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REVIEW

TRYPTAMINE AND RELATED COMPOUNDS IN PLANTS

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Key Word Index—Fungi; Spermatophyta; tryptamine; serotonin; bufotenine; psilocybin; gramine; amines; review.

Abstract—The occurrence of the tryptamines and related compounds in fungi and higher plants is listed on a taxonomic basis. Several of these amines have considerable physiological activity in higher animals.

The indole amines which are derived from the amino acid tryptophan occur in a wide variety of plant families, but are especially common in the Gramineae and Leguminosae. The biosynthesis and metabolism of these amines has been reviewed in ref. [110]. Tryptamine is likely to be the precursor of the plant growth hormone indole acetic acid, at least in some plants [23, 111]. The tryptamines are also the precursors of the tricyclic β-carboline alkaloids formed by condensation with a one- or two-carbon moiety [112].

The psychoactive indole amines dimethyltryptamine, bufotenine and methoxy *N*-dimethyltryptamine are constituents of hallucinatory snuffs and decoctions used by various ethnic groups. These are derived from species of *Piptadenia*, *Banisteriopsis* and *Virola*, and *Mimosa hostilis* and *Lespedeza bicolor*, especially in parts of South America [4, 9, 12, 14, 73, 113, 114]. Dimethyltryptamine is apparently inactive orally probably because it is metabolized by a monoamine oxidase and it is only effective when taken parenterally or as snuff. However, the co-occurrence of the β-carboline alkaloids may potentiate oral activity of dimethyltryptamine since these alkaloids are inhibitors of monoamine oxidase [9]. Psilocybin, a unique phosphorylated indole amine, and psilocin, are also hallucinatory amines found in several genera of basidiomycetes growing in Europe, Central and North America, and South East Asia [8].

Ingestion of large amounts of the tryptamines may be harmful to humans and to some animals. For instance, there may be a connection between the incidence of myocardial fibrosis in West Africa and the high intake of plantains (bananas, *Musa*) in this region, attributable to the high level of 5-hydroxytryptamine (5-HT) in this food [115]. Cattle in Australia fed on pastures of *Phalaris arundinacea* develop a disease known as Phalaris staggers. This is probably due to the high levels of tryptamines present [39]. In Canada this grass is associated with bovine pulmonary emphysema [38]. In addition, gramine reduces adult weight and is a feeding inhibitor for grasshoppers [34].

The excretion of 5-hydroxyindoleacetic acid (5-HIAA) is used in the clinical diagnosis of carcinoid tumour. 5-HIAA is an oxidation product of 5-HT which occurs widely in food plants. A diet free of 5-HT containing foods is therefore necessary before the diagnosis of carcinoid tumour by this technique [116]. The occurrence of tryptamine and 5-HT in food plants has been reviewed in ref [117].

5-HT occurs in the stinging hairs of *Mucuna pruriens* [118], *Girardinia heterophylla* [102] and *Urtica* spp [105, 106] and probably also *Laportea moroides* [103]. It is considered to be one of the active principles in these stings, and is found also in the venoms of several animals [119].

Isolation of tryptamines from plant material may involve extraction of alkaline macerates [Na_2CO_3 or NH_4OH) with $CHCl_3$ or Et_2O. Purification may also be achieved with cation exchange resins. TLC or PC are used for the separation of complex mixtures with the Salkowski, Ehrlich (*p*-dimethylamino-benzaldehyde or -cinnamaldehyde), Pauly, or Dragendorff chromogenic reagents. The nitroso-naphthol reagent may be used for 5-hydroxyindoles. The tryptamines do not require prior derivatization for separation by GLC.

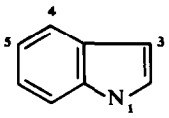
INDOLALKYLAMINES FOUND IN PLANETS

Name	Abbreviation	Position 5	Position 4	Position 3 (side chain)	Position 1
Tryptamine	Try	H	H	—CH_2—CH_2—NH_2	H
Methyltryptamine	MeTry	H	H	—CH_2—CH_2—NH—Me	H
Dimethyltryptamine	diMeTry	H	H	—CH_2—CH_2—N—$(Me)_2$	H*
5-Hydroxytryptamine (serotonin)	Ser	OH	H	—CH_2—CH_2—NH_2	H

* Psychoactive.

Continued

Name	Abbreviation	Position 5	Position 4	Position 3 (side chain)	Position 1
Methylserotonin	MeSer	OH	H	—CH_2—CH_2—NHMe	H
Bufotenine	Buf	OH	H	—CH_2—CH_2—$N(Me)_2$	H*
Dehydrobufotenine	dhBuf	OH	H	—CH=CH—$N(Me)_2$	H
Bufotenidine	Bufd	O^-	H	—CH_2—CH_2—$\overset{+}{N}(Me)_3$	H
Methoxytryptamine	MeOTry	MeO	H	—CH_2—CH_2—NH_2	H
Methoxy *N*-methyltryptamine	MeOMeTry	MeO	H	—CH_2—CH_2—NHMe	H
Methoxy *N*-dimethyltryptamine	MeOdiMeTry	MeO	H	—CH_2—CH_2—$N(Me)_2$	H*
Psilocin	Psilocin	H	OH	—CH_2—CH_2—$\overset{+}{N}H(Me)_2$	H*
Psilocybin	Psilocybin	H	HPO_4^-	—CH_2—CH_2—$\overset{+}{N}H(Me)_2$	H*
Aminomethylindole	AMI	H	H	—CH_2—NH_2	H
Methylaminomethylindole	MAMI	H	H	—CH_2—NH—Me	H
Gramine	Gra	H	H	—CH_2—$N(Me)_2$	H
—*N*-Oxide	*N*ox	various	H	—CH_2—CH_2—$\overset{+}{N}(Me)_2 \rightarrow 0$	H
—Methohydroxide	MeOH	various	H	—CH_2—CH_2—$\overset{+}{N}(Me)_3OH^-$	H
Lespedamine	Lespedamine	H	H	—CH_2—$CH_2N(Me)_2$	OMe



Family	Species	Amine	Tissue‡	Ref.
FUNGI				
	Claviceps purpurea (Fr.) Tulasne	Try		[1]
	Amanita spp.	Ser; MeSer; diMeTry Buf; Buf*N*ox; MeOdiMeTry		[2–4]
	Boletus erythropus	Try		[5]
	Sarcodon imbricatum	Try		[5]
	Coprinus spp.	Try		[6, 7]
	Panaeolus spp.	Try		[3, 4, 8, 9]
	Psilocybe spp.	Ser		
	Conocybe spp.	Psilocybin		
	Stropharia spp.	Psilocin		
HIGHER PLANTS				
Aceraceae	*Acer rubrum* L.	Gra	(Fr)	[10]
	Acer saccharinum L.	Gra	(L)	[11]
Aizoaceae	*Delosperma* sp.	MeTry; diMeTry		[4, 12]
Apocynaceae	*Prestonia amazonica*?	diMeTry		[13, cf. 9, 14]
Araceae	*Symplocarpus foetidus* Nutt.	Ser	(L)	[15]
Bromeliaceae	*Ananas sativus* Schult.	Ser	(Fr)	[16]
Caricaceae	*Carica papaya* L.	Ser		[17]
Chenopodiaceae	*Arthrophytum leptocladum* M. Pop.	MeTry	(L, S)	[18, 19]
	Arthrophytum wackchanica	MeTry		[20]
	Girgensohnia diptera Bge.	MeTry		[21]
	Hammada leptoclada	MeTry	(L, S)	[22]
Cucurbitaceae	*Citrullus vulgaris* Schrad.	Try	(Fr)	[23]
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	Ser	(L, B, Sd)	[24]
	Hippophae rhamnoides L.	Ser	(R)	[25]
Gramineae	*Arundinella hirta* L.	Ser		[26]
	Arundo donax L.	MeOMeTry; diMeTry; diMeTryMeOH; Buf; diMeTry*N*ox; Bufd dhBuf; Gra; Gra*N*ox GraMeOH	(L, Fl, Rh)	[27–30]
	Avena sativa L.	Try	(Sl)	[31]
	Calamagrostis sp	Ser		[26]
	Hordeum jubatum L.	Gra		[34]

continued overleaf

‡ Key to the tissue studied. L = leaf; R = root; Fr = fruit; Sd = seed; Sl = seedling; B = bark; Fl = flowers; Rh = rhizomes; S = stem; W = wood.

Family	Species	Amine	Tissue	Ref.
	Hordeum nodosum L.	Gra		[34]
	Hordeum vulgare L.	Try; Ser; MeSer; AMI; MAMI; Gra	(Sl)	[32, 33]
	Imperata cylindrica	Ser		[26]
	Oryza sativa L.	Ser	(Sl)	[35]
	Phalaris arundinacea L.	Try; MeTry; diMeTry; MeOTry; MeOMeTry; MeOdiMeTry; Buf; Gra	(L)	[36–39]
	Phalaris tuberosa L.	diMeTry; MeOdiMeTry; diMeTryMeOH; MeOdiMeTryMeOH; Buf; Gra	(L, Sl)	[40–43]
	Phyllostachys reticulata	Ser		[26]
	Triticum vulgare Vill.	Try	(Sl)	[31]
	Zea mays L.	Try; CoumarylTry; FerulylTry	(Sd, Sl)	[31, 44]
	Zizania caudiflora	Ser		[26]
Juglandaceae	*Juglans regia* L.	Ser	(Fr)	[45]
Lauraceae	*Nectandra megapotamica* (Sprg.) C. & H.	MeTry	(B)	[46]
	Persea americana Mill.	Ser	(Fr)	[47]
Leguminosae	*Acacia* spp.	Try; MeTry; diMeTry*N*ox;	(L, S, Fl, B]	[28, 48–56]
	Albizzia julibrissin Durazz.	Ser	(L)	[57]
	Burkea africana Hook.	Try	(B)	[58, 59]
	Desmodium gangeticum DC. *Desmodium gyrans* DC. *Desmodium pulchellum* Benth. ex Baker *Desmodium tiliaefolium* G.Don *Desmodium triflorum* DC.	Try; diMeTry; diMeTry*N*ox; Gra; MeSer; Buf; Buf*N*ox; MeOMeTry; MeOdiMeTry; MeOdiMeTry*N*ox; diMeTryMeOH; MeOdiMeTryMeOH	(L, R, S, Sd)	[28, 60–66]
	Dicorynia guianensis Amsh.	Try	(W)	[67]
	Griffonia simplicifolia	Ser	(L, Fr)	[68]
	Lespedeza bicolor Turez.	diMeTry;diMeTry*N*ox; Buf; MeOdiMeTry; MeOdiMeTry*N*ox; Lespedamine	(L, R)	[69, 70]
	Lupinus hartwegii Hindl. *Lupinus hispanicus* Boss. & Reut. *Lupinus luteus* L.	Gra	(L, S)	[71, 72]
	Mimosa hostilis Benth.	diMeTry	(R)	[11]
	Mimosa verrucosa	diMeTry	(B)	[73]
	Mucuna pruriens DC.	Ser, MeOdiMeTry; diMeTry; Buf; diMeTry*N*ox	(L, S, Fr)	[74, 75]
	Petalostylis labicheoides Benth.	Try; diMeTry	(L, S)	[76]
	Phaseolus vulgaris L.	Ser	(L)	[57]
	Piptadenia spp. (*Anadenanthera*)	Try; MeTry; diMeTry diMeTry*N*ox; Buf; Buf*N*ox; Ser; MeSer; MeOMeTry; MeOdiMeTry	(L, B, Sd)	[11, 77–82]
	Pisum sativum L.	Ser	(L)	[57]
	Prosopis juliflora DC.	Try; Ser		[83]
	Prosopis alba Gris.	Try	(L)	[84]
	Prosopis nigra	Try; AcetylTry		[85]
	Samanea saman Merr.	Ser	(L)	[57]
Malpighiaceae	*Banisteriopsis argentea* Spring ex Juss.	diMeTry; diMeTry*N*ox	(L)	[86]
	Banisteriopsis rusbyana ex Small	MeTry; diMeTry; Buf; MeOdiMeTry	(L)	[87, 88]
Malvaceae	*Gossypium hirsutum* L.	Ser	(Fr)	[15]
Musaceae	*Musa sapientum* L.	Ser	(Fr)	[47, 89–91]
Myristicaceae	*Virola* spp.	MeTry; diMeTry; MeOTry; MeOMeTry MeOdiMeTry	(L, R, B, Fl)	[81, 92]
	Gymnacranthera panticulata (A.DC.) Warb.	1,5-diMeOGra		[94]
Passifloraceae	*Passiflora quadrangularis* L.	Ser	(L)	[57]
	Passiflora edulis Sims	Try; AcetylTry	(L)	[95]

Continued

Family	Species	Amine	Tissue	Ref.
Ranunculaceae	*Ranunculus sceleratus* L.	Ser		[96]
Rosaceae	*Prunus* spp.	Try; Ser	(Fr, L)	[47, 97]
Rubiaceae	*Oldenlandia affinis* DC.	Ser		[98]
	Psychotria psychotriaefolia (Seem.) Stand.	diMeTry		[99, cf. 73]
	Psychotria viridis R. & P.	diMeTry		[73]
Rutaceae	*Citrus sinensis* Osbeck	Try	(Fr)	[47]
	Dictyoloma incanescens DC	MeOdiMeTry	(B)	[11]
	Vepris ampody H. Perr.	diMeTry		[100]
Solanaceae	*Lycopersicon esculentum* Mill.	Try; Ser	(L, S, Fr)	[31]
	Solanum melongena L.	Try; Ser	(Fr)	[47]
	Nicotiana tabacum L.	Try	(L)	[31]
Tovariaceae	*Tovaria pendula* Ruiz. & Pavon.	Ser	(L, S)	[101]
Urticaceae	*Girardinia heterophylla* (Decne)	Ser	(L)	[102]
	Laportea moroides	Ser?		[103]
	Urtica dioica L.	Ser	(L)	[104, 107]
	Urtica pilulifera L.	Ser; Buf	(L, S)	[105, 106]
	Urtica parviflora Roxb.	Ser	(L)	[108]
Zygophyllaceae	*Peganum harmala*	6-OHTry; Ser	(Sd, Sl)	[109]

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