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A review: Current analytical methods for the determination of biogenic amines in foods

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Abstract

Analysis of biogenic amines (BA) in foods was reviewed. Biogenic amines are natural antinutrition factors and are important from a hygienic point of view as they have been implicated as the causative agents in a number of food poisoning episodes, and they are able to initiate various pharmacological reactions. Histamine, putrescine, cadaverine, tyramine, tryptamine, β-phenylethylamine, spermine, and spermidine are considered to be the most important biogenic amines occurring in foods. Analysis of BA is important because of their toxicity and their usage as indicators of the degree of freshness or spoilage of food. Several methods have been developed for determination of biogenic amines in food. The analytical methods used for quantification of BA are mainly based on chromatographic methods: thin layer chromatography (TLC), gas chromatography (GC), capillary electrophoresis (CE) and high-performance liquid chromatography (HPLC). HPLC is most often used for the analysis method of BAs. Due to low volatility and lack of chromophores of most BA, UV-spectrometric detectors cannot be used. The large majority of assays employs fluorimetric detection with precolumn or postcolumn derivatization techniques. This review shows that these methods allow quantitative determination of biogenic amines, individually or simultaneously in foods.

Keywords: Biogenic amines; Foods; Chromatographic methods; Determination

Contents

1. Introduction

Biogenic amines (BA) are organic bases with aliphatic (putrescine, cadaverine, spermine, spermidine), aromatic (tyramine, phenylethylamine) or heterocyclic (histamine, tryptamine) structures that can be found in several foods, in which they are mainly produced by microbial decarboxylation of amino acids, with the exception of physiological polyamines (Silla Santos, 1996).

BA may be of endogenous origin at low concentrations in non-fermented food such as fruits, vegetables, meat,

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milk and fish. High concentrations have been found in fermented foods as a result of a contaminating microflora exhibiting amino acid decarboxylase activity (Silla Santos, 1996). Many of them have powerful physiological effects (e.g., histamine, serotonin, dopamine, tyramine) and have an important biological activity (Shalaby, 1996). Moreover, secondary amines such as putrescine and cadaverine play an important role in food poisoning as they can potentiate the toxicity of histamine (Bjeldanes, Schutz, & Morris, 1978). The quantity of BAs is also to be considered a marker of the level of microbiological contamination in food (Leuschner, Kurthara, & Hammes, 1999). For these reasons, it is important to monitor biogenic amines levels in food.

Biogenic amines in food are extensively studied; a lot of information on formation and occurrence of the biogenic amines in foods is given in recent reviews (Davídek & Davídek, 1995; Halasz, Barath, Simon-Sarkadi, & Holzapfel, 1994; Silla Santos, 1996; Stratton, Hutkins, & Taylor, 1991; Suzzi & Gardini, 2003).

Chemical structures of some BA are given in Fig. 1.

2. Their occurence and significance in foods

Biogenically active amines are compounds formed and broken down by usual metabolic processes in the cells of living organisms including growth regulation (spermine, spermidine and cadaverine), neural transmission (catecholamines and serotonin) and as mediators of inflammation (histamine and tyramine) (Tabor & Tabor, 1976). These active amines are also present in a variety of food products like chocolate, sauerkraut, fish and fish products, beer, red wine, mature cheese, etc. The most common monoamines, histamine (HI), tyramine (TY) and tryptamine (TR), and the diamines (or polyamines), putrescine (PUT) and cadaverine (CAD), are formed from histidine, tyrosine, tryptophan, ornithine and lysine, respectively. Polyamines, spermidine (SPD) and spermine (SPM) arise from putrescine. Polyamines are formed by de novo synthesis (Fig. 2) and are involved in important physiological processes, such as fruit growth and development (Esti et al., 1998). On the other hand, interest in polyamines lies in their physiological functions related to cell membrane stabilisation and cell

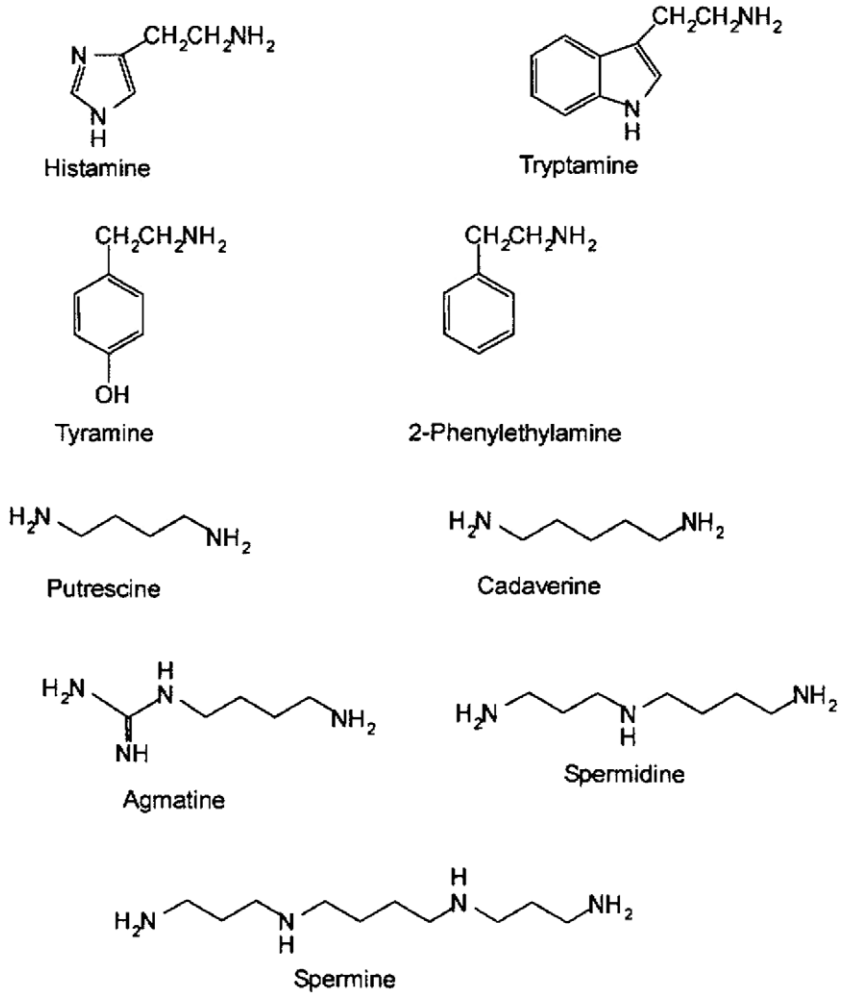

Fig. 1. Chemical structures of some biogenic amines.

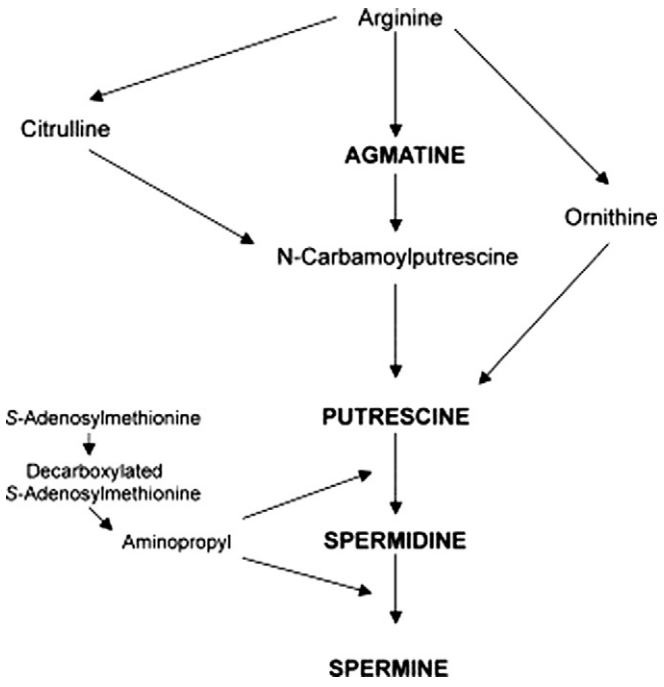

Fig. 2. Biosynthesis of polyamines (Lima & Glória, 1999).

proliferation, since they are involved in DNA, RNA, and protein synthesis. Therefore, they are considered important food microcomponents during periods of intensive tissue growth (infant gut maturation, post-operational recovery, etc.), although in some pathological cases (individuals with tumours) the intake of polyamines should be minimised (Bardócz, 1995).

Biogenic amines can be produced during storage or processing of the products by thermal or bacterial enzymatic decarboxylation of free amino acids by *Bacillus*, *Clostridium*, *Hafnia*, *Klebsiella*, *Morganella morganii*, *Proteus*, *Lactobacillus* such as *Lactobacillus buchneri* and *Lactobacillus delbrueckii* in cheese, Enterobacteriaceae and Enterococcus growing on fish, meat and their products. (Halasz et al., 1994; Lima & Glória, 1999; Udenfriend, Lovenberg, & Sjoerdsma, 1959) (Fig. 3). They are found also in fermented food, like cheese, camembert, wine, beer, sauerkraut and yeast extract.

The presence of BA in food constitutes a potential public health concern due to their physiological and toxicological effects. Some aromatic amines (tyramine, tryptamine, and β-phenylethylamine) show a vasoconstrictor action while others (histamine and serotonin) present a vasodilatador effect. Moreover, tyramine and histamine also act as hormonal mediators in humans and animals. Psychoactive amines, such as dopamine and serotonin, are neurotransmitters in the central nervous system (Bardócz, 1993). Furthermore, some biogenic amines can react with nitrite to form carcinogenic nitrosamines (Warthesen, Scanlan, Bills, & Libbey, 1975). Besides their toxicological effects, biogenic amines are of concern in relation to food hygiene. High amounts of certain amines may be found in food as a consequence of the use of poor quality raw materials, contamination and inappropriate conditions during food processing and storage (Brink, Damink, Joosten, & Huis in't Veld, 1990; Halasz et al., 1994).

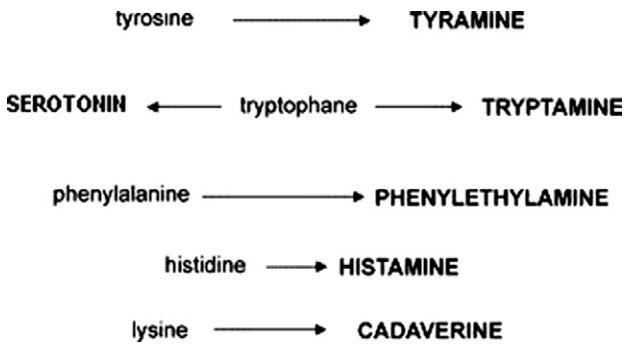

Fig. 3. Synthesis of biogenic amines (Halasz et al., 1994).

3. Toxicological effect

The biogenic amines content of various foods have been widely studied because of their potential toxicity. Biogenic amines, such as tyramine and β-phenylethylamine, have been proposed as the initiators of hypertensive crisis in certain patients and of dietary-induced migraine. Another amine, histamine, has been implicated as the causive agent in several outbreaks of food poisoning. Histamine intake ranged within 8–40 mg, 40–100 mg and higher than 100 mg may cause slight, intermediate and intensive poisoning, respectively (Parente et al., 2001). Nout (1994) pointed out that maximum allowable level of histamine and tyramine in foods should be in the range of 50–100 mg/kg and 100–800 mg/kg, respectively; over 1080 mg/kg tyramine becomes toxic. Putrescine, spermine, spermidine and cadaverine have no adverse health effect, but they may react with nitrite to form carcinogenic nitrosoamines and also can be proposed as indicators of spoilage (Eerola, Sagues, Lilleberg, & Aalto, 1997; Hernandez-Jover, Izquierdo-Pulido, Veciana-Nogues, Marine-Font, & Vidal-Carou, 1997). Tryptamine has toxic effects on human beings such as blood pressure increase, therefore causes hypertension, however there is no regulation on the maximum amount of tryptamine consumption in sausage in some countries (Shalaby, 1996).

Food poisoning may occur especially in conjunction with potentiating factors such as monoamine oxidase inhibiting (MAOI) drugs, alcohol, gastrointestinal diseases and other food amines. Histaminic intoxication, hypertensive crisis due to interaction between food and MAOI antidepressants, and food-induced migraines are the most common reactions associated with the consumption of food containing large amounts of biogenic amines (Mariné-Font, Vidal-Carou, Izquierdo-Pulido, Veciana-Nogués, & Hernández-Jover, 1995). The diamines (putrescine and cadaverine) and the polyamines (spermine and spermidine) have been shown to favour the intestinal absorption and decrease the catabolism of the above amines, thus, potentiating their toxicity (Bardócz, 1995). Formation of

nitrosamines, which are potential carcinogens, constitutes an additional toxicological risk associated to BA, especially in meat products that contain nitrite and nitrate salts as curing agents (Scanlan, 1983).

Determination of the exact toxicity threshold of BA in individuals is extremely difficult, since the toxic dose is strongly dependent on the efficiency of the detoxification mechanisms of each individual (Halasz et al., 1994). Normally, during the food intake process in the human gut, low amounts of biogenic amines are metabolised to physiologically less active degradation products. This detoxification system includes specific enzymes such as diamine oxidase (DAO). However, upon intake of high loads of biogenic amines in foods, the detoxification system is unable to eliminate these biogenic amines sufficiently. Moreover, in the case of insufficient DAO activity, caused for example by generic predisposition, gastrointestinal disease or inhibition of DAO activity due to secondary effects of medicines or alcohol, even low amounts of biogenic amines cannot be metabolised efficiently (Bodmer, Imark, & Kneubuohl, 1999). Some biogenic amines, e.g. histamine and tyramine, are considered as antinutritional compounds. For sensitive individuals they represent a health risk, especially when their effect is potentiated by other substances. Poisoning by histamine with its allergy-like symptoms is usually related to the consumption of scombroid fish such as tuna or mackerel (Veciana Nogue, Marine Font, & Vidal Carou, 1997; Wu, Yang, Yang, Ger, & Deng, 1997) and is considered to be one of the commonest forms of food intoxication reported.

4. Analytical methods

There are two reasons for the determination of amines in foods: the first is their potential toxicity; the second is the possibility of using them as food quality markers. Some of the major applications of biogenic amines analysis are: quality control of raw materials, intermediates and end products, monitoring fermentation processes, process control, research & development.

Various methods have been developed for the analysis of BAs in foods: thin-layer chromatography (TLC), gas chromatography, capillary electrophoretic method (CE) and high performance liquid chromatography (HPLC).

Lapa-Guimaraes and Pickova (2004) introduced one dimensional, double development thin-layer chromatographic technique, using the solvent system chloroform–diethyl ether–triethylamine (6:4:1) followed by chloroform–triethylamine (6:1) for separation and determination of the dansyl derivatives of BAs. One-dimensional TLC technique used for the separation of the eight biogenic amines. The quantitative determination of these amines was performed by densitometry at 254 nm (Shalaby, 1999).

A gas chromatographic-mass spectrophotometric (GC–MS) method in the selected ion-monitoring mode using heptafluorobutyric anhydride as a derivatization reagent was developed for the determination of biogenic amines in Port wines with a total run time of 18 min (Fernandes & Ferreira, 2000). Sample clean-up consisted of the extraction of the amines with the ion-pairing reagent bis-2-ethylhexylphosphate dissolved in chloroform followed by a back-extraction with 0.1 M HCl. A GC method, which reduced the time for determination of histamine in fish and fish products to less than 20 min, was reported (Hwang, Wang, & Choong, 2003). Contrary to traditional GC method, histamine in sample was initially extracted with alkaline methanol and injected into a GC column for analysis without derivatization.

Kvasnicka and Voldrich (2006) developed a direct (no derivatization step or sample cleaning, requiring only dilution or acidic extraction and filtration), sensitive and quick (less than 15 min) capillary electrophoretic method (CE) with conductometric detection for the determination of BAs in food products (salami, cheese, wine, and beer). The method reported by Lange, Thomas, and Wittmann (2002), a capillary electrophoresis (CE) and a high-performance liquid chromatography (HPLC) for the determination of biogenic amines in food were compared. The biogenic amines were separated in less than 9 min by CE or less than 20 min by HPLC. Zhang and Sun (2004) described sensitive capillary zone electrophoresis (CZE) with lamp-induced fluorescence detection method for the simultaneous analysis of histamine and histidine. NDA was used as the fluorescence derivatization reagent. In the another report of Zhang, determination of histamine and polyamines in the lysate of tobacco protoplasts was studied with the use of CE and lamp-induced fluorescence detection with 4-fluor-7-nitro-2,1,3-benzoxadiazole as the derivatization reagent to label these amines (Zhang, Tang, & Sun, 2005). Under the optimum conditions, the seven biogenic amines derivatives were separated within 200 s.

The biogenic amines in milk were separated and quantified by CE with pulsed amperometric detection (PAD) (Sun, Yang, & Wang, 2003). A new methodology was developed to separate and determine volatile amines (trimethylamine and other related amines) directly in fish samples by coupling a continuous flow system (CFS) with commercial CE equipment (Lista, Arce, Ríos, & Valcárcel, 2001). A gas extraction sampling device integrated in CFS was coupled to a capillary electrophoresis equipment. This arrangement allowed the direct introduction and treatment of these solid samples with a high level of automation. The amines compounds were extracted from fish samples in the sampling unit, then they were conditioned in the CFS and injected into the CE vials via a programmable arm. Arce, Rios, and Valcarcel (1998) developed a flow-injection (FI) manifold for automating the determination of biogenic amines in wine using CE with indirect UV detection. The method involves clean-up of the wine samples in the flow injection system by use of ion-exchange cartridges and a preconcentration step. The method allows the determination of a wide range of biogenic amines in less than 10 min. In the other report, *o*-Phthalaldehyde (OPA) derivatives of eight biogenic amines in fish, wine and urine were

Table 1
HPLC conditions for determination of BA

Biogenic amines	Food samples	Sample pretreatment	Stationary phase	Mobile phase flow rate (mL/min)	Derivatization/detection	Ref.
Dopamine, serotonin, TY, HI and PEA	Chocolate	Petroleum ether and 0.1 M $HClO_4$	Dionex CS17 at 40 °C.	Gradient elution aqueous methanesulfonic acid FR: 0.35	Electrochemical detector	Pastore et al. (2005)
HI, TY, TRP, PUT, PEA, CAD, SPD, SPM	Meat products	5% Trichloroacetic acid	For OPA derivatives Zorbax Eclipse XDB C_8. For dansyl derivatives Zorbax Eclipse XDB C18 column	For OPA derivatives: gradient elution 100 mM acetate buffer (A; pH 5.8) and acetonitrile FR:0.6. For dansyl derivatives: gradient elution H_2O/ACN FR:0.8	dansylchloride and *o*-phthaldi-aldehyde/254UV/VIS For OPA; 330 and 440 as excitation and emission wavelengths	Smělá et al. (2003)
HI, methylamine, ethylamine, TY, PEA, PUT and CAD	Meat products	Methanesulfonic acid	IonPac CS17 column, a cation-exchange column	Gradient elution methanesulfonic acid FR:1	UV and MS	Saccani et al. (2005)
HI, TY, TRP, PUT, PEA, CAD, SPD, SPM	Wines	–	Waters Nova-Pak C18	Gradient elution. Eluent A: Na_2HPO_4 and $12H_2O$ (3.6 mg/l, 10 mM). Eluent B: 1% 2-octanol in acetonitrile and eluent A (70:30 v/v). FR:0.8	OPA/340 and 425 as excitation and emission wavelengths, respectively	Marcobal et al. (2005)
PUT, HI, PEA, TY, CAD, SPM, SPD, AGM	Wines	–	Luna C18	Gradient elution. Eluent A: buffer pH 8 (30 mL) + acetonitrile (550 mL) + water (420 mL). Eluent B: buffer, pH 8 (2 mL) + acetonitrile (900 mL) + water (100 mL)	OPA/diode array detector (DAD) (200–550 nm)	Anlı et al. (2004)
HI	Tuna fish	1 M $HClO_4$	Luna C18	Gradient elution. Eluent A: 85% of buffer solution (pH 6.9) and 15% of methanol. Eluent B: acetonitrile	DAD	(Cinquina, Calı et al., 2004)
HI, TRP, PUT, CAD, TY	Beer	–	SGX-C18	Gradient elution 71 % (v/v) methanol in water for HI and TYR 63.5% (v/v) methanol in water for CAD, PUT and TRP FR:0.5	254 nm	Kalac et al. (1997)
HI, TY, PEA, TR, CAD, PUT, AGM, SPM, SPD, dopamine, octopamin, serotonin, creatinine	Alcoholic beverages	–	Nova-Pak C18	Gradient elution eluent A: 0.1 M sodium acetate and 10 mM sodium octanesulfonate (pH 5.3). Eluent B: mixture of solvent B–acetonitrile (6.6:3.4), where solvent B was a solution of 0.2 M sodium acetate and 10 mM sodium octanesulfonate solution adjusted to pH 4.5 FR:1	Post-column derivatizating with OPA/fluorimetric detection, 340 and 445 as excitation and emission wavelengths, respectively	Vidal-Carou et al. (2003)

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Table 1 (*continued*)

Biogenic amines	Food samples	Sample pretreatment	Stationary phase	Mobile phase flow rate (mL/min)	Derivatization/detection	Ref.
Methylamine, ethylamine, TRP, PEA, Isoamylamine, PUT, CAD, HI, TY, SPD, SPM	Alcoholic beverages	Polyvinylpyrrolidone	Inertsil ODS-3	Gradient elution (A) water and (B) acetonitrile, FR:1	Derivatization with dansylchloride, fluorimetric detection 320 and 523 as excitation and emission wavelengths, respectively	Loukou and Zotou (2003)
TY	Cheese	5% (w/v) of $HClO_4$	Phenomenex Luna RP-18	Isocratic elution MeOH:H_2O (70:30) FR:1	Derivatization with 4-chloro-7-nitrobenzofurazan UV detection at 458 nm	Yigit and Ersoy (2003)
HI, TY, PUT, CAD, SPD, SPM, serotonine	Coffee	Trichloroacetic acid	Kromasil C18	Gradient elution 0.5 mM phosphoric acid = acetonitrile = Methanol FR:1	Diode array detector at 254 nm, connected in series with a fluorimetric detector programmed for excitation at 252 nm and emission at 500 nm (derivatization with dansylchloride)	Casal et al. (2002)
PUT, CAD, SPD, HI, TY	Fish and fishery products	5% TCA	C-18μ- Bondapak RP-column	Gradient elution methanol/water FR:1	UV detector at 254	Shakila et al. (2001)
Agmatine, CAD, HI, TY, TRP, PUT, octopamine, PEA, serotonin, SPD, SPM	Fermented cabbage juices, soy sauces	0.1 M HCl or *n*-hexane	Grom-Sil a ODS-3 CP 120 RP-18 encapsulated polymer coated column	Gradient elution. Eluent A: 100 mM NaOAc, pH 7.0; eluent B: 100 mM NaOAc, pH 4.3; eluent C: acetonitrile	UV-absorption at 260 nm	Kirschbaum et al. (2000)
HI, TY, PEA, TR, CAD, PUT, SPM, SPD	Wines	HCl- 3,3′-thiodipropionic acid	LiChrospher 100 RP-18	Gradient elution. Eluent A, consisting of sodium acetate, 10% (v/v) dimethylformamide, and 0.23% (v/v) triethylamine (pH 5). Eluent B, consisted of acetonitrile–*tert.*-butylmethyl ether–water (87.5:10:2.5, v/v/v). FR:1	Derivatization with dabsyl chloride spectrophotometric detection at 446 nm	Romero et al. (2000)
Methylamine, ethylamine, PEA, PUT, CAD, HI, TY and 3-methylbutylamine	Wines	Solid-phase extraction C_{18} and SAX cartridges	Asahipack OP-50 cartridge	Gradient elution (A) 5 mM borate solution (pH 9) with 1% THF, (B) 5 mM borate solution (pH 9) with 12 mM OPA-NAC, and (C) ACN FR:0.8	Derivatization with OPA, fluorimetric detection 340 nm and 450 nm as the excitation and emission wavelengths, respectively.	(Busto et al., 1997)
HI, PUT, CAD, SPD	Fish tissues	Methanesulfonic acid	IonPac CS17 column	Gradient elution methanesulfonic acid gradient FR:1	Electrochemical detection	Cinquina, Calı et al. (2004)
HI, TY and PEA	Cheese	Solid-phase extraction with CN bonded silica	A Luna C18	Gradient elution mixture of 0.1% TFA (v/v) aqueous solution (eluent A) and methanol (eluent B) FR:0.2	Tandem mass spectrometry	Calbiani et al. (2005)

HI, PUT, CAD, SPD, TY, SPM and free amino acids	Dry-cured hams	0.4 M perchloric acid	LiChrospher 100C18	Not available	Derivatised with dansyl chloride reagent UV absorbance at 254 nm	Alfaia et al. (2004)
TR, PEA, PUT, CAD, HI, TY	Wines	–	A Synergi Hydro-RP C18	Gradient elution. Eluent A: 2% (v/v) acetic acid aqueous solution, Eluent B: methanol as organic modifier FR:1	Derivatization with 1,2-naphthoquinone-4-sulfonate spectrophotometric detection at 305 and 270 nm	García-Villar et al. (2006)
HI, TY, PEA, serotonin, creatinine sulfate, TR, octopamine dopamine, CAD, PUT, AGM, SP, SPD, methylamine, ethylamine	Spinach, hazelnut, banana, potato, and milk chocolate	0.6 M perchloric acid	A Nova-Pak C_{18}	Gradient elution. Eluent A: a solution of 0.1 M sodium acetate and 10 mM sodium octanesulfonate (pH 5.23), eluent B: mixture of solvent B–acetonitrile (6.6:3.4), where solvent B was a solution of 0.2 M sodium acetate and 10 mM sodium octanesulfonate solution adjusted to pH 4.5 with acetic acid FR:1.2	Derivatization with OPA, fluorimetric detection 340 and 445 nm as the excitation (ex) and emission (em) wavelengths, respectively	Lavizzari et al. (2006)
Ethanolamine, ethylamine, octopamine, dopamine, TY, 1,4diaminobutane HI, AGM, PEA, TR, SPD, SP	Wines	–	A Zorbax C8 column	Gradient elution. Eluent A: 15% ACN + 85% aqueous solution (15 mM sodium heptanesulfonate (SHS) + 10 mM phosphoric acid); eluent B: 70% ACN + 30% aqueous solution (8 mM SHS + 10 mM phosphoric acid) FR:0.8	Derivatization with 1,2-naphthoquinone-4-sulfonate spectrophotometric detection at 305	Hlabangana et al. (2006)
SP, PEA, SPD, PUT and CAD	Apples and wines	–	ZORBAX Eclipse XDB-C_8	Gradient elution mobile phase: 73% (v/v) methanol, 2% (v/v) water, 25% (v/v) HAc–NaAc buffer (pH 5.8, 1% THF) FR:1	Derivatization with 8-phenyl-(4-oxy-acetic acid *N*-hydroxysuccinimide ester)-4,4-difluoro-1,3,5,7-tetramethyl-4-bora-3a,4a-diaza-*s*-indacene, fluorimetric detection 497 nm (ex) and 509 nm (em)	Li et al. (2006)
Methylamine, ethylamine, PEA, isoamylamine, PUT, CAD, HI, TY, SPD and SP	Wines	–	Inertsil ODS-2 and 3	For the biogenic amines, gradient elution acetonitrile–water FR:1. For the amino acids, eluent A: aqueous solution of 0.68% (w/v) CH_3COONa and 5% (v/v) tetrahydrofuran, adjusted to pH 5.7 with acetic acid; eluent B: absolute methanol, FR:1 For the organic acids, a mobile phase consisting of 2% methanol and 98% 0.02 M KH_2PO_4 (pH 2.88, adjusted with H_3PO_4) FR:0.6	For the biogenic amines, derivatised with dansyl chloride reagent UV absorbance at 254 nm, For the amino acids, derivatization with OPA, fluorimetric detection 340 nm (ex) and 450 nm (em), For the amino acids, UV detection at 230 nm	Soufleros et al. (2007)

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Table 1 (*continued*)

Biogenic amines	Food samples	Sample pretreatment	Stationary phase	Mobile phase flow rate (mL/min)	Derivatization/detection	Ref.
TR, PEA, PUT, CAD, HI, TY, SP, SPD	cheese	0.1 M hydrochloric acid	A reversed-phase Kromasil KR 100-5 C18	Gradient consisting of eluents: (A) acetonitrile and (B) water FR:0.8	Spectrophotometric detector at 254 nm	Innocente et al. (2006)

stabilized at 5 °C by forming inclusion complexes with methyl-β-cyclodextrin. The derivatives were separated and detected by cyclodextrin-modified capillary electrophoresis with UV or laser-induced fluorescence (LIF) detection (Male & Luong, 2001).

Biogenic amines have been determined in nine solid food samples using a full-automated method based on pervaporation coupled on-line with CE and indirect UV detection (Ruiz-Jiménez & Luque de Castro, 2006). CE was interfaced by the appropriate FI manifold enabling the development of and automatic approach for the determination of biogenic amines in solid samples avoiding the problems arising from the complex sample matrix and the low concentration level at which these compounds are present in the samples. Cortacero-Ramírez, Arráez-Román, Segura-Carretero, and Fernández-Gutiérrez (2007) carried out capillary zone electrophoresis (CZE) method using acetone as an organic modifier and laser-induced fluorescence detection (LIF) for the determination of biogenic amines in beers and brewing process samples after derivatization with fluoresceine isothiocianate (FITC).

28 biogenic amines and amino acids were quantitated in red French wines during a 14 year period of ripening of a French red wine from the Cahors region by micellar electrokinetic chromatography (MECC) separation and laser-induced fluorescence (LIF) detection of fluorescein thiocarbamate derivatives (Nouadje et al., 1997). In the other MECC with LIF detection method was applied to the determination of biogenic amines (Liu, Yang, & Lu, 2003). 3-(2-Furoyl)quinoline-2-carboxaldehyde was chosen as a fluorogenic derivatization reagent. The eight biogenic amines derivatives separated within 30 min by LIF detection. This method was also used determination of biogenic amines in extracts of tobacco leaf. Kalac, Savel, Krizek, Pelikánová, and Prokopová (2002) reported a MECC method for the determination of BA as *N*-benzamides in bottled beers. A method for determining biogenic amines in three different food samples (wine, salami and chive) using MECC has been developed (Kovacs, Simon-Sarkadi, & Ganzler, 1999). Derivatization of the amines was performed using 6-aminoquinolyl-*N*-hydroxysuccinimidyl carbamate as reagent. The separation of seven biogenic amines could be achieved within 25–30 min. A method of on-line chemiluminescence detection with capillary electrophoresis for biogenic amines (diaminopropane, putrescine, cadaverine and diaminohexane) labeled with *N*-(4-aminobutyl)-*N*-ethylisoluminol was reported (Liu & Cheng, 2003). Two separation modes, CZE and MECC, were studied.

MECC method was developed for the determination of biogenic amines by benzoylating with benzoyl chloride using UV detection in the two fried fish fillets implicated in the food poisoning incident and 10 samples including marlin, sea bream, tuna, mackerel and their products which were collected from common markets (Su, Chou, Chang, & Hwang, 2000). Another MECC method was developed for the separation of biogenic amines in foods as *N*-substituted

benzamides using an uncoated fused-silica capillary column (Krizek & Pelikanova, 1998). Complete separation was achieved within 35 min.

An electrochemical biosensor for the determination of biogenic amines in food products and its application to salted anchovy samples was described by Draisci et al. (1998). Variations of the amines content in anchovies during ripening time were measured both with the biosensor and ion chromatography with integrated pulsed amperometric detection (IC-IPAD). An enzyme sensor array for the simultaneous determination of the three biogenic amines (histamine, tyramine and putrescine) by pattern recognition using an artificial neural network and its application to different food samples was described (Lange & Wittmann, 2002). Analysis procedure using sensor array was completed within 20 min with only one extraction and subsequent neutralisation step required prior to sensor measurement.

The extent of spoilage of muscle food products was determined through measurement of volatile biogenic amines from on muscle food, namely, meat from several sources: chicken, turkey, beef, porkand fish and the amines were monitored by ion mobility spectrometry (Karpas, Tilman, Gdalevsky, & Lorber, 2002).

HPLC conditions for determination of BA are listed in Table 1.

5. Conclusions

The biogenic amines content of various foods has been widely studied because of their potential toxicity. Histamine, putrescine, cadaverine, tyramine, tryptamine, phenyl ethylamine, spermine and spermidine are the most important biogenic amines (Shalaby, 1996). Biogenic amines could be found in meat, sausages, milk, chocolate, cheese, fish and some beverages (Eerola et al., 1997; Hernandez-Jover et al., 1997; Shalaby, 1996). It is important to monitor biogenic amines levels in foodstuffs and beverages in view of their importance for human health and food safety.

The two highest drawbacks in the analysis of biogenic amines in food are: (1) the complexity of the sample matrix and (2) the low concentration levels at which the compounds are present in the samples. Because the presence of potentially interfering compounds in sample matrix, the several BA simultaneously cannot be determined in the analysis. Pre clean-up procedure comprises extraction of sample with suitable extracting solvents. The extraction of amines indicates the crucial step of the procedure and it affects the analytical recoveries as negatively. Many different solvents have been used for the extraction of BAs from solid food samples, such as hydrochloric acid [wines (Fernandes & Ferreira, 2000), fermented cabbage juices, soy sauces (Kirschbaum, Rebscher, & Brü¨ckner, 2000), wines (Romero, Ga'zquez, Bagur, & Sánchez-Viñas, 2000)], trichloroacetic acid [meat products (Smělá, Pechová, Komprda, Klejdus, & Kubáň, 2003), coffee (Casal, Oliveira, & Ferreira, 2002), fish and fishery products (Shakila, Vasundhara, & Kumudavally, 2001)], perchloric acid [salted anchovies (Draisci et al., 1998), tuna fish (Cinquina, Calı et al., 2004; Cinquina, Longo et al., 2004), cheese (Yigit & Ersoy, 2003), dry-cured hams (Alfaia et al., 2004)], methanesulfonic acid [fish tissues (Cinquina, Calı et al., 2004; Cinquina, Longo et al., 2004)], petrolum ether [chocolate (Pastore et al., 2005)] and other organic solvents. Solid phase extraction has also been used prior to determination (Calbiani et al., 2005; Moret, Bortolomeazzi, & Lercker, 1992).

Several methods to analyse biogenic amines in food based on thin layer chromatography, liquid chromatography, gas chromatography, biochemical assays and capillary electrophoresis have so far been described. TLC is simple and does not require special equipment, but most of the published methods suffer from the excessive time needed for analysis and/or inaccuracy of the obtained results (semi-quantitative). GC is not so often applied for the determination of BA. CE with fluorescence detection has been a most popular analytical tool due to the higher sensitivity over electrochemical and ultraviolet detection. As biogenic amines do not exhibit strong fluorescence, they could not be detected directly in a sensitive manner. The biosensor procedure has advantages, such as low cost, short analysis time, simplicity of use and it can be used outside an organized laboratory. Among the methods, HPLC with pre- or post-column derivatisation is by far the mostly frequently reported technique for biogenic amines separation and quantification. Due to low volatility and lack of chromophores most of BA derivatization procedure (pre- or post-column) has been usually applied. Different chemical reagents have been used for the BA analysis. Dansyl and dabsyl chloride, benzoyl chloride, fluoresceine, 9-fluorenylmethyl chloroformate, *o*-Phthalaldehyde, naphthalene-2,3-dicarboxaldehyde have been used as derivatisation reagents. OPA can easily react with primary amines within about 30 s in the presence of a reducing reagent, such as *N*-acetylcyteine or 2-mercaptoethanol, but the derivatives are not very stable. Dabsyl and dansylchloride react with both primary and secondary amino groups and provide stable derivatives. Dansyl chloride has been the most widely used reagent. For the detection, fluorescence, UV, and electrochemical detectors are used. There are only some methods in which the derivatization procedure is not to be used such as enzymic sensor array method detection (Lange et al., 2002), HPLC with conductometric (Cinquina, Calı et al., 2004), CZE with amperometric detection (Sun et al., 2003) and CE with conductometric detection (Kvasnicka & Voldrich, 2006). No derivatization step or sample cleaning and short analysis time are the advantages of these methods.

Biogenic amines can also be produced by bacterial decarboxylation of amino acids. So any foodstuffs produced by fermentation or exposed to microbial contamination during processing or storage may contain biogenic

amines. The concentration of biogenic amines like histamine, cadaverine, putrescine, spermidine and tyramine gives therefore a good indication of the freshness of foodstuffs. The determination of biogenic amines in fresh and processed foods is of great interest not only due to their toxicity, but also because they can be a useful index of spoilage or ripening. For these reasons, it is important to monitor biogenic amines levels in foodstuffs.

Analytical determination of biogenic amines is not simple because of the complexity of the real matrices to be analysed. The extraction of amines from real matrices is the most critical in terms of obtaining adequate recoveries for all amines. The most of the analysis include derivatization step which causes time consuming in the analytical process. It is needed to develop sensitive less time-consuming and easier analytical methods for the determination and detection of BA in foods undoubtedly need.

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