPD , AG, TRY, ME	HPLC	0.2 M HCl	Bnz-Cl	UV (254 nm)	LOD: 0.2–2.5 mg/L Linearity: 133.6–1433 mg/L	Özdestan and Üren (2010)
Fermented milks	HIM, TYR, PUT, CAD, SPM, TBA	HPLC	5 % $HClO_4$	Bnz-Cl	UV (198 nm)	LOD: 0.03–1.30 mg/L LOQ: 0.20–5.00 mg/L	Costa et al. (2015)
Milk yogurt	PUT, CAD, SPD, SPM, TRY,	RP-HPLC	0.6 M $HClO_4$	Bnz-Cl	UV (254 nm)	LOD: 0.18—4.01 mg/L LOQ: 1–5 mg/L	Silva et al. (2019)
Dairy product	HIM, TYR, PUT, CAD	HPLC	5 % $HClO_4$	Bnz-Cl	UV (198 nm)	LOD: 0.05—150 mg/L LOQ: 0.05—50 mg/L	Molaei, et al. (2019)
Cheese	HIM, TYR, PUT, CAD	HPLC	0.013 N H_2SO_4	Bnz-Cl	UV (254 nm)	–	O'Sullivan et al. (2015)
Yogurt	TYR, PUT, CAD, SPD, SPM	RP-HPLC	0.6 M $HClO_4$	Bnz-Cl	UV (254 nm)	LOD: 0.18—4.01 mg/L. LOQ:1–5 mg/L	Vieira et al. (2020)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	HPLC	0.6 M TCA	Ninhydrin	UV (546 nm)	LOD: 0.02 mmol/kg	Joosten (1988)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	RP-HPLC	0.6 M TCA	Ninhydrin	UV (546 nm)	LOD: 2 mg/kg	Joosten and Olieman (1986)
Dairy beverage	HIM, TYR, PUT, CAD, TRY, PHE, SPD, SPM, DOP, OCT, AGM, AB, ALA	HPLC	0.2 % TFA	Ninhydrin	UV–Vis (570 nm) CAD CLND	LOD CLND: 0.1 μg/ml–0.4 μg/ml	J. Sun et al. (2011)
Cheese	HIM, TYR, PUT, CAD, SPD, SPM, TRY, PHE, ME, ET, PRO, IS	HPLC	Methanol and TCA	NDA	FL (ex. 424 nm, em. 494 nm)	LOD: 0.6–165 mg/kg	Zotou and Notou (2012)
Milk	HIM, TYR, PHE, TRY, PRO	ZF–HPLC	TCA	NDA	FL (ex. 424 nm, em. 494 nm)	LOD 2–2000 μg/L	Notou et al. (2014)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, SPM, SPD, PHE	HPLC	0.1 M HCl	FMOC	FL (ex. 265 nm, em. 315 nm)	–	Kirschbaum and Luckas (1994)
Cheese	HIM, TYR, PUT, CAD	RP-HPLC	PBS	FMOC	FL (ex. 265 nm, em. 315 nm)	LOD: 1 mg/kg	Aygün et al. (1999)
Cheese	HIM, TYR, PUT, CAD, TRY, PHE	HPLC	0.1 N HCl	DEEMM	PDA (269 nm and 280 nm)	LOD: 0.1 mg/kg	Poveda et al. (2016)
Cheese	HIM, TYR, PUT, CAD, TRY, PHE	HPLC	0.1 N HCl	DEEMM	PDA (269 nm and 280 nm)		Poveda et al. (2015)
Cheese	HIM, TYR, PUT, CAD, SPD, SPM, TRY, PHE	HPLC	0.1 M HCl	d3-4-MBA-OSu	Tandem mass spectrometry (MALDI MS and MS/MS)	LOD: 9.5–20.3 μg/kg LOQ: 15.6–25.3 μg/kg	Mazzotti et al. (2014)
Cheese	ETH, ME, ET, PRO, BU, PHE, HE	HPLC	0.1×10^{-3} M HCl	SAMF	FL (ex. 486 nm, em. 516 nm)	LOD: 2-320 fmol	Cao et al. (2005)
Milk and Yogurt	HIM, TYR, PUT, CAD, SPM, SPD, TRY, PHE	RP-HPLC	Acetonitrile	TMBB-Su	FL (ex. 490 nm; em. 510 nm)	LOD: 0.1–0.2 nM	Gao et al. (2011)
Yogurt and cheese	TYR, PUT, CAD, SPD, SPM	HPLC	5% TCA	BCEC-Cl	FL (ex. 279 nm, em. 380 nm)	LOD: 1.1—7.8 ng/ml LOQ: 3.5—26.1 ng/ml	Wu et al. (2015)
Cheese	TYR	HPLC	5% $HClO_4$	NBD-Cl	UV (458 nm)	LOD: 25 μg/g	Yigit and Ersoy (2003)
Cheese	HIM, TYR,PHE	HPLC	MSPD-SPE	–	Tandem mass spectrometry	LOD 0.05–0.25 mg/kg LOQ: 0.09-0.55 mg/kg	Calbiani et al. (2005)
Cheese	HIM, TYR, PUT, CAD, SPM, SPD, TRY	HILIC-HPLC	0.1 M HCl SPE	–	APCI MS/MS method	LOD: 1–3.5 μg/L LOQ: 3–10 μg/L	Gianotti et al. (2008)
Cheese	HIM, TYR, PHE, TRY	HPLC	5% TCA	–	UV and DAD (215 nm)	LOD: 0.006–0.146 μg	Arloriol et al. (1998)
Cheese	HIM, TYR, PUT, CAD, AG, TRY, SPD, SPM, ETH, ME, DIM, ET, OCT, IPR, PRO, BU, MBU	HPLC UPLC	0.6 N $HClO_4$	AQC	UV (254 nm) FL (ex: 250 nm, em: 395 nm)	LOD: 0.8-6.2 mg/kg LOQ: 2.9–60.9 mg/kg	Mayer et al. (2010)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, SPD, SPM, AG, PHE, TR, CO, DIM, ET, OCT, MBU	UHPLC	0.6 M $HClO_4$	AQC	UV (249 nm)	LOD: 0.05–0.44 mg/100 g LOQ: 0.16–1.45 mg/100 g	Fiechter, et al. (2013)
Cheese	HIM, TYR, PUT, CAD, SPD, SPM, TRY, PHE, ISO	UPLC	0.1 M $HClO_4$ in 50% acetonitrile.	Dns-Cl	UV (254 nm)	–	Ascone et al. (2017)
Cheese	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE	UPLC	0.6 M $HClO_4$	Dns-Cl	–	LOQ: 1.2–3.7 mg/kg	Samková et al. (2013)
Cheese	HIM, TYR, PUT, CAD, AGM, PHE, SPD, SPM, TRY, OCT	UHPLC	0.6 M $HClO_4$	OPA	FL (ex. 340 nm, em. 445	LOD: 0.3 mg/kg	Latorre-Moratalla et al. (2009)
Cheese	HIM, TYR, PUT, CAD, PHE, TRY	UHPLC	0.1 M HCl	DEEMM	UV (280 nm)	LOD: 0.08—3.91 μM LOQ: < 13.02 μM	Redruello et al. (2013)
Cheese	HIM, TYR, PUT, CAD, SPM, SPD AG, PHE, TRY	UHPLC	In situ DUADLLME	CCR-acetonitrile	MS/MS	LOD: 0.9–6.0 μg/kg LOQ: 10-30 μg/kg	He et al. (2016)
Cheese and yoghurt	HIM, TYR, PUT, CAD, TRY, SPM, SPD, PHE, ETH, ALA	LC	10 % TCA	Bnz-Cl	Tandem mass spectrometry	LOQ: 0.05 μg/kg	Mayr and Schieberle (2012)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY	LC	0.1 N HCl	OPA	FL (ex. 340 nm, em. 445 nm)	LOD: 0.004 to 0.009 μg/20 μl LOQ: 0.066–0.149 mg/100 g	Vale and Gloria (1997)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG, TRY	LC	0.1 N HCl	OPA	FL (ex. 340 nm, em. 445 nm)	LOD: 1.98 mg/100 g	Vale and Gloria (1998)
Cheese	TYR	LC	0.1 M HCl	OPA	UV (254 nm)	–	Komprda et al. (2008)
Cheese	HIM, TYR, PUT, CAD, PHE, SPM, SPD, AG	LC	0.1 M HCl SPE	–	ELSD	LOD: 0.8-2.6 mg/kg LOQ: 2–6.4 mg/kg	Spizzirri et al. (2013)
Cheese	HIM, TYR, PUT, PHE, SPM, SPD	LC	0.1 M HCl SPE	–	ELSD	LOD: 1.4–3.6 mg/L LOQ: 3.6 —9.3 mg/L	Restuccia et al. (2011)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, PHE, SPM, SPD	LC	0.1 M HCl SPE	Dns-Cl	UV (254 nm)	LOD: 0.03–0.09 mg/L LOQ: 0.1–0.26 mg/L	Restuccia et al. (2011)
Reconstituted powdered milk and ready-to-use liquid milk	HIM, TYR, PUT, CAD,PHE, SPM, SPD	LC	Reconstituted powdered milk: 5 N HCl Liquid milk: SPE	Dns-Cl	UV (254 nm)	LOD Milk powder: 0.2–0.4 μg/g LOQ Milk powder: 0.5–1 μg/g LOD liquid milk:0.03–0.05 μg/ml LOQ liquid milk: 0.08–0.13 μg/ml	Spizzirri et al. (2019)
Acidified milk. Fermented milk. Fermented cream. Yogurt. Milk cheeses. Kefir. Fermented buttermilk	HIM, TYR, CAD, PUT, SPM	LC	0.6 M $HClO_4$	Dns-Cl	UV (254 nm)	Range: 0.5–29.4 mg/kg LOD: 0.24–1.39 mg/kg	Bunkova et al. (2013)
Yogurt and cheese	HIM, TYR, PUT, CAD, SPD	CE	6% TCA	–	Conductometry	LOD: 0.041 and 0.098 mg/L LOQ: 0.14–0.49 mg/L	Adımcılar et al. (2017)
Cheese	HIM, TYR, PHE, TRY	CE	5% TCA	–	UV (214 nm)	LOD: 2 mg/kg	Fernández-García (1999)
Cheese	HIM, TYR	CE	5% TCA	–	UV (214 nm)	–	Fernández-García (2000)
Cheese	HIM, TYR, TRY	CE	5% TCA	–	UV (214 nm)	LOD: 2 mg/kg	Gaya et al. (2005)

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TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD, TRY, PHE	CE	0.1 HCl	FITC	LIF (488 nm)	LOD: 0.5×10^{-10} M–1.5×10^{-10} M	Nouadje et al. (1995)
Milk	PUT, CAD, SPM, SPD	CE	5% $HClO_4$	–	PAD	LOD: 100–400 nM	X. Sun et al. (2003)
Cheese	HIM, TYR, PUT, CAD, AGM, TRY	CZE	0.1 M HCl	–	CD	LOD: 2–5 μmol/L LOQ: 5-15 μmol/L	Kvasnicka and Voldrich (2006)
Cheese	HIM, TYR, PUT, CAD	DLLME–GC	Acetonitrile/1-octanol	IBCF	MS	LOD: 5.9–14 ng/g LOQ: 19.7–46.2 ng/g	Mohammadi et al. (2016)
Cheese	PUT, CAD	GC	On-fiber derivatization (SPME)	TFAA	MS	–	Ali Awan et al. (2008)
Cheese	HIM, PUT, TYR, CAD	MAE-DLLME-GC	0.06 M HCl	IBCF	MS	LOD: 0.5–10,000 ng/g LOQ: 1.3-2.3 ng/g	Kamankesh et al. (2021)
Cheese	HIM	TLC	Methanol	–		LOD: 1.31 mg/L LOQ: 3.54 mg/L	Švarc-Gajic and Stojanovic (2011)
Cheese	HIM, TYR, PUT, CAD, TBA	TLC-densitometry method	5% TCA	Dns-cl	UV (254 nm)	–	Shalaby et al. (2016)
Cheese	HIM, TYR, PUT, CAD, TEA, TMA, AGM, SPM, SPD	LC (IEC)	MSA	–	CD	LOD: 23–65 μg/kg LOQ: 65–227 μg/kg	Palermo et al. (2012)
Cheese	HIM, TYR, PUT, CAD	LC (IEC)	Sodium citrate buffer	Ninhydrin	UV-Vis (570 nm)	0.24–1.39 mg/kg	Pachlova et al. (2012)

(Continues)

TABLE 2 (Continued)

Food	Biogenic amine	Analytical method	Sample treatment	Derivatizing reactive	Detection method	Detection limit	References
Cheese	HIM, TYR, PUT, CAD	LC (IEC)	Sodium citrate buffer	Ninhydrin	UV-Vis (570 nm)	LOD: 0.6-0.89 mg/kg	Bunková et al. (2010)
Cheese	HIM, TYR, PUT, CAD, SPM, TBA	LC (IEC)	10% TCA	Ninhydrin	Colorimetric (ex. 570 nm, em. 440 nm)	–	Rabie et al. (2011)
Cheese	HIM, TYR, PUT, CAD, SPM	LC (IEC)	0.375 M $HClO_4$	–	IPAD	LOD: 1.25–2.50 ng	Draisci et al. (1998)
Cheese	HIM	LC (IEC)	0.1 M HNO3	OPA	PCD-FL (ex. 360, em. 440 nm)	LOD: 0.15 mg/kg	Kouti et al. (2021)
Yoghurt and kefir	HIM	LC (IEC)	Methanol	OPA	FL (ex. 350 nm, em. 444 nm)	LOD: 0.175 mg/kg	Leszczyńska et al. (2004)

Abbreviations: 3-MBU, 3-methylbutylamine; AB, aminobutyric; AG, agmatine; ALA, β-alanine; AM, amylamine; AQC, 6-aminoquinolyl-N-hydroxysuccinimidylcarbamate; BCEC-CL, 2-(11H-benzo[a]-carbazol-11-yl) ethyl chloroformate; Bnz-Cl, benzoyl chloride; BU, butylamine; C4D, capacitively coupled contactless conductivity detection; CAD, cadaverine; CCR, 4′-carbonyl chloride rosamine; CD, conductivity detection; CE, capillary electrophoresis; CO, colamine; CZE, capillary zone electrophoresis; d3-4-MBA-OSu, N-hydroxysuccinimidyl ester of d0/d4-4-methoxybenzoic acid; Dbs-Cl, dabsyl chloride; DEEMM, ethoxymethyl malonate diethyl ester; DIM, dimethylamine; Dns-Cl, dansyle chloride; DLLME, dispersive liquid–liquid microextraction; DOP, dopamine; FIA, flow injection analysis; ET, ethylamine; ETH, ethanolamine; FITC, fluorescein; FL, fluorescence; FMOC-Cl, 9-fluorenylmethyl chloroformate; GC, gas chromatography; HCl, hydrochloric acid; $HClO_4$, perchloric acid; HE, hexylamine; HIM, histamine; IBCF, isobutyl chloroformate; H_2SO_4, sulfuric acid; IPAD, integrated pulsed amperometric detection; IPR, isopropylamine; IEC, ion exchange chromatography; IS, isoamylamine; ISO, isopentylamine; LIF, laser radiation; LOD, limit of detection; LOQ: limit of quantitation; MAE, microwave-assisted extraction; ME, methylamine; MS, mass spectrometry; MSA, methanesul-fonic acid; NBD-CL, 4-Chloro-7-nitrobenzofurazan; NDA, naphtalene-2,3-dicarboxyaldehyde; OCT, octopamine; OPA, o-phthalaldehyde; PAD, pulsed amperometric detection; PBS, phosphate-buffered saline; PHE, phenylethylamine; PRO, propylamine; PUT, putrescine; SAMF, 6-Oxy-(N-succinimidyl acetate)—9-(2′-methoxycarbonyl) fluorescein; SPD, spermidine; SPM, spermine; TBA, total biogenic amines; TCA, triclhoroacetic; TEA, triethylamine; TMA, trimethylamine; TLC, thin-layer chromatography; TMBB-Su, 1,3,5,7-tetramethyl-8-(N-hydroxysuccinimidyl butyric ester)-difluoroboradiaza-s-indacene; TRY, tryptamine; TYR, tyramine.

TABLE 3 Other analytical methods based on non-separation techniques to determine biogenic amines in dairy products

Food	Biogenic amines	Analytical method	Sample treatment	Detection limit	Reference
Cheese	HIM	ELISA	PBS	LOD: 2 mg/kg	Aygün et al. (1999)
Yoghurt and kefir	HIM	ELISA	Methanol	LOD: 0.125 mg/100 g	Leszczyńska et al. (2004)
Cheese	TYR	Biosensor +260 mV Inmobilization: Crosslinking with GA and BSA Crosslinking Mediator: Ferrocene Electrode: SPCE Enzyme: PAO	5% $HClO_4$	LOD: 2.0 ± 0.18 μM	Calvo-Pérez et al. (2013)
Cheese	TYR	Biosensor Inmobilization: Covalent conjugating Electrode: Au NPs Enzyme: TAO		LOD: 2.9 μM	Navarro et al. (2020)
Cheese	HIM	Biosensor Inmobilization: Surface adsorption Electrode: ITO NPs Enzyme: DAO		LOD: 2.7 μM	Kaçar et al. (2020)
Cheese	TYR	Biosensor Inmobilization: Adsorption Electrode: PVF/GRO Enzyme: DAO MAO		LOD: 0.61 μM	Erden et al. (2019)
Cheese	TYR	Biosensor Colorimetric test strips Enzyme:TAO	5% TCA	LOD = $2.6 \cdot 10^{-6}$ M	Oliver et al. (2021)

(Continues)

TABLE 3 (Continued)

Food	Biogenic amines	Analytical method	Sample treatment	Detection limit	Reference
Cheese	HIM, PUT, CAD	FIA Biosensor +700 mV Inmobilization: Crosslinking (GA+Gel) Electrode: Pt Enzyme: DAO	PBS	LOD: 6–12 μM	Carelli et al. (2007)
Cheese	HIM, TYR, PUT	Biosensor +700 mV Inmobilization: Crosslinking (GA- transglutaminase) Electrode: Pt-SPE Enzyme: PAO. TAO. DAO	5% TCA	LOD: 5-10 mg/kg	Lange and Wittman (2002)
Cheese	HIM, TYR, PUT, CAD, PHE	Biosensor +200 mV Inmobilization: Crosslinking (membraneþGA) and electropolymerization Electrode: GC-Pt and GC-Rh/Ru Enzyme: DAO	0.1 M HCl	DAO-GC-Rh/Ru (1 μM PUT. CAD. PHE; 10 μM TRY. 5 μM HIM and TYR) DAO-GC-Pt (0.5 μM PUT. HIM. TYR. PHE; 1 μM CAD. 2 μM TRY)	Compagnone et al. (2001)
Cheese	HIM, TYR, PUT, CAD, SPD, TRY	Ion-pair-assisted extraction followed by H-NMR	0.1 M HCl	LOD: 2.25–6.25 μg/g LOQ: 6.75–18.7 μg/g	Chatzimitakos et al. (2016)
Yoghurt	TYR	MIP electrochemical sensor	–	LOD: 5.7×10–8 M	Huang et al. (2011)

Abbreviations: CAD, cadaverine; DAO, diamine oxidase; ELISA, enzyme-linked immunosorbent assay; GA, glutaraldehyde; GC, gas Chromatography; HCl, hydrochloric acid; $HClO_4$, perchloric acid; HIM, histamine; LOD, limit of detection; LOQ, limit of quantitation; MIP, molecularly imprinted polymer; PAO, plamas amino oxidase; PBS, phosphate buffered saline; PBS, phosphate buffered saline; NMR, nuclear magnetic resonance spectroscopy; PHE, phenylethylamine; PUT, putrescine; SPD, spermidine; TAO, trypanosome alternative oxidase; TCA, Triclhoroacetic; TRY, tryptamine; TYR, tyramine.

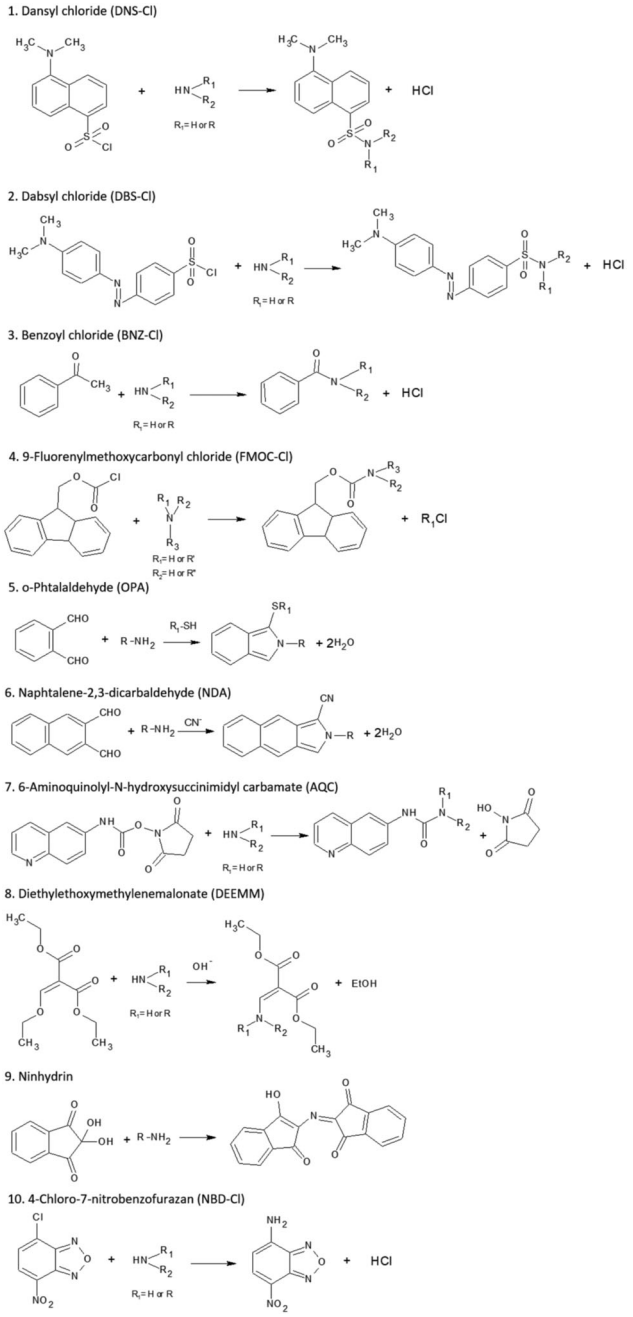

FIGURE 2 The most common derivatization reactions used for the determination of biogenic amines in dairy products with LC

Eerola et al. (1993) for the determination of BA in dry sausages has been modified and applied by several authors (Andiç et al., 2010, 2011; Contreras et al., 2007; Durlu-Özkaya, 2002; Ercan et al., 2019; Lanciotti et al., 2007; Marijan et al., 2014; Min et al., 2004; Tittarelli et al., 2019), in order to quantify BA in different cheeses. This method consists in a first step of acid extraction with 0.4 M $HClO_4$, followed by derivatization of the acid extract with DNS-Cl. Separation of the analytes is carried out by RP-HPLC with a C18 column, and the peaks are detected at 254 nm. The obtained limit of detection (LOD) varies between 1 mg/kg and 5 mg/kg for the different amines.

Another study which has been a reference for many authors (Bonczar et al., 2018; Esatbeyoglu et al., 2016; Forzale et al., 2011; Galgano et al., 2001; Gennaro et al., 2003; Martuscelli et al., 2005; Pluta-Kubica et al., 2020; Schirone et al., 2013; Zazzu et al., 2019) was published by Innocente et al. (2007). Improving upon a previous study by the same author (Innocente & D'Agostin, 2002), this method features a step of extraction of BA from cheese with 0.1 M HCl, after the derivatization of this extract with DNS-Cl. The addition of an L-proline solution is necessary to remove the excess of derivatizing reagent, after which the sample is extracted with diethyl ether, dried, and re-dissolved with ACN for injection. Forzale et al. (2011) used this method for the quantification of BA in several pecorino cheeses, obtaining better sensitivity than with methods based on the work of Eerola et al. (1993); they obtained a LOD of 0.3 mg/kg and a limit of quantitation (LOQ) of 1 mg/kg. A slight modification was proposed by Zazzu et al. (2019): detection was carried out at 218 nm instead of 254 nm, obtaining some improvement in terms of sensitivity (LOD 0.07 to 0.23 mg/kg).

Yang et al. (2016) developed an analytical method for the quantification of BA in cheese. It included a clean-up step using online SPE prior to separation. In spite of the fact that SPE is a cleaning and preconcentration tool, detection limits in that study ranged between 0.05 mg/kg and 0.25 mg/kg, which are not the best ones described in the literature for this derivatizing agent; still, the matrix effect of samples was reduced thanks to SPE. Some of the advantages of automatized analysis were the simplification of the sample pretreatment, as well as reduction of manual error, thereby resulting in a more efficient method.

BA have been also analyzed in commercial milk for infants and young children after derivatization with DNS-Cl and detection by UV-Vis (Spizzirri et al., 2019). Spizzirri used SPE (Supelclean ENVI-18Spe Tubes) for concentration and purification, but only for ready-to-use liquid milks, obtaining LOD one order of magnitude lower, in this case between 0.03 mg/L and 0.05 mg/L, than for powder milk samples.

Fluorescence detection

One example illustrating the better fluorometric properties of dansyl derivatives is the study by Standarová et al. (2010) carried out in 2010. They quantified seven different BA as dansyl derivatives in cheese, using FLD at 330 nm and 500 nm as excitation (ex.) and emission (em.) wavelengths, respectively, except for histamine, which was detected by UV. This method reached the lowest LOD (0.03 mg/kg for putrescine and cadaverine) published for these derivatives, to our knowledge. Excellent sensitivity was likewise

reported in the case of Ramos et al. (2020) who used SALLE as sample preparation step. In spite of good results with FLD, both studies showed that an UV detector is more appropriate for the determination of histamine. Several studies also reported LOD lower than 1 mg/kg for different BA in cheese using this system of detection (Brito et al., 2014; Sawilska-Rautenstrauch et al., 2010), thus achieving better sensitivity than most studies conducted with UV-Vis detection.

MS detection

Derivatization reactions are not only conducted with the purpose improving the detectability of analytes in terms of sensitivity and selectivity. Mazzucco et al. (2010) used a HPLC-MS method to validate a technique with UV detection for the determination of BA and amino acids in cheese and other foods. They found that dansyl derivatives decreased the matrix effect in the case of MS detection. As was expected, better LOD were achieved with this method compared with UV. The authors also included a SPE procedure for cleaning the dansylated sample extract.

That same year, La Torre et al. (2010) also combined dansyl derivatives with MS detection. They developed an excellent method with good linearity, free of matrix effects, and featuring high levels of sensitivity (ranging from 0.5 μg/L to 15 μg/L) for the determination of BA in donkey milk samples.

3.1.2 | Derivatization by dabsyl chloride

This derivatizing agent is a sulfonyl chloride analogous to DNS-Cl. It also acts on primary and secondary amino groups, obtaining compounds with good stability, although they are not detected by fluorescence (Toyo'oka, 1999).

UV-Vis detection

Several authors (Bockhardt et al., 1996; Calzada et al., 2013; Fernández et al., 2007; Valsamaki et al., 2000) have determined BA by extraction with 0.1 M HCl from dairy products, precolumn derivatization with DBS-Cl and UV-Vis detection (436 nm). Krause et al. (1995) pioneered this analytical method for the quantification of amino acids and BA in biological samples and food. LOD was between 0.12 pmol and 0.52 pmol, and repeatability was lower than 3.1%.

Also, Bockhardt et al. (1996) developed a method of derivatization with DBS-Cl in combination with a HPLC analysis for the determination of BA in cheese. Although they used a sample clean-up procedure by ultrafiltration, sensitivity was not improved as compared to the method of Krause et al. (1995) and the LOD was between 0.34 pmol and 0.76 pmol.

3.1.3 | Derivatization by benzoyl chloride

BNZ-Cl is another acyl chloride, similar to DNS-Cl or DBS-Cl, used for derivatization of amines, and obtaining shorter elution times than dansyl derivatives (Toyo'oka, 1999).

UV-Vis detection

Özdestan and Üren (2010) studied BA in kefir samples. They were extracted with 0.2 M HCl, and derivatization was subsequently carried out with BNZ-Cl. Benzamide derivatives were extracted with diethyl ether and redissolved with methanol, injected, and detected with UV at 254 nm. LOD lay between 0.2 mg/L and 2.5 mg/L, and linearity ranged between 133.6 mg/L and 1433 mg/L. Other authors used similar procedures or $HClO_4$ in the extraction step to quantify BA in yogurt (Paulo Vieira et al., 2020; Silva et al., 2019).

An important improvement with this derivatizing agent was the detection wavelength. Costa et al. (2015) quantified BA in fermented milks, and carried out detection at 198 nm. The detection limit thereby decreased to values between 0.03 mg/L and 1.30 mg/L, one order of magnitude lower than detection at 254 nm.

A remarkable analytical method was developed by Molaei et al. (2019) to quantify BA in Kashk, a sour yogurt, milk, and buttermilk used in Persian and Turkish cuisine. Histamine, cadaverine, putrescine, and tyramine were extracted and derivatized using SPE, based on magnetic mesoporous silica nanosorbent. Detection was carried out at 198 nm after chromatographic analysis. An excellent detection limit was reached (8 μg/L for Put), and reproducibility was lower than 4.14% of relative standard deviation (RSD).

MS detection

Using isotopically labeled BA as internal standards, Mayr and Schieberle (2012) developed an analytical method to quantify thirteen BA in several foods, including cheese and yogurt. Analysis of benzamide derivatives was carried out by LC-MS/MS. High sensitivity was reached (LOQ 0.05 μg/kg) and, thanks to the labeled BA, %RSD lower than 5.1% and a matrix effect-free method were obtained.

3.1.4 | Derivatization by 9-fluorenylmethoxycarbonyl chloride

This derivatizing agent has the considerable advantage of reacting not only with primary and secondary amines, but also with tertiary amines. The reaction product can be detected by FLD and UV (Toyo'oka, 1999).

Fluorescence detection

Kirschbaum et al. (1994) quantified BA in cheese after their extraction with 0.1 M HCl, precolumn derivatization with FMOC-Cl, and analysis by HPLC/FLD (ex. 265 nm, em. 315 nm). Only one step was required to remove the excess of reagent, thereby avoiding the interferences of hydrolysis products. Satisfactory detection limits were obtained for determination of BA in cheese, except for tryptamine and serotonine, for which the fluorescence quantum yield was too low.

3.1.5 | Derivatization by o-phthalaldehyde

As in the case of DNS-Cl, this reagent is preferably combined with FLD. Although it has been widely used (probably due to its versatility for pre-, on-, or postcolumn derivatization), it has the disadvantage of not reacting with secondary amines, and its products are less stable than dansyl or benzoyl derivatives (Peña-Gallego et al., 2012; Toyo'oka, 1999).

UV-Vis detection

Determination of BA in foods by o-phthalaldehyde (OPA) derivatization and UV detection is not very common in the literature: for dairy products, only studies of tyramine in cheese by Komprda et al. (2008) and Renes et al. (2014) were found. Komprda et al. (2008) extracted BA with 0.1 M HCl, and the extract was precolumn derivatized by OPA in borate buffer in the presence of 2-sulfonylethan-1-ol. Separation, after derivatization, was carried out with a C18 column, and tyramine was detected using a UV-Vis detector at 254 nm. Although the authors did not include figures of merit for this method, they reported concentrations of tyramine ranging from 5 mg/kg to 392 mg/kg; therefore, it can be supposed that LOD was lower than 5 mg/kg.

Fluorescence detection

Vale and Glória (1998) conducted the first determinations of BA in cheese using OPA as postcolumn derivatizing agent and FLD (340 nm for excitation and 445 nm for emission) (Gençcelep et al., 2008). They optimized the extraction of BA from cheese and the purification of the extracts, whereby 0.1 N HCl and diethyl ether were the best options, respectively. Good precision values, lower than 10% of RSD (except for tryptamine and agmantine) were obtained, and LOD was also acceptable (between 0.6 mg/kg and 1.4 mg/kg). Custódio et al. (2007) also tried out different extraction methods and analyzed the extracts according to the method described by Vale and Gloria (Gençcelep et al., 2008). They likewise concluded that HCl allowed for adequate extraction of BA from cheese; however, they stated that 1 M was more appropriate, resulting in better coefficients of variation.

Santos et al. (2003) conducted a study of formation of BA by *Lactococcus* in milk. BA were extracted with sulphosalicylic acid and analyzed by ion-pair HPLC/FLD after postcolumn derivatization with OPA. The same method was used by Gloria et al. (2011) for the determination of BA in milk, and they reported a highly satisfactory LOQ of < 0.010 mg/L.

3.1.6 | Derivatization by naphthalene-2,3-dicarboxaldehyde

Naphthalene-2,3-dicarboxaldehyde (NDA) has a structure analogous to OPA, although its derivatives are more stable: it can therefore be more properly used as a precolumn derivatizing agent (Toyo'oka, 1999). For analysis of BA in dairy products, FLD (ex 424 nm; em 494 nm) has mainly been used.

Fluorescence detection

Zotou and Notou (2012) developed an analytical method based on the derivatization of BA with NDA combined with analysis by HPLC–FLD for the quantification of BA in cheese. Several parameters of the reaction were studied: time of reaction, concentration of NDA and potassium cyanide (KCN) (used as nucleophile), and derivative stability (18 h at −4°C). The method's LOD lay between 0.6 mg/kg and 165 mg/kg. Some years later, the same authors developed an improvement based on zone-fluidics/HPLC (ZF-HPLC) for the simultaneous analyses of BA and online derivatization for the determination of BA in milk (Fernández et al., 2007). They managed to reduce the amount of NDA, the reaction time (3 instead of 30 min), and detection limits (0.6–6 μg/L in aqueous solutions).

3.1.7 | Derivatization by 6-aminoquinolyl-N-hydroxyuccinimidyl carbamate

6-Aminoquinolyl-N-hydroxyuccinimidyl carbamate (AQC) reacts rapidly with primary and secondary amines, obtaining highly stable derivatives that produce intense fluorescence signals. In spite of this, UV detection is mainly used for dairy products (Toyo'oka, 1999).

UV-Vis detection

A comparison between HPLC/FLD and UPLC/UV after derivatization of BA in cheese with AQC was carried out by Mayer et al. (2010). Results regarding differences in

sensitivity were not shown, and only detection limits with UV detection were supplied, ranging from 0.4 mg/kg to 16.2 mg/kg. In spite of the fact that the determination of AQC derivatives with UV has certain disadvantages, such as their lower signal intensity or a pronounced peak due to the byproduct of the AQC derivatization reaction, they were compensated by a much higher resolution due to the use of UPLC. It is remarkable that dopamine and tryptamine could only be detected by UV because they did not yield fluorescent-active AQC derivatives.

3.1.8 | Derivatization by diethylethoxymethylenemalonate

Diethylethoxymethylenemalonate (DEEMM) reacts with primary and secondary amines, and their derivatives remain stable for several weeks at room temperature. They can be detected by UV-Vis spectroscopy at 280 nm (Toyo'oka, 1999).

UV-Vis detection

Redruello et al. (2013) extracted BA and amino acids from cheese with 0.1 M HCl and quantified them after derivatization with DEEMM and analysis by UPLC. They validated the method, obtaining LOD lower than 0.15 mg/L and intraday repeatability much lower than 1% for BA (values estimated in standard mixtures). No significant effect of the cheese matrix was observed.

3.1.9 | Derivatization by ninhydrin

The reaction between this derivatizing agent and amines (NINHYDRIN only reacts with primary amines) yields purple, blue-violet-colored compounds (Toyo'oka, 1999). Ninhydrin is used for postcolumn derivatization, and only when high sensitivity is not required.

UV-Vis detection

Joosten and Olieman (1986) adapted the analytical method developed by LePage and Rocha (1983) for the determination of BA in cheese and other food products. BA were extracted from cheese using a trisodium citrate solution and 0.6 M trichloroacetic acid (TCA), separated by HPLC and detected after postcolumn derivatization at 546 nm. Although a significant disadvantage of this method lay in the extended amount of time required for it (1.5 h), good repeatability values (less than 10%) were nevertheless achieved. The detection limit for BA in cheeses was 2 mg/kg for each amine.

3.1.10 | Derivatization by 4-chloro-7-nitrobenzofurazan

4-Chloro-7-nitrobenzofurazan (NBD-Cl) reacts with primary and secondary amines, and their products are fluorescent. It is only used for precolumn derivatization (Toyo'oka, 1999).

UV-Vis detection

Despite the fluorescent properties of the NBD-Cl compound, in the case of dairy products it has only been used for UV detection. Yigit and Ersoy (2003) determined tyramine in cheese after extraction with 5% $HClO_4$ and derivatization with NBD-Cl. The reaction product was measured by UV at 458 nm after chromatographic separation on a C18 column. The LOD was 25 mg/kg, and the RSD was lower than 3%.

3.2 | Analytical methods based on LC without derivatization

Although BA are frequently determined after derivatization reactions in order to be analyzed by LC, some studies have quantified them directly. Some of the advantages of analyzing them without derivatization are shorter analysis times, as well as avoiding the cost of derivatizing agents (some of which are expensive), along with the waste products thereof and further solvents used during the derivatization process. Several detection modes have been used, but the development of MS has probably played the greatest role in the growth of the number of studies without derivatization.

One of the earliest detection modes studied was by Arlorio et al. (1998). They determined histamine, tyramine, 2-phenylethylamine, and tryptamine in cheese with ion-pair HPLC. The analytes were detected at 215 nm, and they compared sensitivity using an UV and a diode array detector (DAD), obtaining better results with DAD. One of their remarkable achievements was the addition of octylamine to the eluent in order to reduce peak asymmetry. Further authors (Andiç et al., 2011; Min et al., 2004; A. I. Ordóñez et al., 1997) have also used DAD as a detection method to analyze BA by HPLC.

One of the main reasons for using derivatization is the absence of chromophores, fluorophores or the very weak UV absorbance of some BA; however, the specificity of some detectors, such as a chemiluminescent nitrogen detector (CLND), could serve as a good solution, as was shown by J. Sun et al. (2011). They compared three different detection strategies: CLND, postcolumn derivatization

with ninhydrin, and a charged aerosol detector (CAD) after the separation of 14 BA by ion-pair HPLC and applied them in a variety of samples, including dairy beverages. Narrower peaks, better baselines, and excellent linearity were achieved with the CLND. In terms of sensitivity, detection limits ranged from 0.1 μg/ml to 0.4 μg/ml (estimated in standard solutions), which is lower than with ninhydrin, but not as good as other derivatizing agents.

The evaporative light scattering detector (ELSD) is also another possibility for the quantification of BA without derivatization, although it is not the most adequate one if a high sensitivity is required, as was shown by Restuccia et al. (2011). They compared a method based on LC-ELSD with a method based on derivatization by DNS-Cl for the determination of BA in cheese. Better repeatability was achieved with the derivatization method. As in the case of the CLND, good detection limits were estimated (lower than 3 mg/kg); however, they were not as good as those estimated with DNS-Cl.

In order to obtain very low detection limits without using derivatizing agents, MS needs to be used as a detector. Calbiani et al. (2005) obtained a LOD of 0.05 mg/kg (estimated in cheese samples) for histamine, with a method based on matrix solid phase dispersion (MSPD) followed by LC-MS. This method's figures of merit were highly satisfactory: excellent intraday repeatability (RSD lower than 5%) and linearity over two orders of magnitude.

The comparison carried out by Gosetti et al. (2007) between the analysis of native BA by LC-MS/MS and by LC-UV after derivatization with DNS-Cl showed that, in spite of the higher sensitivity of MS (LOD ranging from 5.1 μg/L to 35 μg/L in ricotta cheese, 1.7 to 22.5 μg/L in standard solutions), some parameters such as the linearity range are better when a derivatizing agent is used.

Draisci et al. (1998) integrated the pulsed amperometric detection method to IEC for the simultaneous determination of underivatized BA, obtaining recoveries ranging from 87.3% to 97.7% and a lower LOD of 1.25–2.50 ng in cheeses. Palermo et al. (2013) applied an analytical method based on IEC conductimetric detection for the determination of certain BA, and obtained recoveries of 82–103 % as well as good LOD, lying between 23 μg/kg and 65 μg/kg.

One of the difficulties of analyzing BA without derivatization is their bad chromatographic properties. Hydrophilic interaction chromatography (HILIC) offers a new possibility to avoid tedious derivatization processes. The hyphenation of HILIC and MS developed by Gianotti et al. (2008) to quantify seven BA in cheese is a perfect example of its possibilities (LOD ranging from 1.0 μg/L to 3.5 μg/L).

3.3 | Analytical methods based on capillary electrophoresis

CE is the second most commonly applied separation technique for the determination of BA in food. CE is sensitive, fast, uses small sample quantities, provides good precision, and does not require derivatization or sample cleaning (Karovičová & Kohajdová, 2005; Kvasnička & Voldřich, 2006). It is powered by high voltage electric fields and capillary separation. The separation is caused by the different mobility and distribution characteristics of each component in the sample (Shah et al., 2020). CE is efficient, but has a lower reproducibility of migration times than LC. Although it is a sensitive technique, its sensitivity is low compared to other methods (as results show below). Therefore, although derivatization is not compulsory, its use is generally recommended to solve the problem of determining BA in food samples. Detection can be carried out in two ways: either it is carried out directly with a UV detector or a DAD, or it is carried out after derivatization of BA with FLD (Etienne, 2006). Some of the reagents used are OPA, DNS-Cl, DBS-Cl, and β-naphthol (Karovičová & Kohajdová, 2005), with the same advantages and disadvantages previously explained for LC.

Nouadje et al. (1995) developed an analytical method based on CE and detection with a ball-lens laser-induced fluorescence detector for the determination of BA in cheeses, previously derivatizing them with fluorescein isothiocyanate (FITC). Detection limits ranged from 0.5 x 10^{-10} M to 1.5×10^{-10} M.

CE without derivatization has also been used for the quantification of BA in cheeses. Fernández-García et al. (1999, 2000) studied the influence of proteinases on the formation of biogenic amines. They were analyzed by CE and detected at 214 nm. The lowest amount of histamine they found was 2.84 mg/kg.

Pulsed amperometric detection (PAD) also offers a possibility for the detection of BA after separation by CE (X. Sun et al., 2003). Ten grams of fresh milk were homogenized with 6 ml of 5% $HClO_4$ for 30 min and centrifuged at 5000 rpm for 10 min. LOD ranged from 10^{-7} M to 4 10^{-7} M. Linearity was two orders of magnitude. Putrescine, cadaverine, spermidine, and spermine were searched for in six different samples, but only spermidine was found.

Kvasnička and Voldřich (2006) developed a capillary zone electrophoresis (CZE) method with conductometric detection for the determination of BA in different foods. For the analysis of two different cheeses, 5 g were extracted with 100 ml of 0.1 M HCl for 30 min in ultrasonic bath. The mixture was then filtered and diluted with demineralized

water before analysis. Linearity lay between 0 μmol/ml and 100 μmol/ml, and LOD ranged from 2 μmol/L to 5 μmol/L.

More recently, a faster method (less than 6 min) based on CE and conductivity detection was applied for the analysis of five different BA in yogurt, kefir, and cheese (Adımcılar et al., 2018). LOD ranged from 0.041 mg/L to 0.098 mg/L, and reproducibility was highly satisfactory (less than 4.25% RSD), as in the previous method.

3.4 | Analytical methods based on thin layer chromatography

TLC is used as a technique for the rapid separation and determination of small amounts of substances. In terms of advantages, TLC is a simple method, does not involve special equipment, and can analyze several samples at the same time (Hernández-Cassou & Saurina, 2011; Önal, 2007; Özdestan & Üren, 2009; Zhang et al., 2019). Nevertheless, in some cases, an excessive amount of time is required for analysis, and results are not sufficiently accurate (Bockhardt et al., 1996; Lázaro de la Torre & Conte-Júnior, 2014; Önal, 2007). The use of a variety of derivatizing agents to determine BA is a common practice.

The first TLC method for determining BA in cheese samples was the one developed by Shalaby (1999). They were extracted with TCA and then derivatized with DNS-Cl. Separation of the dansyl derivatives was achieved on silica gel TLC plates and quantified by densitometry at 254 nm. The limit of detection ranged from 5 ng to 10 ng, and the precision, expressed as %RSD, ranged from 0.15% to 4.41%.

Pham and Nguyen (2016) carried out a study of BA in milk using HPLC and TLC. They demonstrated the use of the TLC technique as a qualitative method and HPLC as a quantitative method to determine histamine. Ninhydrin was sprayed in TLC technique, and a purple spot appeared when histamine was present. The quantitative result was obtained by HPLC.

Švarc-Gajic and Stojanovic (2011) determined histamine concentration in cheese using the chronopotentiometric technique as a detection method after purification of the extract by TLC. LOD was 1.31 mg/L. This is a simple, rapid cheese histamine analysis technique, cheaper than other chromatographic techniques, although its sensitivity is not as good.

3.5 | Analytical methods based on gas chromatography

The volatility and polarity of BA is one of the reasons why the GC technique is not usually applied to determine them; derivatization is thus frequently used to improve those properties (Karovičová & Kohajdová, 2005; Lázaro de la Torre & Conte-Júnior, 2014; Papageorgiou et al., 2018). Frequently analyzed derivatives are trifluoroacetyl, trimethylsilyl or 2,4-dinitrophenyl (Kielwein et al., 1996). The most common detectors used to quantify them are flame ionization detectors (FID), electron capture detectors (ECD), and MS (Etienne, 2006; Kielwein et al., 1996; Silla Santos, 1996).

The number of studies that have analyzed BA in dairy products by GC is low. One featured technique is the analytical method developed by Ali Awan et al. (2008) for the determination of putrescine and cadaverine by SPME–GC–MS. This method is based on on-fiber derivatization using trifluoroacetylacetone (TFAA). Automatization is one of its main advantages, along with the fact that is matrix effect free. Although the authors generally applied the method by GC-MS, they applied it to cheese samples by GC-FID, whereby the concentration of Put and Cad was of 38 and 22 mg/kg, respectively.

Some authors have used GC-MS as a rapid and sensitive method for the analysis of BA in cheese samples (Kamankesh et al., 2021; Mohammadi et al., 2017). Mohammadi et al. (2017) also used simultaneous derivatization and microextraction to quantify BA in cheese samples. In this case, the derivatizing agent was isobutyl chloroformate (IBCF), and the microextraction technique was MAE–DLLME. Derivatization products were detected by GC-MS. The LOD for cheese samples ranged from 5.9 μg/kg to 14 μg/kg, which lies in the range of other works.

3.6 | Rapid methods

3.6.1 | ELISA

ELISA-based methods started to be developed in the 1970s, and they have been expanded since then, mainly due to their speed and low cost (Vaz et al., 2020). The first time that a competitive direct-ELISA (CD-ELISA) was applied to the determination of histamine in cheese was in Aygün et al. (1999). They compared their results with a HPLC method and found a good agreement, although some differences were found in the low concentration range from 2 mg/kg to 10 mg/kg. The LOD of the ELISA method (2 mg/kg) enabled detection of histamine at levels well below those that have been considered safe. They also showed one of the main advantages of ELISA methods: their speed. While more than 30 samples per day could be evaluated by CD-ELISA, the maximum daily evaluation achieved by the LC method was 10 samples of cheese.

Leszczyocha and Pytasz (2018) also compared an ELISA method with a spectrofluorimetric method, but in this case for the determination of histamine in yogurt and

kefir. Their comparison evidenced the possibilities of the immunoenzymatic method, which is faster and, in this case, more sensitive than the reference method, although more expensive and less precise, while adequate for higher concentrations.

3.6.2 | Biosensors

Development and use of sensors and biosensors have been growing exponentially in the last decades. Speed, low price, ease of use, and the minimum required amount of sample are some of the advantages that have contributed to their expansion in a wide number of sectors, including the food industry (Ahangari et al., 2021; Salleres et al., 2016).

Most biosensors used to quantify BA in dairy products are based on electrochemical responses (Compagnone et al., 2001; Rotariu et al., 2016) of the detection of hydrogen peroxide, generated as a byproduct in BA oxidation, catalyzed by amino oxidase enzymes (Calvo-Pérez et al., 2013; Oliver et al., 2021). Other systems also exist, such as the molecularly imprinted electrochemical sensor developed by Huang et al. (2011) for the determination of tyramine in yogurt samples. The LOD was 5.7×10^{-8} M, and the sensor exhibited an excellent selectivity and repeatability.

Compagnone et al. (2001) studied BA by amperometric detection in cheese using immobilized diamine oxidase (DAO). Two different systems were optimized to respond to six BA. The best system's sensitivity ranged from 5×10^{-7} to 2×10^{-6} M, with three orders of magnitude of linearity and good reproducibility (1–3% RSD). Operational lifetime was calculated to last for 300 samples.

The problem of using amine oxidases in biosensors to quantify BA is that most amine oxidases do not react to a single BA, but to several amines. Lange and Wittmann (2002) solved this problem for the determination of histamine, tyramine, and putrescine in different foods (two different cheeses were analyzed) by immobilizing three different amine oxidases and applying neural networks for pattern recognition. The LOD was 10 mg/kg for histamine and tyramine and 5 mg/kg for putrescine. This system was compared with a HPLC method, and good correlation between results was found. This comparison revealed one of the main drawbacks of some biosensors: false-positive and false-negative results, which reached 12% and 25%, respectively.

Selectivity problems were also shown by Carelli et al. (2007), who reported the total content of BA in cheese expressed as histamine equivalents, assuming that it was not possible to discriminate the contribution of each biogenic amine to the biosensor. In order to remove certain interferences, the authors developed a biosensor based on DAO, entrapped by glutaraldehyde, onto an electrosynthesized bilayer film, after having studied different electrodes and films. The sensitivity achieved with this system was high, with LOD between 6 μM and 12 μM.

Calvo-Pérez et al. (2013) developed an amperometric biosensor for the determination of tyramine in cheese, and they used a redox mediator (hydroxymethylferrocene) to reduce the applied potential and thereby decrease the possibility of interferences in the electrochemical measurement. In this case, the detection is based on the signal produced during the reduction of the mediator, instead of the electrochemical detection of H_2O_2 as in most of these systems. The enzyme used was plasma amine oxidase (PAO), and it was immobilized on a screen-printed carbon electrode. The LOD was 2 μM.

Recently, two different biosensors have been developed for the quantification of tyramine in cheese (Navarro et al., 2020; Oliver et al., 2021). One of them (Navarro et al., 2020) is based on the colorimetric determination (540 nm) of gold nanoparticles generated when Au (III) is reduced in the oxidase enzymatic reaction, using tyramine oxidase (TAO) as enzyme. A higher sensitivity is obtained after 30 min of reaction, although results can be achieved more rapidly (after 4 min) if reaction takes place at 50°C. Reproducibility was high (5.6% RSD), and the LOD was 2.9×10^{-6} M. Another biosensor (Oliver et al., 2021) (with similar analytical characteristics) has two important advantages: pretreatment of cheese is not necessary for determination, and measurements are conducted using a smartphone. This system is based on colorimetric test strips containing TAO, peroxidase, and 3,3′,5,5′-tetramethylbenzidine, which are added to the sample for 2 min for the reaction to take place, after which the RGB color coordinates are measured.

4 | CONCLUSION

The considerable number of studies that analyze BA in dairy products reflect general concern about the presence and concentration of BA in this kind of product, in view of the adverse health effects produced by their ingestion, especially in histamine-sensitive or allergic patients. The most common sample pretreatment previous to BA analysis is extraction with acids or solvents to precipitate the proteins and extract the analytes from the matrix. Some studies improve on cleanliness and sensitivity by using SPE; however, a greater number of steps is not always worth the effort. Without a doubt, the most widely used analytical technique for the determination of BA is HPLC with derivatization: sensitivity, the structure of the BA, and the detection technique are the three main reasons for choosing one of the numerous derivatizing agents. One of these techniques' most important drawbacks is their slowness; the development of rapid methods, such

as biosensors, is thus slightly on the increase (less than in other matrices), with good results in terms of sensitivity, although specificity still needs to be improved.

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AUTHOR CONTRIBUTIONS

Marta Moniente: conceptualization; data curation; writing – original draft; writing – review & editing. **Laura Botello-Morte**: conceptualization; writing – review & editing. **Diego García-Gonzalo**: Writing – review & editing. **Rafael Pagán**: conceptualization; funding acquisition; project administration; writing – review & editing. **Ignacio Ontañón**: conceptualization; data curation; supervision; writing – original draft; writing – review & editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

Adımcılar, V., Öztekin, N., & Bedia, E. (2017). A Direct and Sensitive Analysis Method for Biogenic Amines in Dairy Products by Capillary Electrophoresis Coupled with Contactless Conductivity Detection. 4(C D).

Adımcılar, V., Öztekin, N., & Erim, F. B. (2018). A direct and sensitive analysis method for biogenic amines in dairy products by capillary electrophoresis coupled with contactless conductivity detection. *Food Analytical Methods*, *11*(5), 1374–1379. https://doi.org/10.1007/s12161-017-1122-9

Ahangari, H., Kurbanoglu, S., Ehsani, A., & Uslu, B. (2021). Latest trends for biogenic amines detection in foods: Enzymatic biosensors and nanozymes applications. *Trends in Food Science and Technology*, *112*, 75–87. https://doi.org/10.1016/j.tifs.2021.03.037

Ali Awan, M., Fleet, I., & Paul Thomas, C. L. (2008). Determination of biogenic diamines with a vaporisation derivatisation approach using solid-phase microextraction gas chromatography-mass spectrometry. *Food Chemistry*, *111*(2), 462–468. https://doi.org/10.1016/j.foodchem.2008.03.068

Alonso-Lomillo, M. A., Domínguez-Renedo, O., Matos, P., & Arcos-Martínez, M. J. (2010). Disposable biosensors for determination of biogenic amines. *Analytica Chimica Acta*, *665*(1), 26–31. https://doi.org/10.1016/j.aca.2010.03.012

Andiç, S., Genccelep, H., & Kose, S. (2010). Determination of biogenic amines in Herby cheese. *International Journal of Food Properties*, *13*(6), 1300–1314. https://doi.org/10.1080/10942910903061869

Andiç, S., Tunçtürk, Y., & Gençcelep, H. (2011). The effect of different packaging methods on the formation of biogenic amines and organic acids in Kashar cheese. *Journal of Dairy Science*, *94*(4), 1668–1678. https://doi.org/10.3168/jds.2010-3586

Arlorio, M., Coïsson, J. D., & Martelli, A. (1998). Ion-pair HPLC determination of biogenic amines and precursor aminoacids. Application of a method based on simultaneous use of heptanesulphonate and octylamine to some foods. *Chromatographia*, *48*(11–12), 763–769. https://doi.org/10.1007/BF02467645

Ascone, P., Maurer, J., Haldemann, J., Irmler, S., Berthoud, H., Portmann, R., Fröhlich-Wyder, M. T., & Wechsler, D. (2017). Prevalence and diversity of histamine-forming Lactobacillus parabuchneri strains in raw milk and cheese – A case study. *International Dairy Journal*, *70*, 26–33. https://doi.org/10.1016/j.idairyj.2016.11.012

Aygün, O., Schneider, E., Scheuer, R., Usleber, E., Gareis, M., & Märtlbauer, E. (1999). Comparison of ELISA and HPLC for the determination of histamine in cheese. *Journal of Agricultural and Food Chemistry*, *47*(5), 1961–1964. https://doi.org/10.1021/jf980901f

Benkerroum, N. (2016). Biogenic amines in Dairy products: Origin, incidence, and control means. *Comprehensive Reviews in Food Science and Food Safety*, *15*(4), 801–826. https://doi.org/10.1111/1541-4337.12212

Biji, K. B., Ravishankar, C. N., Venkateswarlu, R., Mohan, C. O., & Gopal, T. K. S. (2016). Biogenic amines in seafood: A review. *Journal of Food Science and Technology*, *53*(5), 2210–2218. https://doi.org/10.1007/s13197-016-2224-x

Bockhardt, A., Krause, I., & Klostermeyer, H. (1996). Determination of biogenic amines by RP-HPLC of the dabsyl derivates. *Zeitschrift Fur Lebensmittel-Untersuchung Und-Forschung*, *203*(1), 65–70. https://doi.org/10.1007/BF01267772

Bonczar, G., Filipczak-Fiutak, M., Pluta-Kubica, A., Duda, I., Walczycka, M., & Staruch, L. (2018). The range of protein hydrolysis and biogenic amines content in selected acid- and rennet-curd cheeses. *Chemical Papers*, *72*(10), 2599–2606. https://doi.org/10.1007/s11696-018-0490-y

Brito, C., Cid, N., Muñoz, O., Báez, A., & Horzella, M. (2014). Biogenic amine content in Chilean Gauda cheese: Physico-chemical and microbiological factors that may influence this content. *International Journal of Dairy Technology*, *67*(4), 554–561. https://doi.org/10.1111/1471-0307.12148

Bunkova, L., Adamcova, G., Hudcova, K., Velichova, H., Pachlova, V., Lorencova, E., & Bunka, F. (2013). Monitoring of biogenic amines in cheeses manufactured at small-scale farms and in fermented dairy products in the Czech Republic. *Food Chemistry*, *141*(1), 548–551. https://doi.org/10.1016/j.foodchem.2013.03.036

Buňková, L., Buňka, F., Mantlová, G., Čablová, A., Sedláček, I., Švec, P., Pachlová, V., & Kráčmar, S. (2010). The effect of ripening and storage conditions on the distribution of tyramine, putrescine and

cadaverine in Edam-cheese. *Food Microbiology*, *27*(7), 880–888. https://doi.org/10.1016/j.fm.2010.04.014

Calbiani, F., Careri, M., Elviri, L., Mangia, A., Pistarà, L., & Zagnoni, I. (2005). Rapid assay for analyzing biogenic amines in cheese: Matrix solid-phase dispersion followed by liquid chromatography-electrospray-tandem mass spectrometry. *Journal of Agricultural and Food Chemistry*, *53*(10), 3779–3783. https://doi.org/10.1021/jf048037g

Calvo-Pérez, A., Domínguez-Renedo, O., Alonso-Lomillo, M. A., & Arcos-Martínez, M. J. (2013). Disposable amperometric biosensor for the determination of tyramine using plasma amino oxidase. *Microchimica Acta*, *180*(3–4), 253–259. https://doi.org/10.1007/s00604-012-0926-y

Calzada, J., Del Olmo, A., Picon, A., Gaya, P., & Nuñez, M. (2013). Proteolysis and biogenic amine buildup in high-pressure treated ovine milk blue-veined cheese. *Journal of Dairy Science*, *96*(8), 4816–4829. https://doi.org/10.3168/jds.2012-6409

Cao, L. W., Wang, H., Li, J. S., & Zhang, H. S. (2005). 6-Oxy-(N-succinimidyl acetate)-9-(2′-methoxycarbonyl)fluorescein as a new fluorescent labeling reagent for aliphatic amines in environmental and food samples using high-performance liquid chromatography. *Journal of Chromatography A*, *1063*(1–2), 143–151. https://doi.org/10.1016/j.chroma.2004.11.093

Carelli, D., Centonze, D., Palermo, C., Quinto, M., & Rotunno, T. (2007). An interference free amperometric biosensor for the detection of biogenic amines in food products. *Biosensors and Bioelectronics*, *23*(5), 640–647. https://doi.org/10.1016/j.bios.2007.07.008

Chatzimitakos, T., Exarchou, V., Ordoudi, S. A., Fiamegos, Y., & Stalikas, C. (2016). Ion-pair assisted extraction followed by 1H NMR determination of biogenic amines in food and biological matrices. *Food Chemistry*, *202*, 445–450. https://doi.org/10.1016/j.foodchem.2016.02.013

Chen, R. F. (1967). Fluorescence of dansyl amino acids in organic solvents and protein solutions. *Archives of Biochemistry and Biophysics*, *120*(3), 609–620. https://doi.org/10.1016/0003-9861(67)90526-7

Combarros-Fuertes, P., Fernández, D., Arenas, R., Diezhandino, I., Tornadijo, M. E., & Fresno, J. M. (2016). Biogenic amines in Zamorano cheese: Factors involved in their accumulation. *Journal of the Science of Food and Agriculture*, *96*(1), 295–305. https://doi.org/10.1002/jsfa.7093

Compagnone, D., Isoldi, G., Moscone, D., & Palleschi, G. (2001). Amperometric detection of biogenic amines in cheese using immobilised diamine oxidase. *Analytical Letters*, *34*(6), 841–854. https://doi.org/10.1081/AL-100103596

Contreras, M., Izquierdo, P., Allara, M., García, A., Torres, G., & Céspedes, E. (2007). Determinarion of biogenic amines in matured cheeses. *Revista Cientifica de La Facultad de Ciencias Veterinarias de La Universidad Del Zulia*, *17*(1), 89–95.

Costa, M. P., Balthazar, C. F., Rodrigues, B. L., Lazaro, C. A., Silva, A. C. O., Cruz, A. G., & Conte Junior, C. A. (2015). Determination of biogenic amines by high-performance liquid chromatography (HPLC-DAD) in probiotic cow's and goat's fermented milks and acceptance. *Food Science and Nutrition*, *3*(3), 172–178. https://doi.org/10.1002/fsn3.200

Costa, M. P., Rodrigues, B. L., Frasao, B. S., & Conte-Junior, C. A. (2018). Biogenic amines as food quality index and chemical risk for human consumption. *Food Quality: Balancing Health and Disease*, *13*, 75–108. https://doi.org/10.1016/B978-0-12-811442-1.00002-X

Custódio, F. B., Tavares, É., & Glória, M. B. A. (2007). Extraction of bioactive amines from grated parmesan cheese using acid, alkaline and organic solvents. *Journal of Food Composition and Analysis*, *20*(3–4), 280–288. https://doi.org/10.1016/j.jfca.2006.06.009

Deabes, M. M., Hassan, F. A. M., & Enab, K. (2013). Biogenic amines and chemical composition of different formulations used for manufacture of processed cheese 1. *9*(3), 1477–1483.

del Rio, B., Redruello, B., Linares, D. M., Ladero, V., Fernandez, M., Martin, M. C., Ruas-Madiedo, P., & Alvarez, M. A. (2017). The dietary biogenic amines tyramine and histamine show synergistic toxicity towards intestinal cells in culture. *Food Chemistry*, *218*, 249–255. https://doi.org/10.1016/j.foodchem.2016.09.046

del Rio, B., Redruello, B., Linares, D. M., Ladero, V., Ruas-Madiedo, P., Fernandez, M., Martin, M. C., & Alvarez, M. A. (2018). Spermine and spermidine are cytotoxic towards intestinal cell cultures, but are they a health hazard at concentrations found in foods? *Food Chemistry*, *269*, 321–326. https://doi.org/10.1016/j.foodchem.2018.06.148

Draisci, R., Giannetti, L., Boria, P., Lucentini, L., Palleschi, L., & Cavalli, S. (1998). Improved ion chromatography-integrated pulsed amperometric detection method for the evaluation of biogenic amines in food of vegetable or animal origin and in fermented foods. *Journal of Chromatography A*, *798*(1–2), 109–116. https://doi.org/10.1016/S0021-9673(97)01198-9

Durlu-Özkaya, F. (2002). Biogenic amine content of some Turkish cheeses. *Journal of Food Processing and Preservation*, *26*(4), 259–265. https://doi.org/10.1111/j.1745-4549.2002.tb00483.x

Eerola, S., Hinkkanen, R., Lindfors, E., & Hirvi, T. (1993). Liquid chromatographic determination of biogenic amines in dry sausages. *Journal of AOAC International*, *76*(3), 575–577. https://doi.org/10.1093/jaoac/76.3.575

Ercan, S. Ş., Soysal, Ç., & Bozkurt, H. (2019). Biogenic amine contents of fresh and mature kashar cheeses during refrigerated storage. *Food and Health*, *5*(1), 19–29. https://doi.org/10.3153/FH19003

Erden, P. E., Erdoğan, Z. Ö., Öztürk, F., Koçoğlu, İ. O., & Kılıç, E. (2019). Amperometric Biosensors for Tyramine Determination Based on Graphene Oxide and Polyvinylferrocene Modified Screen-printed Electrodes. *Electroanalysis*, *31*(12), 2368–2378. https://doi.org/10.1002/ELAN.201900369

Esatbeyoglu, T., Ehmer, A., Chaize, D., & Rimbach, G. (2016). Quantitative determination of spermidine in 50 German cheese samples on a core-shell column by high-performance liquid chromatography with a photodiode array detector using a fully validated method. *Journal of Agricultural and Food Chemistry*, *64*(10), 2105–2111. https://doi.org/10.1021/acs.jafc.6b00078

Etienne, M. (2006). Methodology for histamine and biogenic amines analysis. Seafoodplus Traceability. Seafoodplus traceability. project 6.3 - valid. https://archimer.ifremer.fr/doc/00000/6484/

Farooqui, T. (2013). A potential link among biogenic amines-based pesticides, learning and memory, and colony collapse disorder: A unique hypothesis. *Neurochemistry International*, *62*(1), 122–136. https://doi.org/10.1016/j.neuint.2012.09.020

Fernández, M., Del Río, B., Linares, D. M., Martín, M. C., & Alvarez, M. A. (2006). Real-time polymerase chain reaction for quantitative detection of histamine-producing bacteria: Use in cheese

production. *Journal of Dairy Science*, *89*(10), 3763–3769. https://doi.org/10.3168/jds.S0022-0302(06)72417-1

Fernández, M., Linares, D. M., Del Río, B., Ladero, V., & Alvarez, M. A. (2007). HPLC quantification of biogenic amines in cheeses: Correlation with PCR-detection of tyramine-producing microorganisms. *Journal of Dairy Research*, *74*(3), 276–282. https://doi.org/10.1017/S0022029907002488

Fernández-García, E., Tomillo, J., & Núñez, M. (1999). Effect of added proteinases and level of starter culture on the formation of biogenic amines in raw milk Manchego cheese. *International Journal of Food Microbiology*, *52*(3), 189–196. https://doi.org/10.1016/S0168-1605(99)00144-0

Fernández-García, E., Tomillo, J., & Nunez, M. (2000). Formation of biogenic amines in raw milk Hispanico cheese manufactured with proteinases and different levels of starter culture. *Journal of Food Protection*, *63*(11), 1551–1555. https://doi.org/10.4315/0362-028X-63.11.1551

Fiechter, G., Sivec, G., & Mayer, H. K. (2013). Application of UHPLC for the simultaneous analysis of free amino acids and biogenic amines in ripened acid-curd cheeses. *Journal of Chromatography B: Analytical Technologies in the Biomedical and Life Sciences*, *927*, 191–200. https://doi.org/10.1016/j.jchromb.2012.12.006

Flasarová, R., Pachlová, V., Buňková, L., Menšíková, A., Georgová, N., Dráb, V., & Buňka, F. (2016). Biogenic amine production by *Lactococcus lactis* subsp. *cremoris* strains in the model system of Dutch-type cheese. *Food Chemistry*, *194*(2), 68–75. https://doi.org/10.1016/j.foodchem.2015.07.069

Forzale, F., Giorgi, M., Pedonese, F., Nuvoloni, R., D'Ascenzi, C., & Rindi, S. (2011). Biogenic amine content in "Pecorino Del Parco Di Migliarino—San Rossore". *Italian Journal of Food Safety*, *1*(0), 149–153. https://doi.org/10.4081/ijfs.2011.1s.149

Galgano, F., Suzzi, G., Favati, F., Caruso, M., Martuscelli, M., Gardini, F., & Salzano, G. (2001). Biogertic amines during ripening in 'Semicotto Caprino'cheese: Role of enterococci. *International Journal of Food Science and Technology*, *36*(2), 153–160. https://doi.org/10.1046/j.1365-2621.2001.00443.x

Gao, P. F., Guo, X. F., Wang, H., & Zhang, H. S. (2011). Determination of trace biogenic amines with 1,3,5,7-tetramethyl-8-(N-hydroxysuccinimidyl butyric ester)-difluoroboradiaza-s-indacene derivatization using high-performance liquid chromatography and fluorescence detection. *Journal of Separation Science*, *34*(12), 1383–1390. https://doi.org/10.1002/jssc.201100120

García-Villar, N., Hernández-Cassou, S., & Saurina, J. (2009). Determination of biogenic amines in wines by pre-column derivatization and high-performance liquid chromatography coupled to mass spectrometry. *Journal of Chromatography A*, *1216*(36), 6387–6393. https://doi.org/10.1016/j.chroma.2009.07.029

Gardini, F., Rossi, F., Rizzotti, L., Torriani, S., Grazia, L., Chiavari, C., Coloretti, F., & Tabanelli, G. (2012). Role of Streptococcus thermophilus PRI60 in histamine accumulation in cheese. *International Dairy Journal*, *27*(1–2), 71–76. https://doi.org/10.1016/j.idairyj.2012.07.005

Gaya, P., Sánchez, C., Nuñez, M., & Fernández-García, E. (2005). Proteolysis during ripening of Manchego cheese made from raw or pasteurized ewes' milk. Seasonal variation. *Journal of Dairy Research*, *72*(3), 287–295. https://doi.org/10.1017/S0022029905001019

Gençcelep, H., Kaban, G., Aksu, M. I., Öz, F., & Kaya, M. (2008). Determination of biogenic amines in sucuk. *Food Control*, *19*(9), 868–872. https://doi.org/10.1016/j.foodcont.2007.08.013

Gennaro, M. C., Gianotti, V., Marengo, E., Pattono, D., & Turi, R. M. (2003). A chemometric investigation of the effect of the cheese-making process on contents of biogenic amines in a semi-hard Italian cheese (Toma). *Food Chemistry*, *82*(4), 545–551. https://doi.org/10.1016/S0308-8146(03)00009-8

Gianotti, V., Chiuminatto, U., Mazzucco, E., Gosetti, F., Bottaro, M., Frascarolo, P., & Gennaro, M. C. (2008). A new hydrophilic interaction liquid chromatography tandem mass spectrometry method for the simultaneous determination of seven biogenic amines in cheese. *Journal of Chromatography A*, *1185*(2), 296–300. https://doi.org/10.1016/j.chroma.2008.02.038

Gloria, M. B. A., Saraiva, P. R. L., Rigueira, J. C. S., & Brandão, S. C. C. (2011). Bioactive amines changes in raw and sterilised milk inoculated with *Pseudomonas fluorescens* stored at different temperatures. *International Journal of Dairy Technology*, *64*(1), 45–51. https://doi.org/10.1111/j.1471-0307.2010.00637.x

Gobbi, L., Ciano, S., Rapa, M., & Ruggieri, R. (2019). Biogenic amines determination in "Plant Milks". *Beverages*, *5*(2), 40. https://doi.org/10.3390/beverages5020040

Gosetti, F., Mazzucco, E., Gianotti, V., Polati, S., & Gennaro, M. C. (2007). High performance liquid chromatography/tandem mass spectrometry determination of biogenic amines in typical Piedmont cheeses. *Journal of Chromatography A*, *1149*(2), 151–157. https://doi.org/10.1016/j.chroma.2007.02.097

Guo, Y. Y., Yang, Y. P., Peng, Q., & Han, Y. (2015). Biogenic amines in wine: A review. *International Journal of Food Science and Technology*, *50*(7), 1523–1532. https://doi.org/10.1111/ijfs.12833

He, Y., Zhao, X. E., Wang, R., Wei, N., Sun, J., Dang, J., Chen, G., Liu, Z., Zhu, S., & You, J. (2016). Simultaneous determination of food-related biogenic amines and precursor amino acids using in situ derivatization ultrasound-assisted dispersive liquid-liquid microextraction by ultra-high-performance liquid chromatography tandem mass spectrometry. *Journal of Agricultural and Food Chemistry*, *64*(43), 8225–8234. https://doi.org/10.1021/acs.jafc.6b03536

Henao-Escobar, W., Domínguez-Renedo, O., Asunción Alonso-Lomillo, M., & Julia Arcos-Martínez, M. (2013). Simultaneous determination of cadaverine and putrescine using a disposable monoamine oxidase based biosensor. *Talanta*, *117*, 405–411. https://doi.org/10.1016/j.talanta.2013.09.043

Hernández-Cassou, S., & Saurina, J. (2011). Derivatization strategies for the determination of biogenic amines in wines by chromatographic and electrophoretic techniques. *Journal of Chromatography B: Analytical Technologies in the Biomedical and Life Sciences*, *879*(17–18), 1270–1281. https://doi.org/10.1016/j.jchromb.2010.11.020

Herrero-Fresno, A., Martínez, N., Sánchez-Llana, E., Díaz, M., Fernández, M., Martin, M. C., Ladero, V., & Alvarez, M. A. (2012). *Lactobacillus casei* strains isolated from cheese reduce biogenic amine accumulation in an experimental model. *International Journal of Food Microbiology*, *157*(2), 297–304. https://doi.org/10.1016/j.ijfoodmicro.2012.06.002

Huang, J., Xing, X., Zhang, X., He, X., Lin, Q., Lian, W., & Zhu, H. (2011). A molecularly imprinted electrochemical sensor based on multiwalled carbon nanotube-gold nanoparticle composites

and chitosan for the detection of tyramine. *Food Research International*, *44*(1), 276–281. https://doi.org/10.1016/j.foodres.2010.10.020

Ibrahim, M. A., & Amer, A. (2010). Comparison of biogenic amines levels in different processed cheese varieties with regulatory specifications. *May 2014*.

Innocente, N., Biasutti, M., Padovese, M., & Moret, S. (2007). Determination of biogenic amines in cheese using HPLC technique and direct derivatization of acid extract. *Food Chemistry*, *101*(3), 1285–1289. https://doi.org/10.1016/j.foodchem.2005.12.026

Innocente, N., & D'Agostin, P. (2002). Formation of biogenic amines in a typical semihard Italian cheese. *Journal of Food Protection*, *65*(9), 1498–1501. https://doi.org/10.4315/0362-028X-65.9.1498

Jain, A., & Verma, K. K. (2018). Strategies in liquid chromatographic methods for the analysis of biogenic amines without and with derivatization. *TrAC – Trends in Analytical Chemistry*, *109*, 62–82. https://doi.org/10.1016/j.trac.2018.10.001

Joosten, H. M. L. J., & Olieman, C. (1986). Determination of biogenic amines in cheese and some other food products by high-performance liquid chromatography in combination with thermo-sensitized reaction detection. *Journal of Chromatography A*, *356*(C), 311–319. https://doi.org/10.1016/S0021-9673(00)91491-2

Joosten, H. M. L. J. (1988). Conditions allowing the formation of biogenic amines in cheese. *Neth Milk Dairy J.*, *4*, 329–357.

Kamankesh, M., Mohammadi, A., & Ghanati, K. (2021). Determination of biogenic amines in Lighvan cheese using a novel hollow-fibre electromembrane-microextraction coupled with gas chromatography–mass spectrometry. *International Journal of Dairy Technology*, *74*(4), 759–767. https://doi.org/10.1111/1471-0307.12806

Kaçar, C., Erden, P. E., Dalkiran, B., İnal, E. K., & Kiliç, E. (2020). Amperometric biogenic amine biosensors based on Prussian blue, indium tin oxide nanoparticles and diamine oxidase–or monoamine oxidase–modified electrodes. *Analytical and Bioanalytical Chemistry*, *412*(8), 1933–1946. https://doi.org/10.1007/S00216-020-02448-4/TABLES/3

Kamankesh, M., Mohammadi, A., Tehrani, Z. M., Ferdowsi, R., & Hosseini, H. (2013). Dispersive liquid-liquid microextraction followed by high-performance liquid chromatography for determination of benzoate and sorbate in yogurt drinks and method optimization by central composite design. *Talanta*, *109*, 46–51. https://doi.org/10.1016/j.talanta.2013.01.052

Karovičová, J., & Kohajdová, Z. (2005). Biogenic amines in food. *Chemical Papers*, *59*(1), 70–79.

Khaled, M. E.-Z. (2014). Biogenic amines and microbiological profile of Egyptian cheeses. *African Journal of Food Science*, *8*(3), 130–139. https://doi.org/10.5897/ajfs2013.1125

Kielwein, G., Treptow, H., Askar, A., Dross, A., & Wittkowski, R. (1996). Biogene amine in lebensmitteln. In D. M. Beutling (Ed.), Biogene amine in der Ernährung.

Kirschbaum, J., Luckas, B., & Beinert, W. D. (1994). Pre-column derivatization of biogenic amines and amino acids with 9-fluorenylmethyl chloroformate and heptylamine. *Journal of Chromatography A*, *661*(1–2), 193–199. https://doi.org/10.1016/0021-9673(93)E1107-B

Komprda, T., Burdychová, R., Dohnal, V., Cwiková, O., Sládková, P., & Dvořáčková, H. (2008). Tyramine production in Dutch-type semi-hard cheese from two different producers. *Food Microbiology*, *25*(2), 219–227. https://doi.org/10.1016/j.fm.2007.11.006

Korös, Á., Varga, Z., & Molnár-Perl, I. (2008). Simultaneous analysis of amino acids and amines as their o-phthalaldehyde-ethanethiol-9-fluorenylmethyl chloroformate derivatives in cheese by high-performance liquid chromatography. *Journal of Chromatography A*, *1203*(2), 146–152. https://doi.org/10.1016/j.chroma.2008.07.035

Kouti, E., Tsiasioti, A., Zacharis, C. K., & Tzanavaras, P. D. (2021). Specific determination of histamine in cheese and cured meat products by ion chromatography coupled to fluorimetric detection. *Microchemical Journal*, *168*, 106513. https://doi.org/10.1016/j.microc.2021.106513

Krause, I., Bockhardt, A., Neckermann, H., Henle, T., & Klostermeyer, H. (1995). Simultaneous determination of amino acids and biogenic amines by reversed-phase high-performance liquid chromatography of the dabsyl derivatives. *Journal of Chromatography A*, *715*(1), 67–79. https://doi.org/10.1016/0021-9673(95)00578-B

Kvasnička, F., & Voldřich, M. (2006). Determination of biogenic amines by capillary zone electrophoresis with conductometric detection. *Journal of Chromatography A*, *1103*(1), 145–149. https://doi.org/10.1016/j.chroma.2005.11.005

Ladero, V., Calles-Enriquez, M., Fernandez, M., & A Alvarez, M. (2010). Toxicological effects of dietary biogenic amines. *Current Nutrition & Food Science*, *6*(2), 145–156. https://doi.org/10.2174/157340110791233256

Ladero, V., Linares, D. M., Pérez, M., del Rio, B., Fernández, M., & Alvarez, M. A. (2017). Biogenic amines in dairy products. *Microbial Toxins in Dairy Products*, 94–131. https://doi.org/10.1002/9781118823095.ch4

Lanciotti, R., Patrignani, F., Iucci, L., Guerzoni, M. E., Suzzi, G., Belletti, N., & Gardini, F. (2007). Effects of milk high pressure homogenization on biogenic amine accumulation during ripening of ovine and bovine Italian cheeses. *Food Chemistry*, *104*(2), 693–701. https://doi.org/10.1016/j.foodchem.2006.12.017

Lange, J., & Wittmann, C. (2002). Enzyme sensor array for the determination of biogenic amines in food samples. *Fresenius' Journal of Analytical Chemistry*, *372*(2), 276–283. https://doi.org/10.1007/s00216-001-1130-9

La Torre, G. L., Saitta, M., Giorgia Potortì, A., Di Bella, G., & Dugo, G. (2010). High performance liquid chromatography coupled with atmospheric pressure chemical ionization mass spectrometry for sensitive determination of bioactive amines in donkey milk. *Journal of Chromatography A*, *1217*(32), 5215–5224. https://doi.org/10.1016/j.chroma.2010.06.022

Latorre-Moratalla, M. L., Bosch-Fusté, J., Lavizzari, T., Bover-Cid, S., Veciana-Nogués, M. T., & Vidal-Carou, M. C. (2009). Validation of an ultra high pressure liquid chromatographic method for the determination of biologically active amines in food. *Journal of Chromatography A*, *1216*(45), 7715–7720. https://doi.org/10.1016/j.chroma.2009.08.072

Lázaro de la Torre, C. A., & Conte-Júnior, C. A. (2014). Chromatographic methods for biogenic amines determination in foods of animal origin. *Brazilian Journal of Veterinary Research and Animal Science*, *50*(6), 430–446. https://doi.org/10.11606/issn.1678-4456.v50i6p430-446

Lehane, L., & Olley, J. (2000). Histamine fish poisoning revisited. *International Journal of Food Microbiology*, *58*(1–2), 1–37. https://doi.org/10.1016/S0168-1605(00)00296-8

LePage, J. N., & Rocha, E. M. (1983). Liquid chromatography with postcolumn reaction for detection of amines and amino acids. *Analytical Chemistry*, *55*(8), 1360–1364. https://doi.org/10.1021/ac00259a039

Leszczyocha, M., & Pytasz, U. (2018). The histamine content in some samples of food products. *Czech Journal of Food Sciences*, *22*(No. (3), 81–86. https://doi.org/10.17221/3410-cjfs

Leszczyocha, M., & Pytasz, U. (2004). The histamine content in some samples of food products. *Czech Journal of Food Sciences*, *22*(No. 3), 81–86. https://doi.org/10.17221/3410-cjfs

Linares, D. M., MartÍn, M. C., Ladero, V., Alvarez, M. A., & Fernández, M. (2011). Biogenic amines in dairy products. *Critical Reviews in Food Science and Nutrition*, *51*(7), 691–703. https://doi.org/10.1080/10408398.2011.582813

Linares, D. M., del Rio, B., Redruello, B., Ladero, V., Martin, M. C., Fernandez, M., Ruas-Madiedo, P., & Alvarez, M. A. (2016). Comparative analysis of the in vitro cytotoxicity of the dietary biogenic amines tyramine and histamine. *Food Chemistry*, *197*, 658–663. https://doi.org/10.1016/j.foodchem.2015.11.013

Liu, S. J., Xu, J. J., Ma, C. L., & Guo, C. F. (2018). A comparative analysis of derivatization strategies for the determination of biogenic amines in sausage and cheese by HPLC. *Food Chemistry*, *266*, 275–283. https://doi.org/10.1016/j.foodchem.2018.06.001

Madejska, A., Michalski, M., Pawul-Gruba, M., & Osek, J. (2018). Histamine content in rennet ripening cheeses during storage at different temperatures and times. *Journal of Veterinary Research (Poland)*, *62*(1), 65–69. https://doi.org/10.2478/jvetres-2018-0009

Maintz, L., & Novak, N. (2007). Histamine and histamine intolerance. *American Journal of Clinical Nutrition*, *85*(5), 1185–1196. https://doi.org/10.1093/ajcn/85.5.1185

Manca, G., Porcu, A., Ru, A., Salaris, M., Franco, M. A., & de Santis, E. P. L. (2015). Comparison of γ-aminobutyric acid and biogenic amine content of different types of ewe's milk cheese produced in sardinia, *italy. Italian Journal of Food Safety*, *4*(2), 123–128. https://doi.org/10.4081/ijfs.2015.4700

Mascaro, N., Stocchi, R., Ricciutelli, M., Cammertoni, N., Renzi, F., Cecchini, S., Loschi, A. R., & Rea, S. (2010). Biogenic Amine Content and Chemical and Physical Features of Italian Formaggio Di Fossa. *Italian Journal of Food Safety*, *1*(8), 49. https://doi.org/10.4081/ijfs.2010.8.49

Marijan, A., Džaja, P., Bogdanović, T., Škoko, I., Cvetnić, Ž., Dobranić, V., Zdolec, N., Šatrović, E., & Severin, K. (2014). Utjecaj trajanja zrenja na kolicinu pojedinih biogenih amina u sredini i pod korom kravljeg Livanjskog sira. *Mljekarstvo*, *64*(3), 159–169. https://doi.org/10.15567/mljekarstvo.2014.0303

Marks, H. S., & Anderson, C. R. (2005). Determination of putrescine and cadaverine in seafood (finfish and shellfish) by liquid chromatography using pyrene excimer fluorescence. *Journal of Chromatography A*, *1094*(1–2), 60–69. https://doi.org/10.1016/j.chroma.2005.07.088

Martuscelli, M., Gardini, F., Torriani, S., Mastrocola, D., Serio, A., Chaves-López, C., Schirone, M., & Suzzi, G. (2005). Production of biogenic amines during the ripening of Pecorino Abruzzese cheese. *International Dairy Journal*, *15*(6–9), 571–578. https://doi.org/10.1016/j.idairyj.2004.11.008

Mayer, H. K., Fiechter, G., & Fischer, E. (2010). A new ultra-pressure liquid chromatography method for the determination of biogenic amines in cheese. *Journal of Chromatography A*, *1217*(19), 3251–3257. https://doi.org/10.1016/j.chroma.2009.09.027

Mayr, C. M., & Schieberle, P. (2012). Development of stable isotope dilution assays for the simultaneous quantitation of biogenic amines and polyamines in foods by LC-MS/MS. *Journal of Agricultural and Food Chemistry*, *60*(12), 3026–3032. https://doi.org/10.1021/jf204900v

Mazzucco, E., Gosetti, F., Bobba, M., Marengo, E., Robotti, E., & Gennaro, M. C. (2010). High-performance liquid chromatography-ultraviolet detection method for the simultaneous determination of typical biogenic amines and precursor amino acids. applications in food chemistry. *Journal of Agricultural and Food Chemistry*, *58*(1), 127–134. https://doi.org/10.1021/jf9030053

Mazzotti, F., di Donna, L., Napoli, A., Aiello, D., Siciliano, C., Athanassopoulos, C. M., & Sindona, G. (2014). N-hydroxysuccinimidyl p-methoxybenzoate as suitable derivative reagent for isotopic dilution assay of biogenic amines in food. *Journal of Mass Spectrometry*, *49*(9), 802–810. https://doi.org/10.1002/jms.3417

McCabe, B. J., Frankel, E. H., & Wolfe, J. J. (2003). *Handbook of food-drug interactions*. CRC Press. www.crcpress.com

Mercogliano, R., de Felice, A., Chirollo, C., & Cortesi, M. L. (2010). Production of vasoactive amines during the ripening of Pecorino Carmasciano cheese. *Veterinary Research Communications*, *34*(SUPPL. 1), https://doi.org/10.1007/s11259-010-9394-1

Min, J. S., Lee, S. O., Jang, A., Lee, M., & Kim, Y. (2004). Quantitative analysis of biogenic amines in raw and processed foods of animal origin on Korean domestic market. *Asian-Australasian Journal of Animal Sciences*, *17*(12), 1764–1768. https://doi.org/10.5713/ajas.2004.1764

Mohammadi, M., Kamankesh, M., & Hadian, Z. (2016). Determination of Biogenic Amines in Cheese Using Simultaneous Derivatization and Microextraction Method Followed by Gas Chromatography – Mass Spectrometry. *Chromatographia*, https://doi.org/10.1007/s10337-016-3217-7

Mohammadi, M., Kamankesh, M., Hadian, Z., Mortazavian, A. M., & Mohammadi, A. (2017). Determination of biogenic amines in cheese using simultaneous derivatization and microextraction method followed by gas chromatography–mass spectrometry. *Chromatographia*, *80*(1), 119–126. https://doi.org/10.1007/s10337-016-3217-7

Molaei, R., Tajik, H., & Moradi, M. (2019). Magnetic solid phase extraction based on mesoporous silica-coated iron oxide nanoparticles for simultaneous determination of biogenic amines in an Iranian traditional dairy product; Kashk. *Food Control*, *101*, 1–8. https://doi.org/10.1016/j.foodcont.2019.02.011

Moniente, M., García-Gonzalo, D., Ontañón, I., Pagán, R., & Botello-Morte, L. (2021). Histamine accumulation in dairy products: Microbial causes, techniques for the detection of histamine-producing microbiota, and potential solutions. *Comprehensive Reviews in Food Science and Food Safety*, *20*(2), 1481–1523. https://doi.org/10.1111/1541-4337.12704

Moracanin, S. V., Stefanovic, S., Radicevic, T., Borovic, B., & Djukic, D. (2015). Production of biogenic amines by lactic acid bacteria isolated from Uzicka sausages. *Procedia Food Science*, *5*, 308–311. https://doi.org/10.1016/j.profoo.2015.09.068

Moret, S., & Conte, L. S. (1996). High-performance liquid chromatographic evaluation of biogenic amines in foods an analysis of

different methods of sample preparation in relation to food characteristics. *Journal of Chromatography A*, *729*(1–2), 363–369. https://doi.org/10.1016/0021-9673(95)00961-2

Munir, M. A., & Badri, K. H. (2020). The importance of derivatizing reagent in chromatography applications for biogenic amine detection in food and beverages. *Journal of Analytical Methods in Chemistry*, *2020*, Article ID 5814389. https://doi.org/10.1155/2020/5814389

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*(7), R139–R150. https://doi.org/10.1111/j.1750-3841.2010.01774.x

Nalazek-Rudnicka, K., & Wasik, A. (2017). Development and validation of an LC–MS/MS method for the determination of biogenic amines in wines and beers. *Monatshefte Fur Chemie*, *148*(9), 1685–1696. https://doi.org/10.1007/s00706-017-1992-y

Navarro, J., de Marcos, S., & Galbán, J. (2020). Colorimetric-enzymatic determination of tyramine by generation of gold nanoparticles. *Microchimica Acta*, *187*(3), 1–8. https://doi.org/10.1007/s00604-020-4141-y

Nishimura, K., Shiina, R., Kashiwagi, K., & Igarashi, K. (2006). Decrease in polyamines with aging and their ingestion from food and drink. *Journal of Biochemistry*, *139*(1), 81–90. https://doi.org/10.1093/jb/mvj003

Notou, M., Zotou, A., Tzanavaras, P. D., & Themelis, D. G. (2014). Automated derivatization and fluorimetric determination of biogenic amines in milk by zone fluidics coupled to liquid chromatography. *Journal of Chromatography A*, *1356*, 272–276. https://doi.org/10.1016/j.chroma.2014.06.047

Novella-Rodríguez, S., Teresa Veciana-Nogués, M., & Carmen Vidal-Carou, M. (2000). Biogenic amines and polyamines in milks and cheeses by ion-pair high performance liquid chromatography. *Journal of Agricultural and Food Chemistry*, *48*(11), 5117–5123. https://doi.org/10.1021/jf0002084

Novella-Rodríguez, S., Veciana-Nogués, M. T., Izquierdo-Pulido, M., & Vidal-Carou, M. C. (2003). Distribution of biogenic amines and polyamines in cheese. *Journal of Food Science*, *68*(3), 750–756. https://doi.org/10.1111/j.1365-2621.2003.tb08236.x

Novella-Rodríguez, S., Veciana-Nogués, M. T., Roig-Sagués, A. X., Trujillo-Mesa, A. J., & Vidal-Carou, M. C. (2004). Comparison of Biogenic Amine Profile in Cheeses Manufactured from Fresh and Stored (4°C, 48 Hours) Raw Goat's Milk. *Journal of Food Protection*, *67*(1), 110–116. https://doi.org/10.4315/0362-028X-67.1.110

Novella-Rodríguez, S., Veciana-Nogués, M. T., Saldo, J., & Vidal-Carou, M. C. (2002). Effects of high hydrostatic pressure treatments on biogenic amine contents in goat cheeses during ripening. *Journal of Agricultural and Food Chemistry*, *50*(25), 7288–7292. https://doi.org/10.1021/jf025665u

Nouadje, G., Nertz, M., Verdeguer, P., & Couderc, F. (1995). Ballens laser-induced fluorescence detector as an easy-to-use highly sensitive detector for capillary electrophoresis application to the identification of biogenic amines in dairy products. *Journal of Chromatography A*, *717*(1–2), 335–343. https://doi.org/10.1016/0021-9673(95)00464-X

Oliver, S., de Marcos, S., Sanz-Vicente, I., Cebolla, V., & Galbán, J. (2021). Direct minimally invasive enzymatic determination of tyramine in cheese using digital imaging. *Analytica Chimica Acta*, *1164*, 338489. https://doi.org/10.1016/j.aca.2021.338489

Önal, A. (2007). A review: Current analytical methods for the determination of biogenic amines in foods. *Food Chemistry*, *103*(4), 1475–1486. https://doi.org/10.1016/j.foodchem.2006.08.028

Önal, A., Tekkeli, S. E. K., & Önal, C. (2013). A review of the liquid chromatographic methods for the determination of biogenic amines in foods. *Food Chemistry*, *138*(1), 509–515. https://doi.org/10.1016/j.foodchem.2012.10.056

Öner, Z., Gül Karahan, A., & Aloğlu, H. (2006). Changes in the microbiological and chemical characteristics of an artisanal Turkish white cheese during ripening. *LWT - Food Science and Technology*, *39*(5), 449–454. https://doi.org/10.1016/j.lwt.2005.03.015

Ordóñez, A. I., Ibáñez, F. C., Torre, P., & Barcina, Y. (1997). Formation of biogenic amines in Idiazabal ewe's-milk cheese: Effect of ripening, pasteurization, and starter. *Journal of Food Protection*, *60*(11), 1371–1375. https://doi.org/10.4315/0362-028X-60.11.1371

Ordóñez, J. L., Troncoso, A. M., García-Parrilla, M. C., & Callejón, R. M. (2016). Recent trends in the determination of biogenic amines in fermented beverages—A review. *Analytica Chimica Acta*, *939*, 10–25. https://doi.org/10.1016/j.aca.2016.07.045

O'Sullivan, D. J., Fallico, V., O'Sullivan, O., McSweeney, P. L. H., Sheehan, J. J., Cotter, P. D., & Giblin, L. (2015). High-throughput DNA sequencing to survey bacterial histidine and tyrosine decarboxylases in raw milk cheeses. *BMC Microbiology*, *15*(1), 1–12. https://doi.org/10.1186/s12866-015-0596-0

Özdestan, Ö., & Üren, A. (2009). A method for benzoyl chloride derivatization of biogenic amines for high performance liquid chromatography. *Talanta*, *78*(4–5), 1321–1326. https://doi.org/10.1016/j.talanta.2009.02.001

Özdestan, Ö., & Üren, A. (2010). Biogenic amine content of kefir: A fermented dairy product. *European Food Research and Technology*, *231*(1), 101–107. https://doi.org/10.1007/s00217-010-1258-y

Pachlová, V., Buňka, F., Buňková, L., Purkrtová, S., Havlíková, Š., & Němečková, I. (2016). Biogenic amines and their producers in Akawi white cheese. *International Journal of Dairy Technology*, *69*(3), 386–392. https://doi.org/10.1111/1471-0307.12294

Pachlová, V., Buňka, F., Flasarová, R., Válková, P., & Buňková, L. (2012). The effect of elevated temperature on ripening of Dutch type cheese. *Food Chemistry*, *132*(4), 1846–1854. https://doi.org/10.1016/j.foodchem.2011.12.017

Palermo, C., Muscarella, M., & Centonze, D. (2012). A multiresidual method based on ion-exchange chromatography with conductivity detection for the determination of biogenic amines in food and beverages. 1015–1023. https://doi.org/10.1007/s00216-012-6439-z

Palermo, C., Muscarella, M., Nardiello, D., Iammarino, M., & Centonze, D. (2013). A multiresidual method based on ion-exchange chromatography with conductivity detection for the determination of biogenic amines in food and beverages. *Analytical and Bioanalytical Chemistry*, *405*(2–3), 1015–1023. https://doi.org/10.1007/s00216-012-6439-z

Palomino-Vasco, M., Rodríguez-Cáceres, M. I., Mora-Diez, N., Pardo-Botello, R., & Acedo-Valenzuela, M. I. (2019). Biogenic amines profile in red wines regarding aging and storage conditions. *Journal of Food Composition and Analysis*, *83*, 103295. https://doi.org/10.1016/j.jfca.2019.103295

Papageorgiou, M., Lambropoulou, D., Morrison, C., Kłodzińska, E., Namieśnik, J., & Płotka-Wasylka, J. (2018). Literature update of analytical methods for biogenic amines determination in food and beverages. *TrAC – Trends in Analytical Chemistry*, *98*, 128–142. https://doi.org/10.1016/j.trac.2017.11.001

Paulo Vieira, C., Pereira da Costa, M., Silva, V. L. M., da Silva Frasao, B., Campos de Aquino, L. F. M., de Oliveira Nunes, Y. E. C., & Adam Conte-Junior, C. (2020). Development and validation of RP-HPLC-DAD method for biogenic amines determination in probiotic yogurts. *Arabian Journal of Chemistry*, *13*(1), 1582–1597. https://doi.org/10.1016/j.arabjc.2017.12.010

Paulsen, P., Nauman, K., Bauer, F., Avagnina, A., & Smulders, F. J. M. (2017). Game meat fermented products-food safety aspects. *Fermented Meat Products: Health Aspects*, *9*(3), 58–77. https://doi.org/10.1201/9781315369846

Peña-Gallego, A., Hernández-Orte, P., Cacho, J., & Ferreira, V. (2009). Biogenic amine determination in wines using solid-phase extraction: A comparative study. *Journal of Chromatography A*, *1216*(15), 3398–3401. https://doi.org/10.1016/j.chroma.2009.01.106

Peña-Gallego, A., Hernández-Orte, P., Cacho, J., & Ferreira, V. (2012). High-performance liquid chromatography analysis of amines in must and wine: A review. *Food Reviews International*, *28*(1), 71–96. https://doi.org/10.1080/87559129.2011.594973

Pena-Pereira, F., Duarte, R. M. B. O., & Duarte, A. C. (2012). Considerations on the application of miniaturized sample preparation approaches for the analysis of organic compounds in environmental matrices. *Central European Journal of Chemistry*, *10*(3), 433–449. https://doi.org/10.2478/s11532-011-0114-7

Pham, L., & Nguyen, T. (2016). Detection of histamine production by *Lactobacillus*. *Journal of Chemical and Pharmaceutical Research*, *8*(8), 1207–1209.

Pluta-Kubica, A., Filipczak-Fiutak, M., Domagała, J., Duda, I., & Migdał, W. (2020). Contamination of traditionally smoked cheeses with polycyclic aromatic hydrocarbons and biogenic amines. *Food Control*, *112*, 107115. https://doi.org/10.1016/j.foodcont.2020.107115

Pinho, O., Ferreira, I. M. P. L. V. O., Mendes, E., Oliveira, B. M., & Ferreira, M. (2001). Effect of temperature on evolution of free amino acid and biogenic amine contents during storage of Azeitão cheese. *Food Chemistry*, *75*(3), 287–291. https://doi.org/10.1016/S0308-8146(01)00109-1

Pinho, O., Pintado, A. I. E., Gomes, A. M. P., Pintado, M. M. E., Malcata, F. X., & Ferreira, I. M. P. L. V. (2004). Interrelationships among microbiological, physicochemical, and biochemical properties of terrincho cheese, with emphasis on biogenic amines. *Journal of Food Protection*, *67*(12), 2779–2785. https://doi.org/10.4315/0362-028X-67.12.2779

Poveda, J. M., Chicón, R., & Cabezas, L. (2015). Biogenic amine content and proteolysis in Manchego cheese manufactured with Lactobacillus paracasei subsp. paracasei as adjunct and other autochthonous strains as starters. *International Dairy Journal*, *47*, 94–101. https://doi.org/10.1016/j.idairyj.2015.03.004

Poveda, J. M., Molina, G. M., & Gómez-Alonso, S. (2016). Variability of biogenic amine and free amino acid concentrations in regionally produced goat milk cheeses. *Journal of Food Composition and Analysis*, *51*, 85–92. https://doi.org/10.1016/j.jfca.2016.06.012

Rabie, M. A., Siliha, H. I., El-Saidy, S. M., El-Badawy, A. A., & Xavier Malcata, F. (2011). Effect of γ-irradiation upon biogenic amine formation in blue cheese during storage. *International Dairy Journal*, *21*(5), 373–376. https://doi.org/10.1016/j.idairyj.2010.11.009

Ramos, R. M., Brandão, P. F., & Rodrigues, J. A. (2020). Development of a SALLE-HPLC-FLD analytical method for the simultaneous determination of ten biogenic amines in cheese. *Food Analytical Methods*, *13*(5), 1088–1098. https://doi.org/10.1007/s12161-020-01730-6

Rauscher-Gabernig, E., Grossgut, R., Bauer, F., & Paulsen, P. (2009). Assessment of alimentary histamine exposure of consumers in Austria and development of tolerable levels in typical foods. *Food Control*, *20*(4), 423–429. https://doi.org/10.1016/j.foodcont.2008.07.011

Redruello, B., Ladero, V., Cuesta, I., Álvarez-Buylla, J. R., Martín, M. C., Fernández, M., & Alvarez, M. A. (2013). A fast, reliable, ultra high performance liquid chromatography method for the simultaneous determination of amino acids, biogenic amines and ammonium ions in cheese, using diethyl ethoxymethylenemalonate as a derivatising agent. *Food Chemistry*, *139*(1–4), 1029–1035. https://doi.org/10.1016/j.foodchem.2013.01.071

Renes, E., Diezhandino, I., Fernández, D., Ferrazza, R. E., Tornadijo, M. E., & Fresno, J. M. (2014). Effect of autochthonous starter cultures on the biogenic amine content of ewe's milk cheese throughout ripening. *Food Microbiology*, *44*, 271–277. https://doi.org/10.1016/j.fm.2014.06.001

Restuccia, D., Spizzirri, U. G., Puoci, F., Cirillo, G., Curcio, M., Parisi, O. I., Iemma, F., & Picci, N. (2011). A new method for the determination of biogenic amines in cheese by LC with evaporative light scattering detector. *Talanta*, *85*(1), 363–369. https://doi.org/10.1016/j.talanta.2011.03.080

Rezaee, M., Assadi, Y., Milani Hosseini, M. R., Aghaee, E., Ahmadi, F., & Berijani, S. (2006). Determination of organic compounds in water using dispersive liquid-liquid microextraction. *Journal of Chromatography A*, *1116*(1–2), 1–9. https://doi.org/10.1016/j.chroma.2006.03.007

Rice, N. M., Irving, H. M. N. H., & Leonard, M. A. (1993). Nomenclature for liquid-liquid distribution (solvent extraction). *Pure and Applied Chemistry*, *65*(11), 2373–2396. https://doi.org/10.1351/pac199365112373

Rotariu, L., Lagarde, F., Jaffrezic-Renault, N., & Bala, C. (2016). Electrochemical biosensors for fast detection of food contaminants—Trends and perspective. *TrAC – Trends in Analytical Chemistry*, *79*, 80–87. https://doi.org/10.1016/j.trac.2015.12.017

Ruiz-Capillas, C., & Herrero, A. M. (2019). Impact of biogenic amines on food quality and safety. *Foods*, *8*(2), 62. https://doi.org/10.3390/foods8020062

Saaid, M., Saad, B., Ali, A. S. M., Saleh, M. I., Basheer, C., & Lee, H. K. (2009). In situ derivatization hollow fibre liquid-phase microextraction for the determination of biogenic amines in food samples. *Journal of Chromatography A*, *1216*(27), 5165–5170. https://doi.org/10.1016/j.chroma.2009.04.091

Salleres, S., González, I., Rantzamendi, A. A., González, R., Maza, S., Jaureguibeitia, A., Hungerford, J. M., DeWitt, C. A., & Benner, R. A. (2016). Validation of the biofish-300 HIS enzymatic biosensor for the detection of histamine in fishery products. *Journal of AOAC International*, *99*(5), 1338–1355. https://doi.org/10.5740/jaoacint.16-0180

Samková, E., Dadáková, E., & Pelikánová, T. (2013). Changes in biogenic amine and polyamine contents in smear-ripened cheeses during storage. *European Food Research and Technology*, *237*(3), 309–314. https://doi.org/10.1007/s00217-013-1993-y

Santos, W. C., Souza, M. R., Cerqueira, M. M. O. P., & Glória, M. B. A. (2003). Bioactive amines formation in milk by *Lactococcus* in the presence or not of rennet and NaCl at 20 and 32°C. *Food Chemistry*, *81*(4), 595–606. https://doi.org/10.1016/S0308-8146(02)00502-2

Sawilska-Rautenstrauch, D., Fonberg-Broczek, M., Gawarska, H., Starski, A., Jedra, M., & Karłowski, K. (2010). Occurrence of

biogenic amines in ripening cheeses taken from the Warsaw market. *Roczniki Państwowego Zakładu Higieny*, *61*(4), 361–365.

Schirone, M., Tofalo, R., Fasoli, G., Perpetuini, G., Corsetti, A., Manetta, A. C., Ciarrocchi, A., & Suzzi, G. (2013). High content of biogenic amines in pecorino cheeses. *Food Microbiology*, *34*(1), 137–144. https://doi.org/10.1016/j.fm.2012.11.022

Shah, N., Arain, M. B., & Soylak, M. (2020). Historical background: Milestones in the field of development of analytical instrumentation. In Susan Dennis (Ed.), *New generation green solvents for separation and preconcentration of organic and inorganic species* (pp. 45–73). INC. https://doi.org/10.1016/b978-0-12-818569-8.00002-4

Shalaby, A. R. (1999). Simple, rapid and valid thin layer chromatographic method for determining biogenic amines in foods. *Food Chemistry*, *65*(1), 117–121. https://doi.org/10.1016/S0308-8146(98)00113-7

Shalaby, A. R., Anwar, M. M., Sallam, E. M., & Emam, W. H. (2016). Quality and safety of irradiated food regarding biogenic amines: Ras cheese. *International Journal of Food Science and Technology*, *51*(4), 1048–1054. https://doi.org/10.1111/ijfs.13058

Shishov, A., Chromá, R., Vakh, C., Kuchár, J., Simon, A., Andruch, V., & Bulatov, A. (2019). In situ decomposition of deep eutectic solvent as a novel approach in liquid-liquid microextraction. *Analytica Chimica Acta*, *1065*, 49–55. https://doi.org/10.1016/j.aca.2019.03.038

Silla Santos, M. H. (1996). Biogenic amines: Their importance in foods. *International Journal of Food Microbiology*, *29*(2–3), 213–231. https://doi.org/10.1016/0168-1605(95)00032-1

Silva, V. L. M., Costa, M. P., Vieira, C. P., & Conte-Junior, C. A. (2019). Short communication: Biogenic amine formation during fermentation in functional sheep milk yogurts. *Journal of Dairy Science*, *102*(10), 8704–8709. https://doi.org/10.3168/jds.2019-16379

Spano, G., Russo, P., Lonvaud-Funel, A., Lucas, P., Alexandre, H., Grandvalet, C., Coton, E., Coton, M., Barnavon, L., Bach, B., Rattray, F., Bunte, A., Magni, C., Ladero, V., Alvarez, M., Fernández, M., Lopez, P., de Palencia, P. F., Corbi, A., … Lolkema, J. S. (2010). Biogenic amines in fermented foods. *European Journal of Clinical Nutrition*, *64*, S95–S100. https://doi.org/10.1038/ejcn.2010.218

Spizzirri, U. G., Puoci, F., Iemma, F., & Restuccia, D. (2019). Biogenic amines profile and concentration in commercial milks for infants and young children. Food Additives and Contaminants - Part A Chemistry. *Analysis, Control, Exposure and Risk Assessment*, *36*(3), 337–349. https://doi.org/10.1080/19440049.2018.1563306

Spizzirri, U. G., Restuccia, D., Curcio, M., Parisi, O. I., Iemma, F., & Picci, N. (2013). Determination of biogenic amines in different cheese samples by LC with evaporative light scattering detector. *Journal of Food Composition and Analysis*, *29*(1), 43–51. https://doi.org/10.1016/j.jfca.2012.09.005

Standarová, E., Borkovcová, I., Dušková, M., Přidalová, H., Dračková, M., & Vorlová, L. (2009). Effect of some factors on the biogenic amines and polyamines content in blue-veined cheese niva. *Czech Journal of Food Sciences*, *27*(SPEC. ISS.), S410–S413. https://doi.org/10.17221/965-cjfs

Standarová, E., Vorlová, L., Kordiovská, P., Janštová, B., Dračková, M., & Borkovcová, I. (2010). Biogenic amine production in Olomouc curd cheese (Olomoucké tvarůžky) at various storage conditions. *Acta Veterinaria Brno*, *79*(1), 147–156. https://doi.org/10.2754/avb201079010147

Standarová, E., Borkovcová, I., Dušková, M., Přidalová, H., Dračková, M., & Vorlová, L. (2009). Effect of some factors on the biogenic amines and polyamines content in blue-veined cheese niva. *Czech Journal of Food Sciences*, *27*(SPEC. ISS.), https://doi.org/10.17221/965-cjfs

Sun, J., Guo, H. X., Semin, D., & Cheetham, J. (2011). Direct separation and detection of biogenic amines by ion-pair liquid chromatography with chemiluminescent nitrogen detector. *Journal of Chromatography A*, *1218*(29), 4689–4697. https://doi.org/10.1016/j.chroma.2011.05.051

Sun, X., Yang, X., & Wang, E. (2003). Determination of biogenic amines by capillary electrophoresis with pulsed amperometric detection. *Journal of Chromatography A*, *1005*(1–2), 189–195. https://doi.org/10.1016/S0021-9673(03)00927-0

Suzzi, G., & Gardini, F. (2003). Biogenic amines in dry fermented sausages: A review. *International Journal of Food Microbiology*, *88*(1), 41–54. https://doi.org/10.1016/S0168-1605(03)00080-1

Švarc-Gajic, J., & Stojanovic, Z. (2011). Determination of histamine in cheese by chronopotentiometry on a thin film mercury electrode. *Food Chemistry*, *124*, 1172–1176. https://doi.org/10.1016/j.foodchem.2010.07.030

Tang, Y. Q., & Weng, N. (2013). Salting-out assisted liquid-liquid extraction for bioanalysis. *Bioanalysis*, *5*(12), 1583–1598. https://doi.org/10.4155/bio.13.117

Telsnig, D., Kassarnig, V., Zapf, C., Leitinger, G., Kalcher, K., & Ortner, A. (2012). Characterization of an amperometric biosensor for the determination of biogenic amines in flow injection analysis. *International Journal of Electrochemical Science*, *7*(11), 10476–10486.

Tittarelli, F., Perpetuini, G., Di Gianvito, P., & Tofalo, R. (2019). Biogenic amines producing and degrading bacteria: A snapshot from raw ewes' cheese. *LWT – Food Science and Technology*, *101*, 1–9. https://doi.org/10.1016/j.lwt.2018.11.030

Toro-Funes, N., Bosch-Fuste, J., Latorre-Moratalla, M. L., Veciana-Nogués, M. T., & Vidal-Carou, M. C. (2015). Biologically active amines in fermented and non-fermented commercial soybean products from the Spanish market. *Food Chemistry*, *173*, 1119–1124. https://doi.org/10.1016/j.foodchem.2014.10.118

Toyo'oka, T. (1999). *Modern derivatization methods for separation sciences*. Wiley.

Ubaldo, J. C. S. R., Carvalho, A. F., Fonseca, L. M., & Glória, M. B. A. (2015). Bioactive amines in mozzarella cheese from milk with varying somatic cell counts. *Food Chemistry*, *178*, 229–235. https://doi.org/10.1016/j.foodchem.2015.01.084

UE. (2005). *Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs (Text with EEA relevance)*.

Vale, S. R., & Gloria, M. B. A. (1997). Determination of biogenic amines. *Food Control*, *80*(5), 1006–1012. https://doi.org/10.1016/j.foodcont.2007.08.013

Vale, S., & Glória, M. B. A. (1998). Biogenic amines in Brazilian cheeses. *Food Chemistry*, *63*(3), 343–348. https://doi.org/10.1016/S0308-8146(98)00019-3

Valsamaki, K., Michaelidou, A., & Polychroniadou, A. (2000). Biogenic amine production in Feta cheese. *Food Chemistry*, *71*(2), 259–266. https://doi.org/10.1016/S0308-8146(00)00168-0

van Boekel, M. A. J. S., & Arentsen-Stasse, A. P. (1987). Determination of aromatic biogenic amines and their precursors in cheese by

high-performance liquid chromatography. *Journal of Chromatography A*, *389*(C), 267–272. https://doi.org/10.1016/S0021-9673(01)94433-4

Vaz, A., Cabral Silva, A. C., Rodrigues, P., & Venâncio, A. (2020). Detection methods for aflatoxin M1 in dairy products. *Microorganisms*, *8*(2), 246. https://doi.org/10.3390/microorganisms8020246

Wu, H., Li, G., Liu, S., Ji, Z., Zhang, Q., Hu, N., Suo, Y., & You, J. (2015). Simultaneous determination of seven biogenic amines in foodstuff samples using one-step fluorescence labeling and dispersive liquid–liquid microextraction followed by HPLC-FLD and method optimization using response surface methodology. *Food Analytical Methods*, *8*(3), 685–695. https://doi.org/10.1007/s12161-014-9943-2

Yang, S. S., Yang, Y. N., Li, X. L., & Zhang, Y. (2016). Determination of biogenic amines in cheese by on-line solid phase extraction coupled with capillary high performance liquid chromatography. *Chinese Journal of Analytical Chemistry*, *44*(3), 396–402. https://doi.org/10.1016/S1872-2040(16)60915-5

Yigit, M., & Ersoy, L. (2003). Determination of tyramine in cheese by LC-UV. *Journal of Pharmaceutical and Biomedical Analysis*, *31*(6), 1223–1228. https://doi.org/10.1016/S0731-7085(02)00698-2

Zazzu, C., Addis, M., Caredda, M., Scintu, M. F., Piredda, G., & Sanna, G. (2019). Biogenic amines in traditional fiore sardo pdo sheep cheese: Assessment, validation and application of an RP-HPLC-DAD-UV method. *Separations*, *6*(1), 11. https://doi.org/10.3390/separations6010011

Zhang, Y. J., Zhang, Y., Zhou, Y., Li, G. h., Yang, W. z., & Feng, X. S. (2019). A review of pretreatment and analytical methods of biogenic amines in food and biological samples since 2010. *Journal of Chromatography A*, *1605*, 360361. https://doi.org/10.1016/j.chroma.2019.07.015

Zotou, A., & Notou, M. (2012). Study of the naphthalene-2,3-dicarboxaldehyde pre-column derivatization of biogenic mono- and diamines in mixture and fluorescence-HPLC determination. *Analytical and Bioanalytical Chemistry*, *403*(4), 1039–1048. https://doi.org/10.1007/s00216-011-5543-9

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