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**Brandt, SD, Kavanagh, PV, Dowling, G, Talbot, B, Westphal, F, Meyer, MR, Maurer, HH and Halberstadt, AL**

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Analytical characterization of *N,N*-diallyltryptamine (DALT) and 16 ring-substituted derivatives

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Keywords:	New psychoactive substances, Tryptamines, DALT, Chemistry, Forensic, Clinical
Abstract:	<p>Many <i>N,N</i>-dialkylated tryptamines show psychoactive properties in humans and the number of derivatives involved in multidisciplinary areas of research has grown over the last few decades. Whereas some derivatives form the basis of a range of medicinal products, others are predominantly encountered as recreational drugs, and in some cases, the areas of therapeutic and recreational use can overlap. In recent years, 5-methoxy-<i>N,N</i>-diallyltryptamine (5-MeO-DALT) has appeared as a new psychoactive substance (NPS) and 'research chemical' whereas 4-acetoxy-DALT and the ring-unsubstituted DALT have only been detected very recently. Strategies pursued in the authors' laboratories included the preparation and biological evaluation of previously unreported <i>N,N</i>-diallyltryptamines (DALTs). This report describes the analytical characterization of seventeen DALTs. Fifteen DALTs were prepared by a microwave-accelerated Speeter and Anthony procedure following established procedures developed previously in the authors' laboratories. In addition to DALT, the substances included in this study were 2-phenyl-, 4-acetoxy-, 4-hydroxy-, 4,5-ethylenedioxy-, 5-methyl-, 5-methoxy-, 5-methoxy-2-methyl-, 5-ethoxy-, 5-fluoro-, 5-fluoro-</p>

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	<p>2-methyl-, 5-chloro-, 5-bromo-, 5,6-methylenedioxy-, 6-fluoro-, 7-methyl, and 7-ethyl-DALT, respectively. The DALTs were characterized by nuclear magnetic resonance spectroscopy (NMR), gas chromatography (GC) quadrupole and ion trap (EI/CI) mass spectrometry (MS), nominal and high mass accuracy MS/MS, ultraviolet diode array detection and GC solid-state infrared analysis, respectively. A comprehensive collection of spectral data was obtained that are provided to research communities who face the challenge of encountering newly emerging substances where analytical data are not available. These data are also relevant to researchers who might wish to explore the clinical and non-clinical uses of these substances.</p>

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## Analytical characterization of N,N-diallyltryptamine (DALT) and 16 ring-substituted derivatives

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**Running title:** Analytical characterization of N,N-diallyltryptamines (DALTs)

**Keywords:** New psychoactive substances; tryptamines; DALT; chemistry; forensic

## Abstract

Many *N,N*-dialkylated tryptamines show psychoactive properties in humans and the number of derivatives involved in multidisciplinary areas of research has grown over the last few decades. Whereas some derivatives form the basis of a range of medicinal products, others are predominantly encountered as recreational drugs, and in some cases, the areas of therapeutic and recreational use can overlap. In recent years, 5-methoxy-*N,N*-diallyltryptamine (5-MeO-DALT) has appeared as a new psychoactive substance (NPS) and 'research chemical' whereas 4-acetoxy-DALT and the ring-unsubstituted DALT have only been detected very recently. Strategies pursued in the authors' laboratories included the preparation and biological evaluation of previously unreported *N,N*-diallyltryptamines (DALTs). This report describes the analytical characterization of seventeen DALTs. Fifteen DALTs were prepared by a microwave-accelerated Speeter and Anthony procedure following established procedures developed previously in the authors' laboratories. In addition to DALT, the substances included in this study were 2-phenyl-, 4-acetoxy-, 4-hydroxy-, 4,5-ethylenedioxy-, 5-methyl-, 5-methoxy-, 5-methoxy-2-methyl-, 5-ethoxy-, 5-fluoro-, 5-fluoro-2-methyl-, 5-chloro-, 5-bromo-, 5,6-methylenedioxy-, 6-fluoro-, 7-methyl-, and 7-ethyl-DALT, respectively. The DALTs were characterized by nuclear magnetic resonance spectroscopy (NMR), gas chromatography (GC) quadrupole and ion trap (EI/CI) mass spectrometry (MS), low and high mass accuracy MS/MS, ultraviolet diode array detection and GC solid-state infrared analysis, respectively. A comprehensive collection of spectral data was obtained that are provided to research communities who face the challenge of encountering newly emerging substances where analytical data are not available. These data are also relevant to researchers who might wish to explore the clinical and non-clinical uses of these substances.

## Introduction

Many *N,N*-dialkylated tryptamine derivatives show psychoactive properties in humans.<sup>[1-5]</sup> Naturally occurring *N,N*-dimethyltryptamines, such as psilocybin, have been used for religious purposes since antiquity. Recently, *N,N*-dialkyltryptamines have also been the focus of attention due to increasing research efforts in clinically important areas<sup>[6-10]</sup> including potential treatment options for cluster headaches.<sup>[11-14]</sup> Non-medical and recreational use of both synthetic and naturally occurring derivatives and occurrences of untoward effects have been also been observed in recent years.<sup>[15,16]</sup>

One of the many potential and yet less explored substitution patterns is the synthetic *N,N*-diallyl substituted tryptamine template. The synthesis of the ring-unsubstituted tryptamine derivative *N,N*-diallyltryptamine (DALT) (**1**) (Figure 1) was first published in 1959<sup>[17]</sup> and indications about its psychoactive properties emerged in 1962, when it was briefly noted by Szára and Hearst.<sup>[18]</sup> In the following years, Szára mentioned a 'psychotropic dose' of 60 mg.<sup>[19]</sup> Subsequently, Alexander T. Shulgin synthesized both DALT (**1**) and 5-MeO-DALT (**7**) (A.T. Shulgin, personal communication). Although DALT (**1**) appeared to have few distinct effects at oral doses up to 42 mg<sup>[20]</sup> (80 mg has also been noted elsewhere<sup>[21,22]</sup>), 5-MeO-DALT (**7**) was found to produce

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3 short-lived, psychoactive effects at a dosage range of 12-20 mg. Remarkably, oral  
4 administration led to a comparatively fast onset of effects. Some of the information  
5 shared by Shulgin and Shulgin appeared on various Internet sites in 2004, which  
6 coincided with the marketing of 5-MeO-DALT (**7**) by chemical suppliers, presumably  
7 in response to data shared by Shulgin and Shulgin.<sup>[20,23-27]</sup> Reports linked to the  
8 detection of 5-MeO-DALT (**7**) began to surface in 2007<sup>[28-31]</sup> and continued to emerge  
9 until the present day. In recent years, 5-MeO-DALT (**7**) has been frequently  
10 discussed within the context of being a new psychoactive substance (NPS) where  
11 many of these substances are advertised as 'research chemicals' and available for  
12 purchase from Internet retailers or shops.<sup>[32,33]</sup> As far as the availability of analytical  
13 data are concerned, the majority of available reports describing the detection and  
14 characterization DALT derivatives focus on 5-MeO-DALT (**7**), reflecting its  
15 appearance in forensically related casework and/or from retail purchases<sup>[17,20,27,31,34-61]</sup>  
16 (**Table 1**).

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20 Strategies pursued in the authors' laboratories include the preparation of previously  
21 unreported DALT analogs in order to make available the analytical data to  
22 researchers who encounter these types of new psychoactive substances (NPS) and  
23 'research chemicals'. Furthermore, the psychoactive properties associated with a  
24 range of *N,N*-dialkylated tryptamines make the DALT compounds a desirable target  
25 for pharmacological and pharmacokinetic investigations as reported recently for  
26 some of the compounds characterized in the present study.<sup>[59,61-63]</sup> In addition to 5-  
27 MeO-DALT (**7**),<sup>[30]</sup> the two additional DALT analogs 4-AcO-DALT (**3**)<sup>[64]</sup> and DALT  
28 (**1**),<sup>[65]</sup> also described in the present study, have been detected by the European  
29 Early-Warning System and reported to the European Monitoring Centre for Drugs  
30 and Drug Addiction (EMCCDA), which suggested that the development of new DALT  
31 analogs might be a likely prospect within the 'research chemical' context.

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36 Research communities confronted with the NPS phenomenon face a number of  
37 challenges, which include the lack of analytical data when dealing with newly  
38 emerging substances. The present study addresses the need for providing a  
39 comprehensive collection of analytical data for DALT analogs (**1**) – (**17**) (Figure 1).  
40 The majority of spectral data described in this report are described for the first time.  
41 Synthesized compounds were characterized by nuclear magnetic resonance  
42 spectroscopy (NMR), gas chromatography (GC) quadrupole and ion trap (EI/CI)  
43 mass spectrometry (MS), and low and high mass accuracy MS/MS, ultraviolet diode  
44 array detection and GC solid-state infrared analysis, respectively.

## 45 46 47 48 **Experimental**

### 49 50 **Materials**

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52 4-AcO-DALT (**3**) and 4-OH-DALT (**4**), sold as the fumarate salt, were from Scientific  
53 Supplies (London, UK). 5-MeO-2-Me-DALT HCl (**8**) and 5-EtO-DALT HCl (**9**) were  
54 available from previous studies.<sup>[39,42]</sup>  
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3 The synthesis of *N,N*-diallyltryptamines (DALTs) reported in this study adopted the  
4 well-established procedure of Speeter and Anthony.<sup>[66]</sup> As summarized in the  
5 Supporting Information, the substituted indole starting material (**a**) was acylated to  
6 give the acid chloride intermediate (**b**) followed by amination with *N,N*-diallylamine to  
7 the yield glyoxalylamide (**c**). The reduction with lithium aluminum hydride provided  
8 the DALT analogs. The reduction of the corresponding glyoxalylamide (**c**) (0.3 mmol)  
9 was carried out under microwave-accelerated conditions as described in detail by the  
10 authors previously.<sup>[35,39,42]</sup> High accuracy electrospray ionization mass spectra of the  
11 protonated molecules and their key product ions are summarized in Table 3. All <sup>1</sup>H  
12 and <sup>13</sup>C NMR data for intermediates (**c**) and DALTs (**1**) – (**17**) are presented as  
13 Supporting Information.  
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## 16 17 **Instrumentation**

### 18 19 *Gas chromatography-mass spectrometry (GC-MS)*

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21 Electron ionization (EI) mass spectra (70 eV) were recorded using a Finnigan TSQ  
22 7000 triple stage quadrupole mass spectrometer coupled to a gas chromatograph  
23 (Trace GC Ultra, Thermo Electron) using a CTC CombiPAL (CTC Analytics,  
24 Switzerland) autosampler. The emission current was 200  $\mu$ A and the scan time was  
25 1 s spanning a scan range between  $m/z$  29 –  $m/z$  600. The ion source temperature  
26 was maintained at 175 °C. Samples were introduced via GC with splitless injection  
27 using a fused silica capillary DB-1 column (30 m x 0.25 mm, film thickness 0.25  $\mu$ m).  
28 The temperature program consisted of an initial temperature of 80 °C, held for 1 min,  
29 followed by a ramp to 280 °C at 15 °C/min. The final temperature was held for 21  
30 min. The injector temperature was 220 °C. The transfer line temperature was  
31 maintained at 280 °C and the carrier gas was helium in constant flow mode at a flow  
32 rate of 1.0 mL/min. Approximately 2 mg were dissolved in 1.5 mL methanol. For  
33 analysis, 1  $\mu$ L sample solutions were injected into the GC-MS system.  
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### 37 38 *Gas chromatography solid-state infrared analysis (GC-sIR)*

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40 The methanolic solution was measured on a GC-solid phase-IR-system consisting of  
41 an Agilent GC 7890B (Waldbronn, Germany) with probe sampler Agilent G4567A  
42 and a DiscovIR-GC™ (Spectra Analysis, Marlborough, Massachusetts, USA). The  
43 column eluent was cryogenically accumulated on a rotating ZnSe disk that was  
44 cooled by liquid nitrogen. The IR spectra were directly recorded through the IR-  
45 transparent ZnSe disk using a nitrogen cooled MCT detector. GC parameters: the  
46 injection was carried out in splitless mode with an injection port temperature of  
47 240 °C and a DB-1 fused silica capillary column (30 m x 0.32 mm i.d., 0.25  $\mu$ m  
48 film thickness). The carrier gas was helium with a flow rate of 2.5 mL/min; oven  
49 temperature program: 80 °C for 2 min, ramped to 290 °C at 20 °C/min, and held at  
50 the final temperature for 25 min. The transfer line heater was set at 280 °C. IR  
51 conditions: oven temperature, restrictor temperature, disc temperature, and Dewar  
52 cap temperatures were 280 °C, 280 °C, -40 °C, and 35 °C, respectively. The vacuum  
53 was 0.2 mTorr, disc speed 3 mm/s, spiral separation was 1 mm, wavelength  
54 resolution 4  $\text{cm}^{-1}$  and IR range 650–4000  $\text{cm}^{-1}$ . Acquisition time was 6s/file with 64  
55 scans/spectrum. Data were processed using GRAMS/AI Ver. 9.1 (Grams  
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3 Spectroscopy Software Suite, Thermo Fischer Scientific) followed by implementation  
4 of the OMNIC Software, Ver. 7.4.127 (Thermo Electron Corporation).  
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#### 7 *High-resolution electrospray ionization mass spectrometry (HR-ESI-MS)*

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9 High-resolution mass spectral and MS/MS analyses were performed on an  
10 LTQ/Orbitrap™ Discovery mass spectrometer (Thermo Scientific, Bremen,  
11 Germany). This hybrid system consists of a linear ion trap (LTQ™) coupled to an  
12 Orbitrap™ Fourier transform mass spectrometer for accurate mass measurements.  
13 Samples were dissolved in acetonitrile/water (1:1, containing 0.1% formic acid) and  
14 infused at a rate of 5 µL/min. Measured accurate masses were within ± 5 ppm of the  
15 theoretical masses. The following conditions were used: drying gas (N<sub>2</sub>) 10 L/min,  
16 capillary temperature 310 °C, spray voltage 4 V, capillary voltage, 22 V and tube lens  
17 77 V. A normalized collision energy™ (NCE) of 45% (of a maximum of 5 eV) was  
18 used for CID. Full scan high-resolution (30,000 FWHM) spectra (*m/z* 75 – 400) were  
19 acquired in positive electrospray ionization (ESI) mode. Mass calibrations were  
20 performed using solutions of caffeine, *L*-methionyl-arginyl-phenylalanylalanine  
21 acetate × H<sub>2</sub>O (MRFA), Ultramark 1621®, sodium dodecyl sulfate and sodium  
22 taurocholate.  
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#### 26 *Diode array detection (DAD)*

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28 HPLC-DAD analyses were performed on an Agilent 1200 HPLC system equipped  
29 with the following modules: G1312B BinPump SL, G13798 degasser, G1367D HiP  
30 ALS SL plus autosampler, a G1316B column compartment (set at 35 °C), and a  
31 G1315C diode array detector (Agilent, Waldbronn, Germany). Data acquisition rate  
32 was 80 Hz with the scan rate set between 210 – 400 nm (spectrum step 1 nm). The  
33 injection volume was 10 µL (0.1 mg/mL analyte solution). A Synergi Max-RP (250 x  
34 4.6 mm, 4 µm) column from Phenomenex (Macclesfield, United Kingdom) was used  
35 and analytes were eluted under gradient conditions. Mobile phase A consisted of 25  
36 mM triethylammonium phosphate (TEAP) buffer solution and mobile phase B  
37 comprised of 70% acetonitrile and 30% water containing 25 mM TEAP. The gradient  
38 elution commenced at 70% A and decreased to 5% within 5 min. This was then held  
39 until 12 min and returned to initial conditions by a 5 min post time.  
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#### 44 *Liquid chromatography-mass spectrometry (LC-MS)*

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46 LC-MS analyses were performed on an Agilent 1100 HPLC system equipped with a  
47 G13795 degasser, G1312A BinPump, a G1313A ALS and G1316A column oven  
48 (COLCOM) (Agilent, Little Island, Cork, Ireland). Separation was obtained on a  
49 Kinetex phenyl-hexyl column (2.6 µm, 100 x 2.10 mm) Phenomenex (Macclesfield,  
50 Cheshire, United Kingdom). The analytes were eluted under isocratic conditions  
51 using a mobile phase of 97% water and 3% acetonitrile (both containing 0.1% formic  
52 acid). The Agilent single quadrupole MSD settings were as follows: positive  
53 electrospray mode, capillary voltage 3500 V, drying gas (N<sub>2</sub>) 12 L/min at 350 °C, and  
54 nebulizer gas (N<sub>2</sub>) pressure 50 psi. In-source collision-induced dissociation  
55 experiments were carried out with an increased fragmentor voltage of 110 V.  
56 Samples were dissolved in acetonitrile/water (1:1, containing 0.1% formic acid) at a  
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3 concentration of 10 µg/mL. The injection volume was 0.5 µL, flow rate was 0.4  
4 mL/min and the column temperature was set at 30 °C. Total run time was 25 min.  
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## 7 Results and discussion

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9 Electron ionization (EI) quadrupole mass spectra recorded for DALTs (1) – (17)  
10 featured a fragmentation behavior similar to other *N,N*-dialkyltryptamines<sup>[67,68]</sup> and a  
11 generalized scheme is proposed in Figure 2 to encompass the key features. The  
12 associated main fragments are summarized in Table 2 and all EI quadrupole mass  
13 spectra are provided as Supporting Information. Consistent with previously published  
14 reports about 5-MeO-DALT (7) and some of the other DALT analogs (Table 1), base  
15 peak formation of the iminium ion was observed at *m/z* 110 via alpha-cleavage  
16 (Figure 2A, pathway 'a'). The allyl ion at *m/z* 41 was also frequently observed,  
17 possibly formed by secondary fragmentation of *m/z* 110 or directly from the ionized  
18 allyl double bond in the intact molecular ion. An  $[M - 41]^+$  species, albeit occasionally  
19 low in relative abundance, is proposed to fragment further into  $[C_{10}H_8NR'R'']^+$  and  
20  $[C_8H_4NR'R'']^+$ , respectively (Figure 2A, pathway 'b'). Formation of  $[C_{10}H_7NR'R'']^+$  and  
21  $[C_8H_3NR'R'']^+$  ions might have followed the proposed mechanism shown in Figure 2B  
22 whereas detection of  $[C_9H_6NR'R'']^+$  might have resulted from alpha-cleavage  
23 instigated from ionization of C<sub>2</sub> – C<sub>3</sub> double bond of the indole ring (Figure 2C).  
24 Implementation of GC ion trap mass spectrometry showed some variations, for  
25 example, in relative abundance of fragment ions when compared those formed under  
26 quadrupole mass spectrometry conditions, which might have reflected the tendency  
27 to display self-ionization phenomena within the ion trap. For completeness, GC ion  
28 trap MS (GC-IT-MS) data using both EI and chemical ionization methods have been  
29 included as Supporting Information. Interestingly, an ion at *m/z* 228 was observed in  
30 the EI mass spectrum of MD-DALT (14) (Table 2, Figure 3A) and it was speculated  
31 that the associated loss of 56 amu from the molecular ion might have arisen from  
32 mechanisms proposed in Figure 3B and 3C. In the first scenario, MD-DALT (14)  
33 would have been required to degrade into an *ortho*-benzoquinone derivative before  
34 being subjected to a neutral loss off propene (Figure 3B). An alternative pathway  
35 might have involved an H-shift and rearrangement, possibly including an epoxide and  
36 benzoquinone intermediate. A subsequent loss of a methyl radical followed by a loss  
37 of an allyl radical could have accounted for *m/z* 228 (Figure 3C).  
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44 One of the challenges that might be encountered when identifying a new  
45 psychoactive substance on the market includes the consideration of potential  
46 isomers,<sup>[69,70]</sup> especially if not all of these substances are commercially available for  
47 analytical comparisons. From this perspective, it has become increasingly helpful to  
48 consider supporting implementation of analytical procedures by synthesis of the  
49 isomers of interest to support the verification process.<sup>[71-74]</sup> Figure 4 shows the  
50 similarity of EI mass spectra recorded for 5-F-DALT (10) and 6-F-DALT (15). As  
51 expected, these similarities precluded unambiguous identification and although the  
52 GC retention index values were slightly dissimilar under the conditions used but not  
53 sufficient for unambiguous identification without having both standards (see also  
54 supplemental GC-IT-MS data). An inspection of the photodiode array spectra  
55 obtained for both substances revealed only minor differences of potential  
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3 significance, such as distinct shoulders at lower wavelengths between 200 nm and  
4 230 nm (Figure 5A). The photo diode array spectra (PDA) of all DALTs are given as  
5 Supporting Information. The recorded PDA spectrum of 5-MeO-DALT (7) was  
6 consistent with one reported in the literature.<sup>[31]</sup>  
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9 The most promising data was obtained from GC solid-state infrared analysis (GC-  
10 sIR) as shown in Figure 5B – 5E. The expanded spectral regions shown in Figure 5C  
11 (5-F-DALT (10)) and Figure 4E (6-F-DALT (15)) confirmed that distinct differences  
12 could be noted between the two positional isomers. In case of 6-F-DALT (15), the  
13 more prominent differences included the sharp signals at wavenumbers 1630.0,  
14 1460.7 1348.2, 1150.3 and 802.2 cm<sup>-1</sup>, respectively. The advantage of employing a  
15 GC-sIR procedure was the formation of solid and amorphous free base material  
16 following elution of the analyte from the GC column. Consequently, IR spectra  
17 obtained from this procedure are comparable to standard spectra of the free bases  
18 recorded from attenuated total reflectance IR devices and are especially useful in  
19 identification of the correct isomers in analysis of mixtures. The GC-sIR spectra of all  
20 DALTs (1) – (17) are provided as Supplementary Information.  
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24 Positive electrospray (ES+) high-resolution MS and MS/MS data for all DALTs are  
25 summarized in Table 3 and, consistent with literature reported previously (Table 1),  
26 two key product ions were detected. The detected product ions were comparable to  
27 those observed when exposing the DALTs to analysis by LC positive mode single  
28 quadrupole mass spectrometry and in-source collision-induced dissociation. All mass  
29 spectra have been provided as Supporting Information.  
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32 The present study provided a comprehensive set of spectral data obtained from  
33 seventeen *N,N*-diallyltryptamines (DALTs) in order to facilitate the identification and  
34 exploration of these newly emerging substances. Another challenge frequently  
35 encountered with new psychoactive substances is the lack of information regarding  
36 their biological properties, which triggered a first set of studies carried out in the  
37 authors' laboratories in the areas of metabolism<sup>[59]</sup> and cytochrome P450 inhibition.<sup>[61]</sup>  
38 Receptor binding data for 5-MeO-DALT (7)<sup>[45]</sup> and additional DALTs substituted at  
39 the 5-position have also appeared recently.<sup>[63]</sup> The fact that a range of closely related  
40 *N,N*-dialkylated tryptamines (e.g. sumatriptan) show important therapeutic  
41 applications demonstrates that there is a need to disentangle the different  
42 pharmacological features associated with the tryptamine template.<sup>[5,75-81]</sup> Anecdotal  
43 reports suggest that 5-MeO-DALT (7) might provide relief from cluster headaches.<sup>[82]</sup>  
44 However, the extent to which this might apply to this particular compound or other  
45 DALTs warrants further investigation.  
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## 50 Conclusion

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52 The new psychoactive substances phenomenon is an area of investigation that  
53 attracts attention from multi-disciplinary stakeholders who face the challenge of  
54 keeping up-to-date with newly emerging substances where few data are available  
55 that aid their identification. The characterization of seventeen *N,N*-diallyltryptamines  
56 yielded a comprehensive set of analytical data that were collected to serve these  
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research communities that are involved with the study of psychoactive substances including both clinical and non-clinical applications.

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### Figure captions:

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35 **Figure 1.** Structures of ring-substituted *N,N*-diallyltryptamines (1) – (17)  
36 characterized in this study.  
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39 **Figure 2.** Proposed, generalized mass spectral fragmentation pathways for (1) –  
40 (17) recorded under electron ionization conditions (see also Table 2).  
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43 **Figure 3.** A: Electron ionization mass spectrum recorded for MD-DALT (14). B and  
44 C: Two proposed alternative mass spectral fragmentation pathways that may  
45 account for the formation of *m/z* 228.  
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48 **Figure 4.** Electron ionization mass spectra recorded for the two isomers 5-F-DALT  
49 (10) and 6-F-DALT (15).  
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52 **Figure 5.** A. Implementation of photodiode array detection for both isomers 5-F-  
53 DALT (10) and 6-F-DALT (15). B and C: Gas chromatography solid-state infrared  
54 data recorded for (10). D and E: Gas chromatography solid-state infrared data  
55 recorded for (15). Isomers (10) and (15) could be differentiated due to differences  
56 observed in the partial spectra C and E.  
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**Table 1.** Reports that describe the analysis of *N,N*-diallyltryptamines

Compound <sup>a</sup>	Techniques <sup>b</sup>	Comment	Ref.
DALT (1)	Elemental analysis	Synthesis employing 3-(2-bromoethyl)indole and <i>N,N</i> -diallylamine	[17]
DALT (1)	GC-MS, IR	Synthesis employing <i>N,N</i> -dialkylation of tryptamine	[20]
5-MeO-DALT (7)	GC-MS, IR	Synthesis employing <i>N,N</i> -dialkylation of 5-methoxytryptamine	[27]
5-MeO-DALT (7)	GC-MS, LC-MS, LC-PDA	Analytical characterization	[31]
5-MeO-DALT (7) <sup>c</sup>	GC-MS, IR, <sup>1</sup> H NMR <sup>c</sup>	Synthesis employing <i>N,N</i> -dialkylation of 5-methoxytryptamine <sup>c</sup>	[34]
<i>d</i> <sub>4</sub> -DALT (1) <i>d</i> <sub>4</sub> -5-MeO-DALT (7)	<sup>1</sup> H and <sup>13</sup> C NMR	Synthesis of deuterated standards <i>via</i> microwave-accelerated Speeter and Anthony procedure	[35]
5-MeO-DALT (7)	GC-MS, LC-PDA	Five out of 29 tryptamine products purchased between April 2005 and March 2008 were found to contain 5-MeO-DALT (7).	[36]
5-MeO-DALT (7)	LC-MECD	Analytical characterization	[37]
5-MeO-DALT (7) <sup>c</sup>	LC-MS <sup>c</sup>	Analytical characterization <sup>c</sup>	[38]
5-EtO-DALT (9) <i>d</i> <sub>4</sub> -5-EtO-DALT (9)	GC-EI-IT-MS, GC-CI-IT-MS/MS, <sup>1</sup> H and <sup>13</sup> C NMR	Synthesis <i>via</i> microwave-accelerated Speeter and Anthony procedure	[39]
5-MeO-DALT (7) <sup>c</sup>	LC-MS, LC-PDA <sup>c</sup>	Analytical characterization <sup>c</sup>	[40]
DALT (1)	LC-UV, <sup>1</sup> H and <sup>13</sup> C NMR, IR	Synthesis employing 3-(2-bromoethyl)indole and <i>N,N</i> -diallylamine	[41]
5-MeO-2-Me-DALT (8)	GC-EI-IT-MS, GC-CI-IT-MS/MS, <sup>1</sup> H and <sup>13</sup> C NMR	Synthesis <i>via</i> microwave-accelerated Speeter and Anthony procedure	[42]
5-MeO-DALT (7)	LC-DAD, LC-MS	Detection in postmortem femoral blood	[43]
5-MeO-DALT (7) <sup>d</sup>	-- <sup>d</sup>	Synthesis employing <i>N,N</i> -dialkylation of 5-methoxytryptamine <sup>d</sup>	[44]
5-MeO-DALT (7)	<sup>1</sup> H and <sup>13</sup> C NMR, UV, IR	Analytical characterization and receptor binding assays	[45]
5-MeO-DALT (7)	GC-MS, LC-MS, NMR, DART-TOF-MS	Liquid (n = 111) and powdered (n = 13) products purchased <i>via</i> the Internet between September 2009 and February 2012. Tryptamines including 5-MeO-DALT (7) detected in 31% of the samples.	[46]
5-MeO-DALT (7)	GC-MS	Detection in herbal mixture also containing phenazepam and two synthetic cannabinoids	[47]
5-MeO-DALT (7)	Presumptive color test	No reaction observed with sodium 1,2-naphthoquinone-4-sulphonate (NQS)	[48]
5-MeO-DALT (7)	SRI-ToF-MS	Compounds derived from test purchases	[49]
5-MeO-DALT (7)	GC-MS	Detection in herbal products (8 out of 75) containing synthetic cannabinoids	[50]

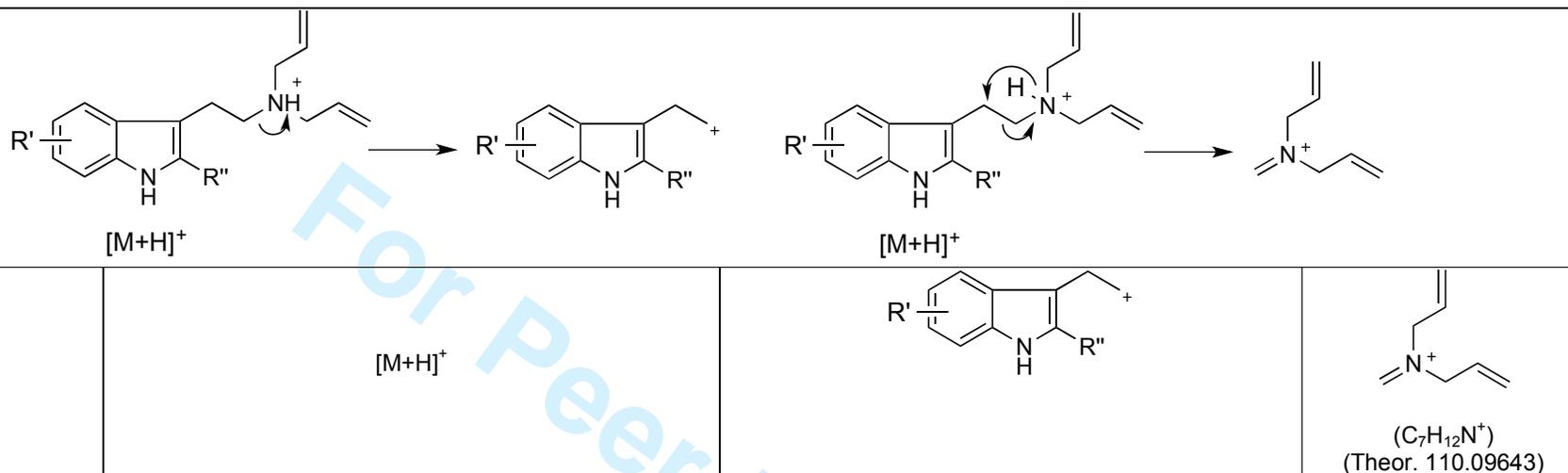
		collected between 2011 and June 2013.	
5-MeO-DALT (7)	LC-DAD, LC-MS/MS, LC-QTOF-MS/MS	One detection in casework in 2010	[51]
5-MeO-DALT (7)	Not reported	Case report featuring acute toxicity; no analytical confirmation	[52]
DALT (1) 2-Ph-DALT (2) 5-Me-DALT (6) 5-MeO-DALT (7) 5-MeO-2-Me-DALT (8) 5-EtO-DALT (9) <i>d</i> <sub>4</sub> -5-EtO-DALT (9) MD-DALT (14) 7-Me-DALT (16) 7-Et-DALT (17) 5-BnO-DALT <sup>e</sup>	LC-LIT-MS	Method development and detection in human urine and plasma	[53]
5-MeO-DALT (7) 5-MeO-DALT-TMS <sup>f</sup>	GC-MS, LC-QqQ-MS, <sup>1</sup> H NMR	Synthesis employing <i>N,N</i> -dialkylation of 5-methoxytryptamine and characterization.	[54]
5-MeO-DALT (7)	LC-CLND	Analysis of seized samples collected between 2011 – 2013.	[55]
5-MeO-DALT (7)	LC-DAD, LC-MS/MS, LC-QTOF-MS/MS	5-MeO-DALT (7) remained stable for over 21 days in both blood and plasma stored at room temperature	[56]
5-MeO-DALT (7)	GC-MS, LC-HR-MS	Detection in a seized sample	[57]
5-MeO-DALT (7)	Portable NIR	Presumptive testing and application to forensic samples	[58]
DALT (1) <i>d</i> <sub>4</sub> -DALT (1) 5-MeO-DALT (7)	GC-MS, LC-HR-MS, LC-LIT-MS	Identification of phase I and II metabolites in rat urine and in pooled human liver microsomes and initial CYP activity screening	[59]
5-MeO-DALT (7)	DLLME, LC-MS/MS	Detection in spiked blood samples	[60]
DALT (1) ED-DALT (5) 5-Me-DALT (6) 5-MeO-DALT (7)	LC-HR-MS, LC-QqQ-MS/MS	Cytochrome P450 inhibition assays and determination of in vivo CYP1A2 inhibition by 5-MeO-DALT (7) (caffeine as test substrate)	[61]

5-F-DALT (10) 5-F-2-Me-DALT (11) 5-Cl-DALT (12) 5-Br-DALT (13) MD-DALT (14) 6-F-DALT (15) 7-Me-DALT (16)			
<p><sup>a</sup> Substances other than 5-MeO-DALT (7) have also been studied in a number of references cited in this table.</p> <p><sup>b</sup> GC-MS: gas chromatography mass spectrometry; IR: infrared spectroscopy; NMR: nuclear magnetic resonance spectroscopy; LC: various forms of high performance liquid chromatography; PDA: photo diode array detection; MECD: multi-channel electrochemical detection; GC-EI-IT-MS: GC electron ionization ion trap mass spectrometry; GC-CI-IT-MS/MS: GC chemical ionization ion trap tandem mass spectrometry; UV: ultraviolet spectroscopy; DART: direct analysis in real time; TOF: time-of-flight; SRI: selective reagent ionization; QTOF: quadrupole time-of-flight; HR-MS: high-resolution MS; LIT: linear ion trap; QqQ: triple quadrupole; CLND: chemiluminescence nitrogen detection; NIR: near infrared spectroscopy; DLLME: dispersive liquid/liquid microextraction.</p> <p><sup>c</sup> Reference in abstract form [written in Japanese] via SciFinder<sup>®</sup>.</p> <p><sup>d</sup> Patent source written in Chinese.</p> <p><sup>e</sup> 5-BnO-DALT: 5-benzyloxy-DALT; not included in the present study.</p> <p><sup>f</sup> TMS: Trimethylsilyl derivative.</p>			

**Table 2.** Electron ionization mass spectral data

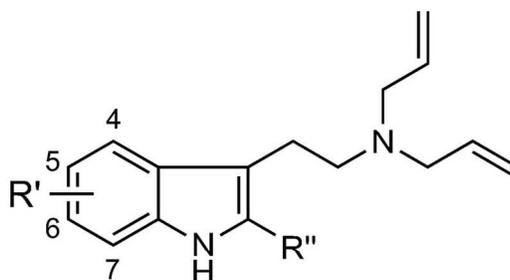
No.	R'	R''	M <sup>+</sup>	[M-41] <sup>+</sup>	[C <sub>9</sub> H <sub>6</sub> NR'R''] <sup>+</sup>	[C <sub>10</sub> H <sub>8</sub> NR'R''] <sup>+</sup> , [C <sub>10</sub> H <sub>7</sub> NR'R''] <sup>+</sup>	[C <sub>8</sub> H <sub>4</sub> NR'R''] <sup>+</sup> , [C <sub>8</sub> H <sub>3</sub> NR'R''] <sup>+</sup>	Other fragments
1	H	H	240	199	130	144, 143	116, 115	--
2	H	Ph	316	275	206	220, 219	192, 191	--
3	4-AcO	H	298	257	188	202, 201	174, 173	256 (M - C <sub>2</sub> H <sub>2</sub> O), 239 (M - <sup>•</sup> OAc), 160 (188 - CO), 146 (188 - C <sub>2</sub> H <sub>2</sub> O)
4	4-OH	H	256	215	146	160, 159	132, 131	--
5	4,5-ED <sup>a</sup>	H	298	257	188	202, 201	176, 175	160 (188 - C <sub>2</sub> H <sub>4</sub> ), 132 (160 - CO)
6	5-CH <sub>3</sub>	H	254	213	144	158, 157	130, 129	--
7	5-OCH <sub>3</sub>	H	270	239	160	174, 173	146, 145	239 (M - <sup>•</sup> OCH <sub>3</sub> ), 145 (160 - <sup>•</sup> CH <sub>3</sub> ), 240 (M - CH <sub>2</sub> O), 130 (160 - CH <sub>2</sub> O), 117 (145 - CO)
8	5-OCH <sub>3</sub>	CH <sub>3</sub>	284	243	174	188, 187	160, 159	253 (M - <sup>•</sup> OCH <sub>3</sub> ), 159 (174 - <sup>•</sup> CH <sub>3</sub> ), 144 (174 - CH <sub>2</sub> O), 131 (159 - CO)
9	5-OC <sub>2</sub> H <sub>5</sub>	H	284	241	174	188, 187	160, 159	269 (M - <sup>•</sup> CH <sub>3</sub> ), 239 (M - C <sub>2</sub> H <sub>5</sub> O <sup>•</sup> ), 146 (174 - C <sub>2</sub> H <sub>4</sub> )
10	5-F	H	258	217	148	162, 161	134, 133	--
11	5-F	CH <sub>3</sub>	272	231	162	176, 175	148, 147	--
12	5-Cl	H	274/276	233/235	164/166	178/180, 177/179	150/152, 149/147	239 (M - Cl <sup>•</sup> )
13	5-Br	H	318/320	277/279	208/210	222/220, 221/223	194/192, 193/191	239 (M - Br <sup>•</sup> )
14	5,6-MD <sup>b</sup>	H	284	243	174	188, 187	160, 159	228, 144 (174 - CH <sub>2</sub> O)
15	6-F	H	258	217	148	162, 161	134, 133	--
16	7-CH <sub>3</sub>	H	254	213	144	158, 157	130, 129	--
17	7-C <sub>2</sub> H <sub>5</sub>	H	268	227	158	172, 171	144, 143	239 (M - C <sub>2</sub> H <sub>5</sub> <sup>•</sup> )

<sup>a</sup> 4,5-(OCH<sub>2</sub>CH<sub>2</sub>O): 4,5-ethylenedioxy; <sup>b</sup> 5,6-(OCH<sub>2</sub>O): 5,6-methylenedioxy.

**Table 3.** Positive electrospray high-resolution MS and MS/MS data

No.	R	R'	Formula	Theor.	Found	$\Delta$ (ppm)	Formula	Theor.	Found	$\Delta$ (ppm)	Found	$\Delta$ (ppm)
1	H	H	$C_{16}H_{21}N_2^+$	241.16993	241.16978	-0.58	$C_{10}H_{10}N^+$	144.08078	144.08072	-0.39	110.09638	-0.40
2	H	Ph	$C_{22}H_{25}N_2^+$	317.20123	–	–	$C_{16}H_{14}N^+$	220.11208	220.11179	-1.32	110.09634	-0.81
3	4-AcO	H	$C_{18}H_{23}N_2O_2^+$	299.17540	229.17523	-0.58	$C_{12}H_{12}NO_2^+$	202.08626	202.08627	0.09	110.09646	0.29
4	4-OH	H	$C_{16}H_{21}N_2O^+$	257.16484	257.16479	-0.17	$C_{10}H_{10}NO^+$	160.07569	160.07588	1.20	110.09648	0.50
5	4,5-ED <sup>a</sup>	H	$C_{18}H_{23}N_2O_2^+$	299.17540	299.17459	-2.72	$C_{12}H_{12}NO_2^+$	202.08626	202.08606	-0.97	110.09640	-0.26
6	5-CH <sub>3</sub>	H	$C_{17}H_{23}N_2^+$	255.18558	255.18533	-0.95	$C_{11}H_{12}N_2^+$	158.09643	158.09634	-0.52	110.09637	-0.54
7	5-OCH <sub>3</sub>	H	$C_{17}H_{23}N_2O^+$	271.18049	271.17999	-1.83	$C_{11}H_{12}NO^+$	174.09134	174.09113	-1.24	110.09633	-0.88
8	5-OCH <sub>3</sub>	CH <sub>3</sub>	$C_{18}H_{25}N_2O^+$	285.19614	285.19565	-1.72	$C_{12}H_{14}NO^+$	188.10699	188.10666	-1.76	110.09628	-1.30
9	5-OC <sub>2</sub> H <sub>5</sub>	H	$C_{18}H_{25}N_2O^+$	285.19614	285.19574	-1.40	$C_{12}H_{14}NO^+$	188.10699	188.10678	-1.11	110.09631	-1.09
10	5-F	H	$C_{16}H_{20}FN_2^+$	259.16050	259.16010	-1.57	$C_{10}H_9FN^+$	162.07135	162.07117	-1.15	110.09633	-0.88
11	5-F	CH <sub>3</sub>	$C_{17}H_{22}FN_2^+$	273.17615	273.17578	-1.36	$C_{11}H_{11}FN^+$	176.08700	176.08679	-1.20	110.09633	-0.88
12	5-Cl	H	$C_{16}H_{20}^{35}ClN_2^+$	275.13095	275.13092/	-0.12	$C_{10}H_9^{35}ClN^+$	178.04180	178.04187	0.44	110.09645	0.23
			$C_{16}H_{20}^{37}ClN_2^+$	277.12800	277.12759	-1.48	--	--	--	--	--	--
13	5-Br	H	$C_{16}H_{20}^{79}BrN_2^+$	319.08044	319.07999/	-1.41	$C_{10}H_9^{79}BrN^+$	221.99129	221.99121	-0.35	110.09642	-0.05
			$C_{16}H_{20}^{81}BrN_2^+$	321.07839	321.07779	-1.87	--	--	--	--	--	--
14	5,6-MD <sup>b</sup>	H	$C_{17}H_{21}N_2O_2^+$	285.15975	285.15918	-2.02	$C_{11}H_{10}NO_2^+$	188.07061	188.07062	-0.07	110.09638	-0.40
15	6-F	H	$C_{16}H_{20}FN_2^+$	259.16050	259.16013	-1.46	$C_{10}H_9FN^+$	162.07135	162.07117	-1.26	110.09628	-1.30
16	7-CH <sub>3</sub>	H	$C_{17}H_{23}N_2^+$	255.18558	255.18524	-1.31	$C_{11}H_{12}N^+$	158.09643	158.09621	-1.38	110.09631	-1.09
17	7-C <sub>2</sub> H <sub>5</sub>	H	$C_{18}H_{25}N_2^+$	269.20123	269.20068	-2.01	$C_{12}H_{14}N^+$	172.11208	172.11194	-0.80	110.09637	-0.47

<sup>a</sup> 4,5-(OCH<sub>2</sub>CH<sub>2</sub>O): 4,5-ethylenedioxy; <sup>b</sup> 5,6-(OCH<sub>2</sub>O): 5,6-methylenedioxy.



No.	R'	R''	Abbreviation
(1)	H	H	DALT
(2)	H	C <sub>6</sub> H <sub>5</sub>	2-Ph-DALT
(3)	4-AcO	H	4-AcO-DALT
(4)	4-OH	H	4-OH-DALT
(5)	4,5-ED <sup>a</sup>	H	ED-DALT
(6)	5-CH <sub>3</sub>	H	5-Me-DALT
(7)	5-OCH <sub>3</sub>	H	5-MeO-DALT
(8)	5-OCH <sub>3</sub>	CH <sub>3</sub>	5-MeO-2-Me-DALT
(9)	5-OC <sub>2</sub> H <sub>5</sub>	H	5-EtO-DALT
(10)	5-F	H	5-F-DALT
(11)	5-F	CH <sub>3</sub>	5-F-2-Me-DALT
(12)	5-Cl	H	5-Cl-DALT
(13)	5-Br	H	5-Br-DALT
(14)	5,6-MD <sup>b</sup>	H	MD-DALT
(15)	6-F	H	6-F-DALT
(16)	7-CH <sub>3</sub>	H	7-Me-DALT
(17)	7-C <sub>2</sub> H <sub>5</sub>	H	7-Et-DALT

<sup>a</sup> 4,5-(OCH<sub>2</sub>CH<sub>2</sub>O): 4,5-ethylenedioxy

<sup>b</sup> 5,6-(OCH<sub>2</sub>O): 5,6-methylenedioxy

Figure 1. Structures of ring-substituted *N,N*-diallyltryptamines (1) – (17) characterized in this study.  
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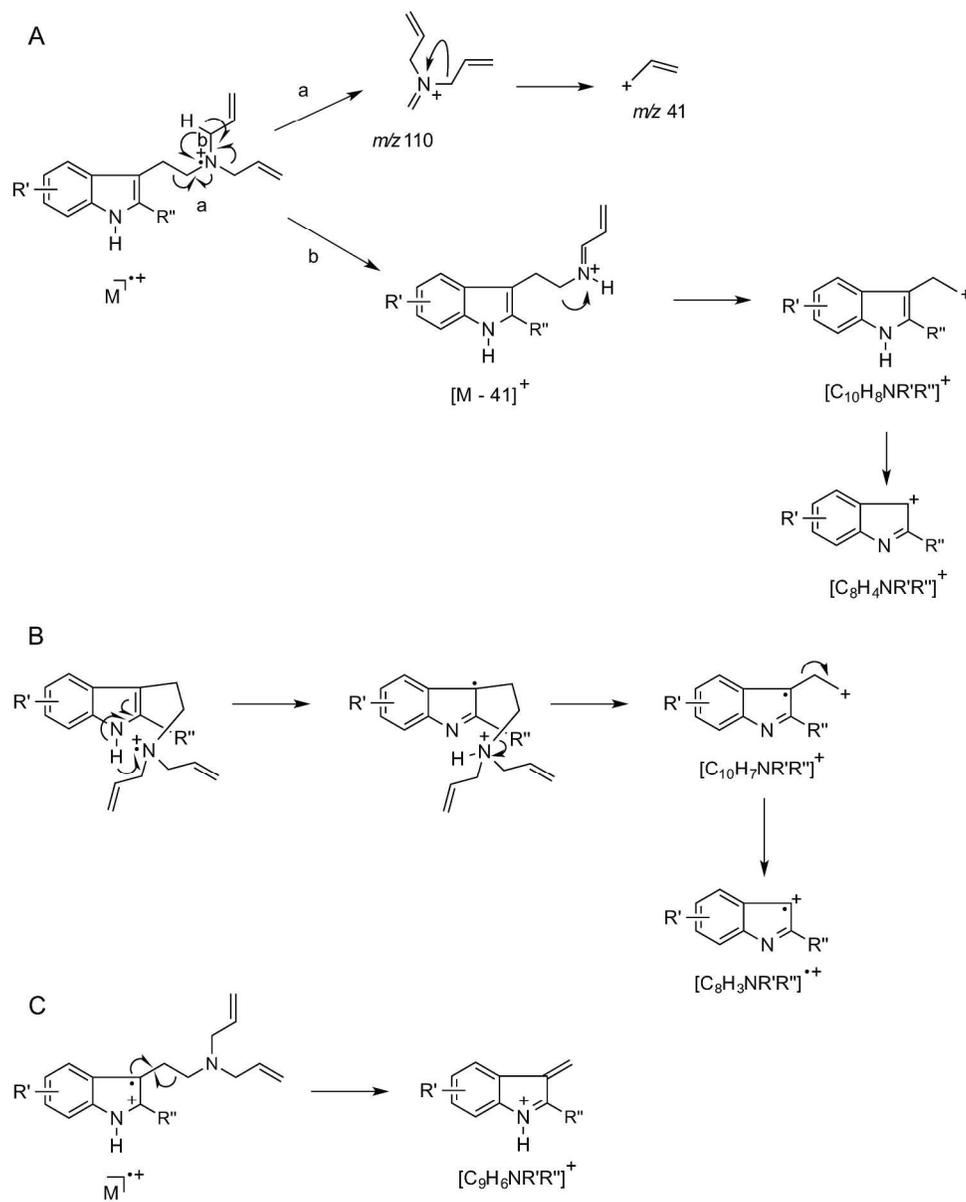


Figure 2. Proposed, generalized mass spectral fragmentation pathways for **(1)** – **(17)** recorded under electron ionization conditions (see also Table 2).

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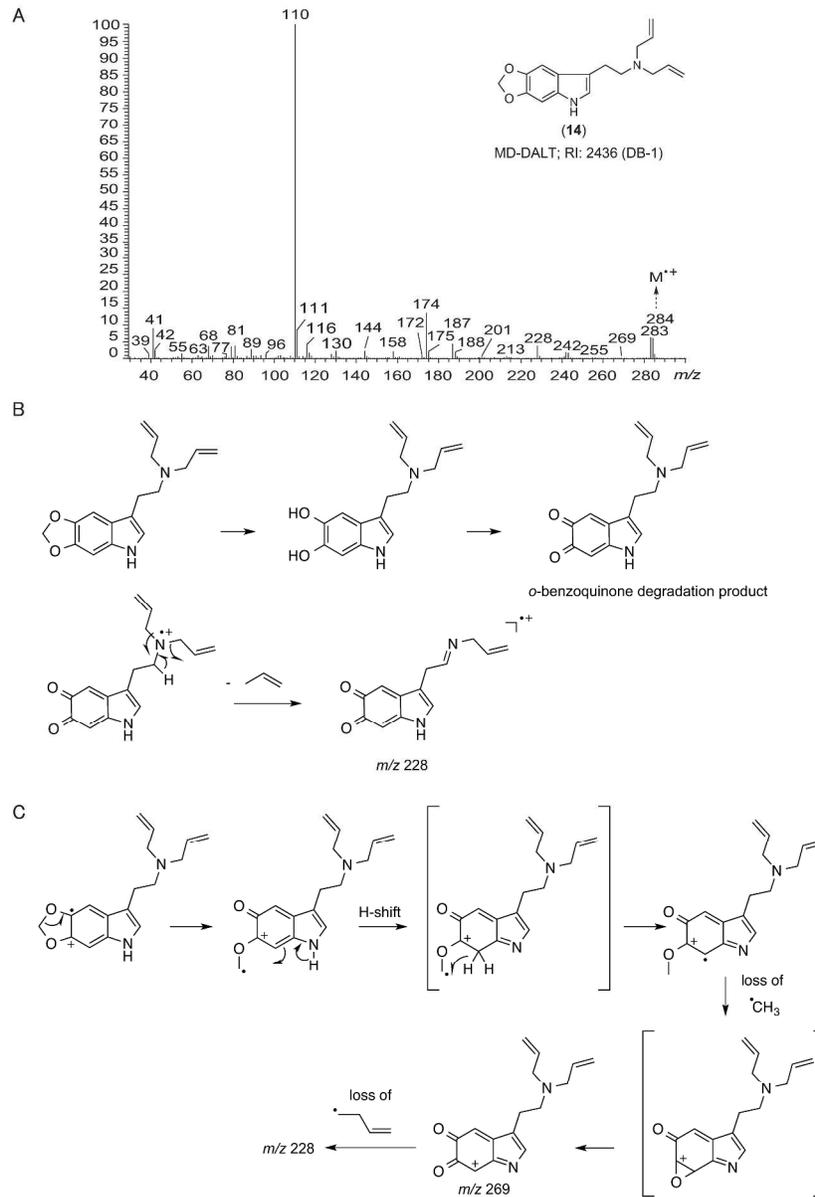


Figure 3. A: Electron ionization mass spectrum recorded for MD-DALT (**14**). B and C: Two proposed alternative mass spectral fragmentation pathways that may account for the formation of  $m/z$  228.  
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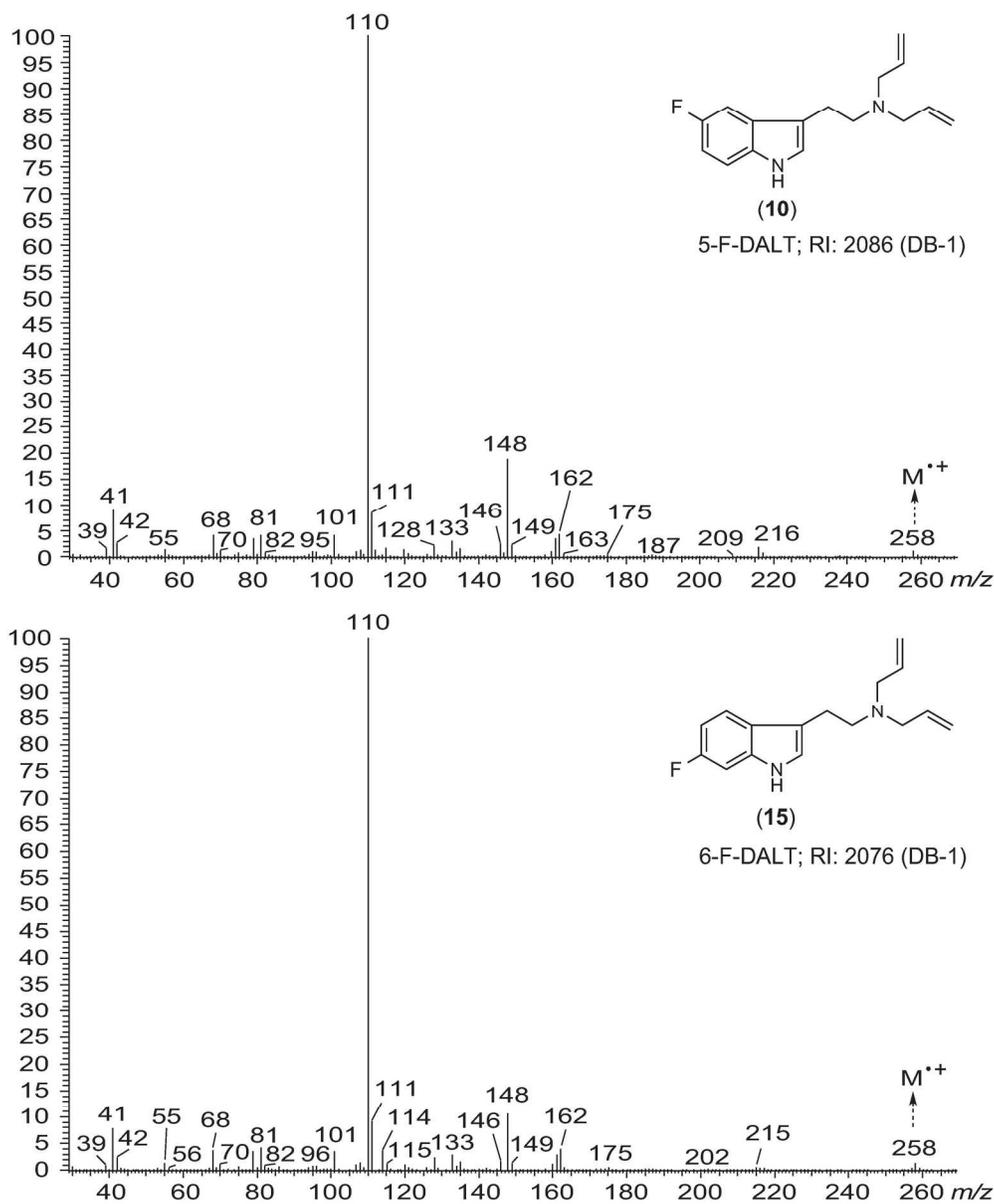


Figure 4. Electron ionization mass spectra recorded for the two isomers 5-F-DALT (**10**) and 6-F-DALT (**15**).  
180x218mm (300 x 300 DPI)

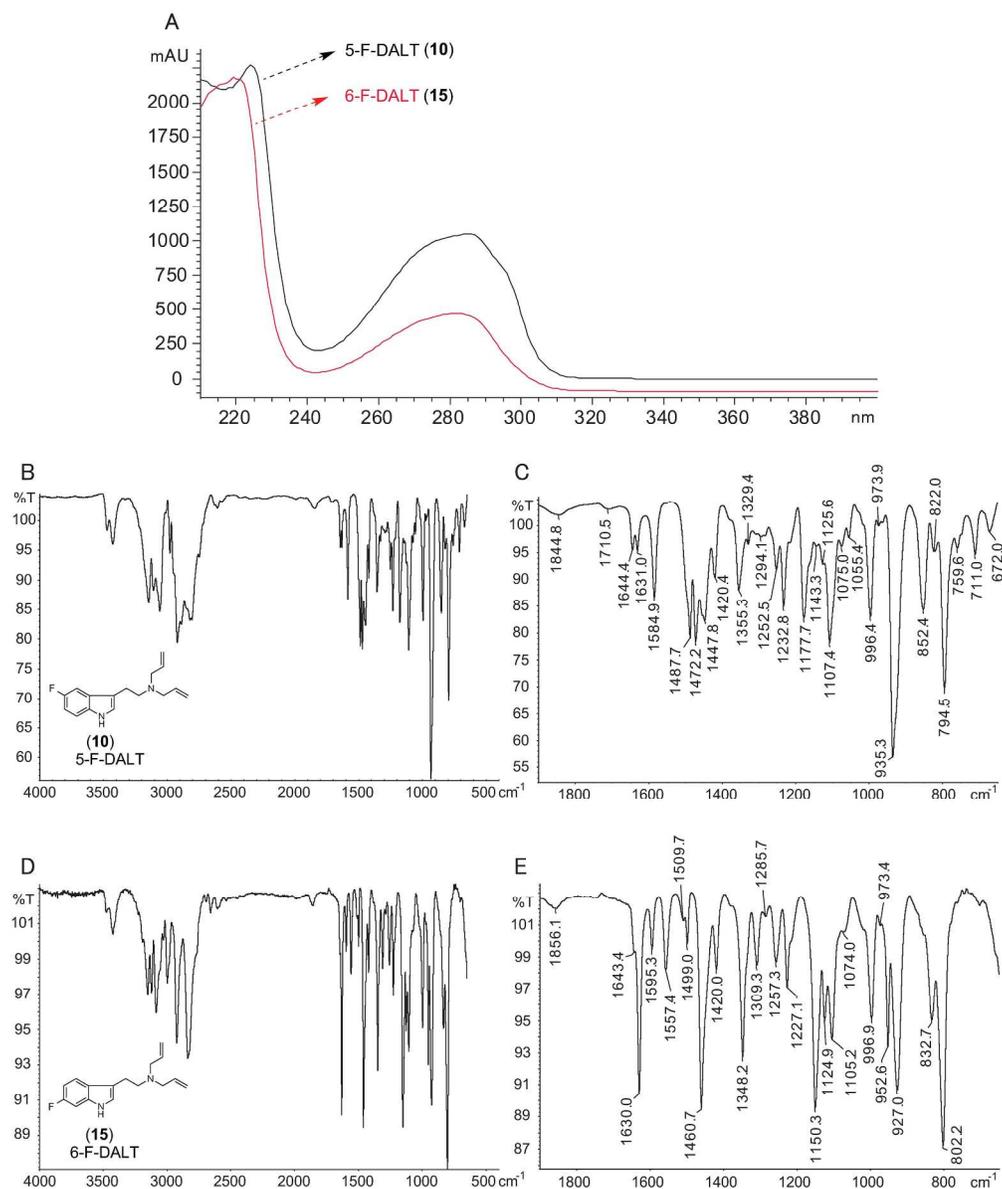


Figure 5. A. Implementation of photodiode array detection for both isomers 5-F-DALT (**10**) and 6-F-DALT (**15**). B and C: Gas chromatography solid-state infrared data recorded for (**10**). D and E: Gas chromatography solid-state infrared data recorded for (**15**). Isomers (**10**) and (**15**) could be differentiated due to differences observed in the partial spectra C and E.

245x291mm (300 x 300 DPI)