ELSEVIER

Fitoterapia 72 (2001) 644–648

FITOTERAPIA

www.elsevier.com/locate/fitote

Distribution of hyoscyamine and scopolamine in *Datura stramonium*

Elisabetta Miraldi[a,*], Alessandra Masti[b], Sara Ferri[a], Ida Barni Comparini[b]

[a] *Dipartimento di Scienze Ambientali, Sezione Biologia Farmaceutica, Università di Siena, Via Mattioli 4, 53100 Siena, Italy*

[b] *Dipartimento di Scienze Medico-Legali e Socio-Sanitarie, Università di Siena, Via delle Scotte, 53100 Siena, Italy*

Received 12 December 2000; accepted in revised form 13 March 2001

Abstract

The production of hyoscyamine and scopolamine in *Datura stramonium* has been investigated in the different plant parts, at different stages of their life cycle. Maximum contents were found in the stems and leaves of young plants, hyoscyamine being always the predominant component.

Keywords: *Datura stramonium*; Alkaloids; Hyoscyamine; Scopolamine

1. Introduction

Datura stramonium L. belongs to the family of Solanaceae, which includes species with variable contents of tropane alkaloids. These compounds are included in many official Pharmacopoeias because of their anticholinergic activities. Leaves (alone or with flowering tops) of belladonna (*Atropa belladonna* L.), henbane (*Hyoscyamus niger* L. or sometimes *H. albus* L.) and jimson weed (*D. stramonium*

* Corresponding author. Tel.: +39-0577-232852; fax: +39-0577-232860.
E-mail address: miraldi@unisi.it (E. Miraldi).

0367-326X/01/$ - see front matter
PII: S0367-326X(01)00291-X

L.), also called thorn-apple, referring to the fruit covered with prickles, are well known sources of these active principles.

The major of these alkaloids are hyoscyamine (generally the most abundant) and scopolamine, while atropine may be formed from hyoscyamine by racemization during the extractive procedure. The hyoscyamine/scopolamine ratio in these species is approximately 20, 1.2 and 2 for belladonna, henbane and jimson weed, respectively [1,2].

In literature [1,3–5] it is reported that hyoscyamine is the predominant alkaloid in *D. stramonium* from the time of flowering on. Thorn-apple leaves contain 0.2–0.45% of total alkaloids, seeds approximately 0.2% [1,2]. No data are available about the alkaloid content of stems and pods. Isolated organ cultures of thorn apple indicated that the root is the principal site of alkaloid synthesis [1], while growth and production of hyoscyamine and scopolamine of root cultures are favoured by using medium diluted to half that of normal concentration of salts (B5/2) [6].

Recently, the presence of high alkaloid levels in *D. stramonium* caused its abuse as a hallucinogenic both in USA [8–14] and in Europe [7,15,16].

We report here on atropine and scopolamine contents in *D. stramonium* different plant parts at different stages of growth.

2. Experimental

2.1. Plant material

Samples of *D. stramonium* were collected in South-central Tuscany (Italy), in Grosseto province, in the locality of Pian d'Alma, situated a few kilometres near the sea. The sampling was performed on plants at two different periods of the life cycle, following two classes of age: young (length not exceeding 30 cm); and adult (more than 30 cm). Each sampling was done from at least 10 different individuals of a homogeneous class of age, following the growth of the individuals from June to August. The material was then dried at room temperature and samples were randomised and used for GC/MS analysis. For each sample at least six GC/MS determinations were carried out. Voucher specimens were deposited in the Herbarium of Siena University.

2.2. Extraction

Powdered plant material (10 mg) was wetted with aq. 0.1 N NaOH, added with a solution of nicotine in MeOH (1 μg/μl) as I.S. and extracted with $CHCL_3$ (5 ml) for 24 h. After centrifugation for 5 min, the supernatant liquid was separated and evaporated to dryness under a nitrogen stream. The residue was resuspended in 100 μl of *N*,*O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA), kept for 1 h at 70 °C and GC/MS analysed.

2.3. GC / MS assay

A GC Varian mod. 3300/3400, interfaced to a Finnigan Mat mod. ITS 40 Mass Spectrometer with ion trap detector in full scan (40–500 amu) and equipped with a capillary column J. & W. OV1 (15 × 0.25 mm, film thickness 0.25 μm) was used. Samples (1 μl) were injected in split-less, column temperature was held at 100 °C for 1 min and then programmed to 280 °C and held there for 30 min. Manifold was 220 °C, injector 280 °C, transfer line 290 °C.

Alkaloids were identified by comparing their retention times and mass spectra with those of authentic samples purchased from Aldrich (purity 98%).

3. Results and discussion

The contents of atropine (formed from hyoscyamine) and scopolamine, obtained by GC/MS analysis of samples, are reported in Table 1.

Table 1
Alkaloid contents (μg/mg) in *Datura stramonium*[a]

Samples	Young plants		Adult plants	
	Atropine	Scopolamine	Atropine	Scopolamine
Small leaves[b]	0.156 ± 0.008	0.073 ± 0.001	0.165 ± 0.006	0.016 ± 0.007
Medium leaves[c]	0.831 ± 0.014	0.047 ± 0.005	0.150 ± 0.002	0.022 ± 0.005
Big leaves[d]	0.228 ± 0.004	0.035 ± 0.009	0.134 ± 0.004	0.044 ± 0.006
Stems	0.915 ± 0.015	0.129 ± 0.014	0.001 ± 0.001	–
Roots	0.121 ± 0.015	0.014 ± 0.004	–	–
Flowers	Flower buds		Open flowers	
	0.299 ± 0.021	0.106 ± 0.031	0.270 ± 0.026	0.066 ± 0.004
Fruits	Immature fruits		Mature fruits	
Pericarp	0.001 ± 0.001	–	0.001 ± 0.001	–
Seeds	0.170 ± 0.003	0.012 ± 0.001	0.387 ± 0.015	0.089 ± 0.010

[a] Values are mean ± S.D. ($n = 6$); –, absent.
[b] Young, 1–5 cm; adult, 3–7 cm.
[c] Young, 5–9 cm; adult, 8–13 cm.
[d] Young, 9–11 cm; adult, 14–25 cm.

The obtained results demonstrate that atropine and scopolamine contents depend on both the plant part considered and the stage of plant growth. In young plants, maximum atropine content was found in leaves of medium surface, while highest scopolamine content was observed in the apical leaves. According to many authors [1,3–5,17,18], in leaves of young *D. stramonium* plants scopolamine content is higher than that of atropine. On the contrary, in our samples, atropine was always the principal alkaloid, scopolamine content decreasing at the increase of leaf surface.

The above referred literature reports for leaves of adult plants a hyoscyamine (calculated as atropine)/scopolamine ratio of 2:1. The present analyses demonstrate that in leaves of adult plants the atropine content is noticeably higher than indicated by this ratio and also that atropine decreases in older leaves, while scopolamine content increases.

In the literature, no data concerning alkaloid content in stems of *D. stramonium* could be found. Our results demonstrate that the thin and tender stems of *D. stramonium* young plants contain the highest quantity of atropine and scopolamine with respect to all other samples tested, atropine being almost three times higher than in seeds (0.915 and 0.384 μg/mg, respectively), which are generally considered to be the organs with the highest content in tropine alkaloids.

Several authors [1,19–21] reported that the root is the principal site of alkaloid synthesis and that secondary modifications of the alkaloids occur in the aerial parts. This study shows that alkaloid synthesis occurs mainly in young plants, as high contents were found in the roots of young plants, while the alkaloids were even absent in roots of adult plants.

Concerning the flowers, this study demonstrates that flower buds are rich in scopolamine, which gradually decreases during anthesis. In the literature, only results on flowers from *D. metel*, shown to be richer in scopolamine than atropine, are reported [22].

The fruits of *D. stramonium*, pericarp and seeds separately, were also analysed. Scopolamine was completely lacking and only a very low content of atropine was detected in the pericarp of both closed and mature capsules, while in the seeds, the alkaloid content strongly increased during maturation (from 0.2 to 0.4 μg/mg). Dugan and co-workers [10] reported an atropine content of 2.71 μg/mg and a scopolamine content of 0.66 μg/mg of seed.

In conclusion, this study confirmed that the content of tropane alkaloids is higher in young than in adult *D. stramonium*, but scopolamine was never the main alkaloid, in contrast with some previous reports. For the first time, stems of this species were analysed and the interesting result was that stems of young plants, not the seeds as generally held, are the plant parts with the highest content of tropane alkaloids.

References

[1] Evans WC. Trease and Evans pharmacognosy. Baillière Tindall, 1989:554–559.
[2] Longo R. Le monografie tedesche. Studio Edizioni, 1994, p. 22.
[3] Bruni A. Farmacognosia generale e applicata. Piccin Nuova Libraria, 1999:387–388.
[4] Oshima T, Sagara K, Tong Y, Zhan GG, Chen Y. Chem Pharm Bull 1989;37:2456.
[5] Papadoyannis IN. Nat Toxins 1995;3:310.
[6] Cusido RM, Palazòn J, Piñol MT, Bonfilland M, Morales C. Planta Med 1999;65:144.
[7] Micke MM. J Sch Health 1996;66:277.
[8] Chang SS, Wu ML, Deng JF, Lee CC, Chin TF, Liao SJ. Vet Hum Toxicol 1999;41:242.
[9] Dewitt MS, Swain R, Gibson Jr. LB. W V Med J 1997;93:182.

[10] Dugan GM, Gumbmann MR, Friedman M. Food Chem Toxicol 1989;27:501.
[11] Forno Jr. FJ, Terry RA. J Am Osteopath Assoc 1998;98:502.
[12] Guharoy SR, Baraya SM. Vet Hum Toxicol 1991;33:588.
[13] Nogué S, Pujol L, Sanz P, De La Torre L. J Int Med Res 1995;23:132.
[14] Tiongson J, Salen P. Del Med J 1998;70:471.
[15] Coremans P, Lambrech G, Schepens P, Vanwelden J, Verhaegen H. J Toxicol Clin Toxicol 1994;32:589.
[16] Klein-Schwartz W, Oderda GM. Am J Dis Child 1984;138.
[17] Miraldi E, Masti A. Acta Phytother 1997;3:29.
[18] Duez P, Chamart S, Hanocq J, Molle L, Vanhaele M, Vanhaelen-Fastre R. J Chromatogr 1985;329:415.
[19] Hanna JP, Schmidley JW, Braselton WE. Clin Neuropharm 1992;15:109.
[20] Mirzamotov RT, Luftulin KL. Chem Nat Comp 1986;22:359.
[21] Ollagnier S, Kervio E, Rétey J. FEBS Lett 1998;437:309.
[22] Abo KA, Salami OO, Adulegan IO. Afr J Med Sc 1993;22:45.