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*ORIGINAL RESEARCH*

# Identification of *N*,*N*-dimethyltryptamine and β-carbolines in psychotropic ayahuasca beverage

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ABSTRACT: Recently many people have shown great interest in traditional indigenous practices and popular medicine, involving the ingestion of natural psychotropic drugs. We received a request to analyze and determine the nature of a dark green liquid with a dark brown plant sediment, which the police had seized at an airport and inside the home of a person belonging to the 'Santo Daime' religious movement. Gas chromatography/mass spectrometry analysis of the extract identified *N*,*N*-dimethyltryptamine, a potent hallucinogen, and the β-carboline alkaloids harmine and harmaline, revealing monoamine oxidase A-inhibiting properties. These substances are typical components of Ayahuasca, a South American psychotropic beverage obtained by boiling the bark of the liana *Banisteriopsis caapi* together with the leaves of various admixture plants, principally *Psychotria viridis*. Copyright © 2008 John Wiley & Sons, Ltd.

KEYWORDS: Ayahuasca; *N*,*N*-dimethyltryptamine; harmine; harmaline; psychotropic drugs; gas chromatography/mass spectrometry

## INTRODUCTION

Recently, in the USA and Europe recourse to Shamanism as a means to help interior research, self-analysis and the treatment of illness has become very widespread. Ethnomedicine takes into consideration all the human dimensions and the inherent energies. Therefore, illness is the wrong conjunction or the disequilibrium of these energies. In this context, medicinal plants, also those acting on the central nervous system (CNS), have the purpose of making restoration of energy easier (Carlini, 2003). Many species of hallucinogenic plants are used throughout the world, in different contexts, to achieve states of mind distortion. Among these, recently, Ayahuasca has become extremely popular in Europe and North America (Halpern, 2004).

Ayahuasca is a psychotropic drink of ancient origin used in all regions of the Amazonian forest in the context of magical-religious practices and popular medicine. It is thought to give the person who consumes the drink visionary powers, and is used by the shamans to reach oneiric states where they can meet ancestors and spirits, to find out the cause of spells and illnesses and to see the past and the future (Carlini, 2003).

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**Abbreviations used:** CNS, central nervous system; DMT, *N*,*N*-dimethyltryptamine; MAO-A, monoamine oxidase A.

In Brazil, it is used by devotees of syncretistic religions, such as the 'Santo Daime' movement, a fusion of native religious practices with Christian elements (Yritia *et al*., 2002). Another use is recreational; in Peru, Brazil and Columbia 'Ayahuasca tours' are commonly organized as part of a travel package (Halpern, 2004). The internet also has abundant information about how to prepare Ayahuasca tea (Winkelman, 2005).

The ritual of taking Ayahuasca is divided into several phases, from the collection of the plant to its brewing, and then the ceremony, which follows a series of rules for drinking it. Usually the beverage is prepared as concoction of the cortex and stems of *Banisteriopsis caapi* (containing the β-carboline alkaloids, mainly harmine and harmaline, powerful inhibitors of monoamino oxidase enzyme), together with rubiaceous-type plants, in particular *Psychotria viridis*, whose leaves contain the hallucinogen *N*,*N*-dimethyltryptamine (DMT) (Halpern, 2004).

These active principles are very interesting both for their pharmacologic nature and their characteristic synergistic interaction. In fact, the psychic effects of Ayahuasca depend on DMT, which is not orally active. However, the presence in the drink of β-carbolines, which are monoamine oxidase A (MAO-A) reversible inhibitors, protects DMT from rapid digestive deamination, enabling it to reach the brain (Yritia *et al*., 2002).

The presence of DMT in the beverage, a controlled substance, causes legal problems. In Brazil, for instance, Ayahuasca is only allowed for the 'Santo Daime' and

similar religious entities. In the USA it has opened a controversy between the opponents of the use of drugs and those who want religious freedom. On 21 February 2006 the Supreme Court of the USA issued a unanimous decision affirming Religious Liberty in the case of *Gonzales vs. O Centro Espirita Beneficente União do Vegetal*. This decision is final, and cannot be appealed against further. In Italy, the right to practise a certain religion, which is free and protected, cannot be justified if it also entails criminal activity.

We recently received a request to analyse and determine the nature of a dark green liquid, with a dark brown sediment, which the police had seized at an airport. It was addressed to a person belonging to the 'Santo Daime' religious movement. The same material was also found in subsequent police searches of this person's house. Identification of the analytes was based on the gas chromatography–mass spectrometry method.

## MATERIALS AND METHODS

**Sample.** The sample was a dark green liquid with a strong bitter odour in a 1 L plastic bottle. There was a dark brown plant sediment at the bottom.

**Reagents and chemicals.** Reagents and solvents were of analytical quality and purchased from Merck (Darmstadt, Germany). Diphenhydramine was from Sigma-Aldrich Srl (Milano, Italy).

**Extraction.** To 5 mL of sample, diphenhydramine hydrochloride (25 μg/mL) was added as an internal standard and NaOH 1 M at pH = 9. Extraction was performed by rolling (30 min) with 10 mL of diethyl ether followed by centrifugation at 3000 rpm for 15 min. The organic phase was collected and evaporated under a nitrogen stream. The dried residue was dissolved in 1 mL of methanol and subjected to GC/MS analysis.

**Instrumentation.** Gas chromatography/mass spectrometry (GC/MS) analyses were carried out using a Varian (Varian Inc., Harbor City, CA, USA) Saturn 2000 mass detector equipped with a Varian CP3800 gas chromatograph. Instrument control and data processing were performed with an IBM computer and Saturn 2000 workstation data processing system. GC separation was achieved on a Chrompack (4330 EA Middleburgh, The Netherlands) capillary column CP–SIL 8CB-MS (length 30 m, inside diameter 0.25 mm, film thickness 0.25 μm), operated with helium at a flow rate of 1 mL/min and temperature programming at 80°C for 1 min ramped at 8°C/min to 220°C held for 1 min and finally ramped to 300°C and held for 15 min. Injections of 1 μL were effected at 250°C in the splitless mode (0.8 min) into a split–splitless injector. Transfer line was heated to 280°C and the ion trap temperature was 220°C. The ion source was operated in the electron impact mode with 70 eV electron energy, scan range 40–600 amu.

## RESULTS

Analysis of the extract by GC/MS identified *N*,*N*-dimethyltryptamine, harmaline and harmine, typical components of Ayahuasca beverage. Analytes identification was made via Nist Library Search.

Figure 1 shows chromatogram, mass spectra and structure of all the analytes. The concentrations of alkaloids reported in *Banisteriopsis caapi* range from 0.05% dry weight to 1.95% dry weight. In *Psychotria*, the concentration of alkaloids ranged from 0.1 to 0.66% dry weight (McKenna and Towers, 1984). The concentrations of alkaloids in the Ayahuasca beverages are, not surprisingly, several times greater than in the source plants from which they are prepared (McKenna, 2004). Quantitative analysis of the sample brought to our laboratory for analysis revealed that a typical 100 mL dose of the beverage contained 24, 6 and 34 mg DMT, harmaline and harmine, respectively.

## DISCUSSION AND CONCLUSION

The sample brought to our laboratory was Ayahuasca, a beverage prepared by boiling or soaking the bark and stems of *Banisteriopsis caapi* together with *P. viridis*. These plants combine the hallucinogenic agent DMT (24 mg in 100 mL in our sample) with β-carboline alkaloids showing monoamine oxidase-inhibiting properties. The pharmacological effects of DMT depend on its interaction with the serotoninergic system, acting as an agonist of the receptors 5-HT2, 5-HT1a and on the 5-HT-protein transporter (Carlini, 2003).

β-Carbolines could have pharmacological effects which contribute to the psychotropic effect of DMT even if, with the present knowledge, it is improper to characterize these effects as 'hallucinogenic' or 'psychedelic' (McKenna, 2004). As MAO inhibitors, β-carbolines can increase serotonin levels, blocking its deamination (McKenna, 2004). However, their main action in Ayahuasca is to protect DMT from peripheral degradation, so enabling it to reach the CNS, where its pharmacological effect occurs (Riba *et al.*, 2003). DMT alone is inactive following oral administration at doses up to 1000 mg, while it is active at a dose of about 25 mg after parenteral administration (McKenna, 2004). Studies in humans have shown that when administered parenterally, DMT provokes dramatic modifications in perception, the sense of self and reality. Its action can be very intense but relatively short in duration (Strassman *et al.*, 1994). In fact, blood peak of DMT and subjective effects were seen within 2 min after drug administration, and were negligible at 30 min (Strassman and Qualls, 1994). Dimethyltryptamine has a dose-dependent effect on elevated blood pressure, heart rate, pupil diameter and rectal temperature, in



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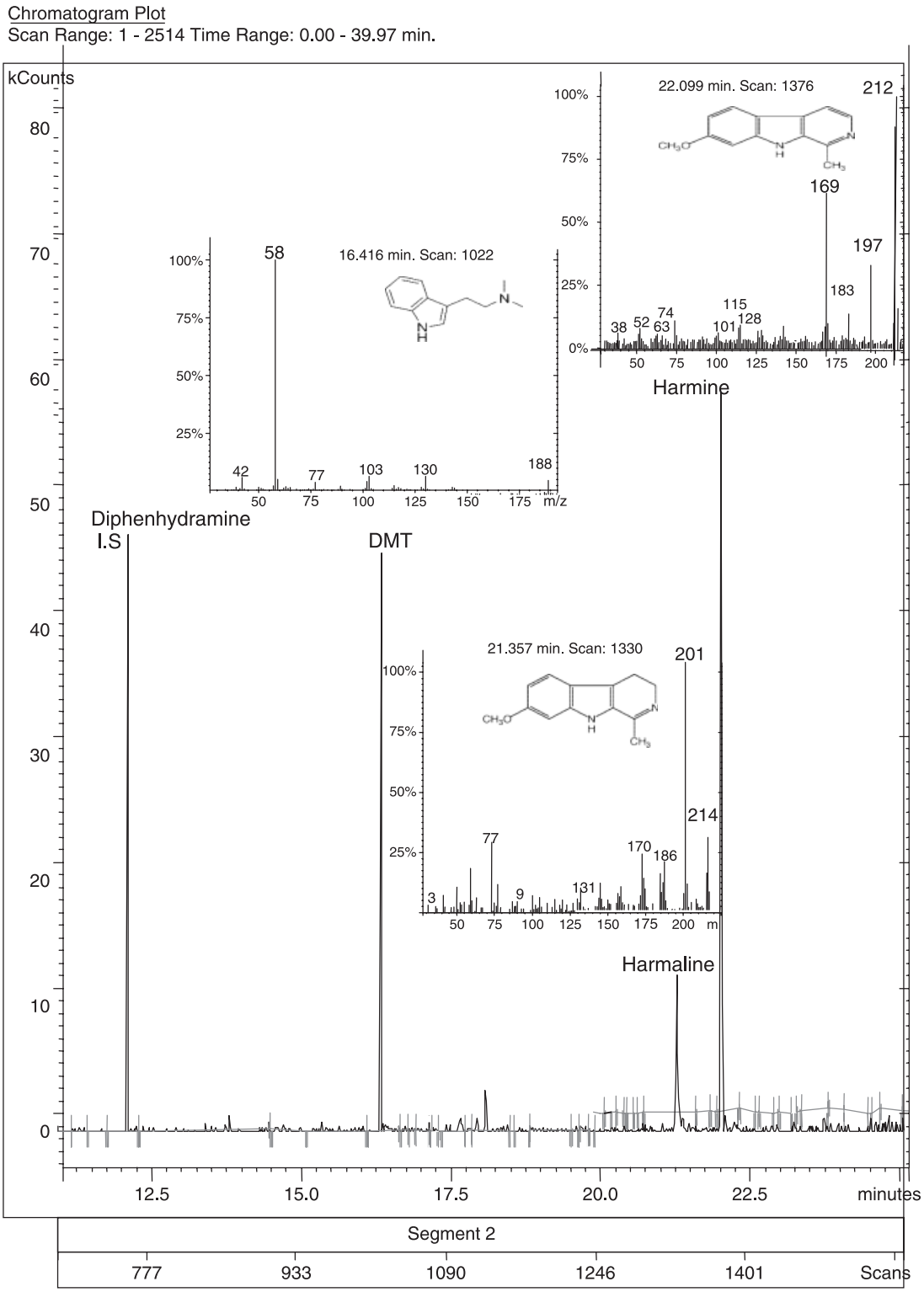


**Figure 1.** GC/MS chromatogram, structure and mass spectra of DMT, harmaline and harmine identified in the sample.

addition to raising blood concentrations of $\beta$-endorphin, corticotropin, cortisol and prolactin (Strassman and Qualls, 1994). Ayahuasca, instead, produces an experience that lasts for 3–4 h. The first effect can be seen within 30–40 min and is less intense than parenterally administered synthetic DMT (McKenna, 2004). Ayahuasca produced significant subjective effects, involving perceptual modifications and increased ratings of positive



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mood and activation (Stuckey *et al*., 2005). Some users may hear a humming in their ears, may perspire excessively or start trembling (McKenna and Towers, 1984). After the first few effects, the experience becomes mainly visual, with dreamlike visions and geometric figures (McKenna, 2004). A recent study (Riba *et al*., 2006) shows that administering the beverage led to significant activation of frontal and paralimbic brain regions, suggesting that Ayahuasca interacts with neural systems that are central to interoception and emotional processing and point to a modulatory role of serotoninergic neurotransmission in these processes.

Dizziness, diarrhea and vomiting are among the first physical effects that can occur; vomiting is considered as an integral part of the ritual experience (McKenna, 2004). The beverage is usually well tolerated from a cardiovascular point of view, with a trend toward an increase in systolic blood pressure (Riba *et al*., 2001).

The consequences of drinking Ayahuasca are not very clear. Characterization of its possible neurobiological and behavioral effects following chronic use, especially outside the traditional religious context, suggest in our opinion the need for greater information about this beverage, its active ingredients and their pharmacological action on the CNS. Recently a case of a young male who was found dead the morning after consuming herbal extracts containing β-carbolines and hallucinogenic tryptamines has been reported (Sklerov *et al*., 2005), which supports this need.

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