

## Chemotaxonomic interest of volatile components in *Lepista inversa* and *Lepista flaccida* distinction

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**Abstract** – Wild *Lepista inversa* and *L. flaccida* were investigated for volatile constituents by gas chromatography-mass spectrometry (GC-MS). More than 40 compounds were identified with this technique from diethyl ether extracts as aliphatic alcohols, aldehydes and cetones as well as numerous aromatic compounds. Chlorinated compounds only detected in *L. inversa* samples clearly differentiated them from those obtained from *L. flaccida*. However, the chemotaxonomic value of these secondary metabolites to distinguish these two related clitocyboid species has to be checked with the litter incidence.

**Basidiomycota / chlorinated volatile compound / GC-MS analysis / Lepisteeae / solvent extraction / Tricholomataceae**

**Résumé** – Des sporophores sauvages de *Lepista inversa* et de *L. flaccida* ont été étudiés par chromatographie en phase gazeuse couplée à la spectrométrie de masse (CG-SM) pour leur contenu en composés volatils. A partir d'extraits étherés, plus de 40 composés ont été identifiés par cette technique d'analyse, tels que des alcools, des aldéhydes, des cétones ainsi que de nombreux composés aromatiques. Des composés chlorés, uniquement détectés dans les échantillons de *L. inversa* les différencient clairement de ceux issus de *L. flaccida*. L'intérêt chimiotaxonomique de ces métabolites secondaires pour distinguer ces deux très proches espèces clitocyboïdes doit cependant être précisé par rapport à l'éventuelle influence de la litière.

**Analyse CG-SM / Basidiomycota / composé volatil chloré / extraction par solvant / Lepisteeae / Tricholomataceae**

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## INTRODUCTION

Many reports deal with sporophore odours of Basidiomycota (Claus; 1978; Moreau, 2002). The aroma chemistry of mushrooms investigated through volatile components can be of interest for both discovery of original "natural" label for flavouring compounds and chemotaxonomic investigation. Previous reviews placed the volatile fraction as being the major contributor to characterize mushroom flavour (Hanssen, 1982; Maga, 1981; Mau *et al.*, 1994, 1997). The broad spectrum of volatile components identified in mushroom species is about 150 and represents a wide variety of natural compound classes (Abraham & Berger, 1994; Audouin *et al.*, 1989; Breheret *et al.*, 1999; Fons *et al.*, 2003; McAfee & Taylor, 1999; Rapior *et al.*, 1997, 2003).

Few data are reported on the chemical composition of *Lepista* species. First, the sterols, triterpenes and fatty acids were determined for *L. nuda* and *L. nebularis* (Dembitsky *et al.*, 1993; Morelli *et al.*, 1981; Régérat *et al.*, 1976; Senatore, 1992). Bioactive diterpenoids (lepistol, lepestol) on human leukaemic cells were then identified from fermentation of *L. sordida* (Mazur *et al.*, 1996). Specific nucleosides as clitocine (Kubo *et al.*, 1986) and nebularine (Löfgren & Lünig, 1954) were identified in *L. inversa* and *L. nebularis*, respectively and mainly investigated for their cytotoxic properties (Moss *et al.*, 1988; Secrist *et al.*, 1994). Recently, a crude methanolic extract of *L. inversa* was reported to be active on various cancer cell lines (Bézivin *et al.*, 2002) and clitocine was thought to be the major active compound on L1210 mice leukaemia *in vivo* (Bézivin *et al.*, 2003).

Little is known in terms of volatile composition from sporophores of *Lepista* species. Low concentrations of 1-octen-3-ol as well as of glutamic acid were first observed in *L. nuda* fruiting-bodies (Disjckstra, 1976). In the 1990's, more than 30 volatile components including bisabolane derivatives (lepistirones) were identified from submerged cultures of *L. irina* (Strong-scented Blewit), edible mushroom with a typical "iris oil" or "orange blossoms" flavour (Abraham *et al.*, 1991; Krings *et al.*, 1995). At the same time, linalool seems to be a key compound in *L. nuda* (Wood Blewit) and *L. nebularis* (Clouded Agaric) odours (Audouin *et al.*, 1989; Breheret *et al.*, 1997a, b). Moreover, Noël-Suberville *et al.* (1996) reported a correlation between fatty acid content and C<sub>8</sub>-derivative effluents (1-octen-3-ol, 1-octen-3-one, 3-octanone) in *L. nuda*: the gills are the major compartments for the metabolic interconversion of linoleic acid into 1-octen-3-ol ("mushroom alcohol"). Recently, major and minor volatile compounds contributing to the overall smell of *L. nebularis* were identified from frozen and fresh materials, respectively (Rapior *et al.*, 1996, 2003).

In the present study, *L. inversa* and related *L. flaccida* were investigated for apolar and low polar compounds from diethyl ether extracts by Gas Chromatography-Mass Spectrometry (GC-MS). The volatile compositions were compared and the chemotaxonomic value of some constituents was discussed therein.

## MATERIALS AND METHODS

Wild sporophores representing a combination of young and old basidiocarps of either *Lepista inversa* (Scop.) Patouillard (Tawny Funnel Cap) or *L. flaccida* (Sow.:Fr.) Patouillard were collected under *Picea* species (fall of 1999 and

2002) and under *Quercus* species (2000 and 2003), near Rennes and L'Esp rou (France), respectively. After identification by two of us (JB and SR), soil particles and the lower part of the stipe were cautiously discarded for both species; the clean fungal materials were cut into small pieces and then frozen at  $-18^{\circ}\text{C}$ .

Solvent extraction was performed with diethyl ether (w/4v) directly added to the frozen mushrooms – without thawing – to stop enzymatic activity and then left in the darkness for 15 days. The organic extracts were gently concentrated to a small volume (0.5 mL) under nitrogen stream and analysed (1.0  $\mu\text{L}$ ) in duplicate by Gas Chromatography-Mass Spectrometry (GC-MS).

GC-MS analyses were carried out using a gas chromatograph Hewlett-Packard (5890) and a mass selective detector Hewlett-Packard (5971) with a potential of 70 eV for ionization by electron impact. Solvent extract analyses were performed using a  $25\text{ m} \times 0.20\text{ }\mu\text{m} \times 0.13\text{ }\mu\text{m}$  dimethylpolysiloxane BPX5 (Macherey-Nagel) fused silica capillary column. The injector and detector temperatures were  $200^{\circ}\text{C}$  and  $270^{\circ}\text{C}$ , respectively. The column was temperature programmed as follows:  $50^{\circ}\text{C}$  (2 min) to  $230^{\circ}\text{C}$  ( $3^{\circ}\text{C}/\text{min}$ ). The carrier gas was helium with a constant flow rate set close to 0.9 mL/min. All volatile components were identified by comparison with mass spectral library NBS (MacLafferty & Stauffer, 1989), literature spectra (Adams, 1995; Jennings & Shibamoto, 1980; National Institute of Standard and Technology, 1994) and our own data bank.

## RESULTS

The yields of residue for the diethyl ether *Lepista* extracts were about 2% of the fresh sporophores. Using GC-MS analyses, 32 and 20 volatile components were identified from *L. inversa* and *L. flaccida*, respectively (Table I). Most of these natural substances belong to various but usual classes of chemical products biosynthesized from the lipidic, shikimic and terpenic pathways. The common classes of compounds encountered in mushrooms are present as hexa- to undeca-carbon derivatives at different oxidized stages, i.e., 1-octanol, 3-octanone, (E)-2-octenal, and non-aromatic carboxylic acids (2-methylbutyric acid, hexanoic acid...) as well as aromatic derivatives (benzoic acid, phenylacetaldehyde...) and terpenic compounds (nerolidol).

The two related clitocyboid species have different volatile profiles. The *L. inversa* volatile fraction was characterized by three chlorinated molecules (RI = 1193, 1315 and 1423) as well as phenylacetic acid. None of the natural chlorinated metabolites detected from *L. inversa* were present when GC-MS analysis was carried out on *L. flaccida*; aromatic compounds derived from the shikimic pathway at various oxidized stages, i.e., benzaldehyde, *p*-hydroxybenzaldehyde, phenylacetaldehyde and phenylacetic acid, were found to be the major compounds for the latter species.

## DISCUSSION

*L. inversa* (Tawny Funnel Cap) was described as possessing a mushroom-like odour (Bon, 1988; Borgarino & Hurtado, 2001); no specific odour was repor-

Table I. Volatile components (percentage) of *Lepista inversa* and *L. flaccida*.

| Volatile compounds                | RI <sup>a</sup> | <i>L. inversa</i> | <i>L. flaccida</i> |
|-----------------------------------|-----------------|-------------------|--------------------|
| $\gamma$ -Butyrolactone           | 795             | 0.4 <sup>b</sup>  |                    |
| Hexanal                           | 797             | 1.9               | 0.3                |
| Octane                            | 800             | 0.3               |                    |
| 3-Methylbutyric acid              | 836             |                   | 2.2                |
| 2-Methylbutyric acid              | 842             | 0.9               | 0.3                |
| (E)-2-Hexenal                     | 850             | 6.1               |                    |
| Benzaldehyde                      | 954             | 1.1               | 43.0               |
| 1-Octen-3-one                     | 970             | 0.3               |                    |
| 1-Octen-3-ol                      | 975             | 1.5               |                    |
| 3-Octanone                        | 979             | 0.6               |                    |
| 2,3-Octanedione                   | 985             |                   | 0.2                |
| 2-Pentylfuran                     | 990             | 0.3               | 0.1                |
| 3-Octanol                         | 992             | 0.4               |                    |
| Benzyl alcohol                    | 1022            |                   | 0.2                |
| Phenylacetaldehyde                | 1037            | 1.6               | 24.0               |
| (E)-2-Octenal                     | 1060            | 0.5               | 3.0                |
| 1-Octanol                         | 1069            | 0.6               |                    |
| Nonanal                           | 1100            | 1.6               | 0.3                |
| Hexyl isobutyrate                 | 1147            | 2.1               |                    |
| 3-Methylthiopropionic acid        | 1150            | 4.4               |                    |
| Heptanoic acid                    | 1152            |                   | 0.3                |
| (E)-2-Nonenal                     | 1157            | 0.5               |                    |
| Clitolactone <sup>c</sup>         | 1193            | 35.4              |                    |
| (E,E)-2,4-Nonadienal              | 1214            | 0.6               |                    |
| Nonanoic acid                     | 1260            | 1.4               | 0.4                |
| 2-Undecanone                      | 1295            | 2.4               |                    |
| (E)-2-Decenal                     | 1254            | 0.7               |                    |
| Phenylacetic acid                 | 1279            | 23.5              | 1.6                |
| (Z,E)-2,4-Decadienal              | 1298            | 1.0               |                    |
| Benzoic acid                      | 1305            | 0.2               | 2.1                |
| Chlorinated I <sup>c</sup>        | 1315            | 0.5               |                    |
| (E,E)-2,4-Decadienal              | 1325            | 1.3               |                    |
| Decanoic acid                     | 1357            |                   | 1.1                |
| (E)-2-Undecenal                   | 1358            | 0.3               |                    |
| <i>p</i> -Hydroxybenzaldehyde     | 1414            |                   | 13.5               |
| Chlorinated II <sup>c</sup>       | 1423            | 4.5               |                    |
| Cinnamic acid                     | 1455            | 0.7               |                    |
| Phenylacetamide                   | 1510            |                   | 0.2                |
| (E)-Nerolidol                     | 1560            | 0.5               |                    |
| <i>p</i> -Hydroxybenzoic acid     | 1660            |                   | 2.4                |
| <i>N-p</i> -Ethoxyphenylacetamide | 1703            |                   | 1.2                |
| Myristic acid                     | 1765            |                   | 2.0                |

<sup>a</sup> Retention Indices due to the GC column used.

<sup>b</sup> Relative percentage of the volatile compounds based on the GC-MS chromatographic area.

<sup>c</sup> Mass spectra of the three chlorinated compounds: m/z (%).

Clitolactone [5-(chloromethyl)-3-methyl-2(5*H*)-furanone]: 97(100), 41(85), 39(55), 69(41), 49(14), 51(11), 146(8), 148(3), 117(4), 119 (2), 110(2).

RI = 1315: 147(100), 39(83), 149(35), 67(32), 49(25), 51(18), 74(23), 83(22), 102(20), 41(16), 160(11), 76(8), 130(5), 104(5), 162(3), 132(2), 178(1).

RI = 1423: 132(100), 39(90), 69(40), 75(37), 134(33), 131(31), 104(28), 133(23), 50(23), 49(21), 51(18), 64(11), 77(10), 41(7), 106(5), 148(2).



ted for *L. flaccida* (Bon, 1997). Unlike Romagnesi (1971) and Malençon and Bertault (1975), it might be noted that Moser (1983) and Bon (1997) as well as Courteuisse and Duhem (2000) distinguished *L. inversa* from *L. flaccida* on the basis of macro and micromorphological descriptions, and environmental conditions (Gymnosperms and Angiosperms substrates, respectively). Considering these two species found in North America where *L. flaccida* appears to be the most common species growing on humus under conifers (spruce) as well as hardwoods, Bigelow (1985) mainly distinguished them on macroscopical characters, particularly as the gills of *L. flaccida* do not become rufescent with age while Pomerleau (1980) reported only one species as *Lepista inversa* (Fr.) Pat. (= *Clitocybe flaccida* (Fr.) Kum.) under both hardwoods and softwoods.

According to Courteuisse and Duhem (2000), both clitocyboid species belong to the *Tricholomataceae*, *Tricholomatoideae*, tribe *Lepisteeae*, genus *Lepista* (Fr.) W.G. Smith, subgenus *Lepista*, section *Inversae*. It should be mentioned that *L. inversa*, and *L. flaccida* indeed, could be confused with species responsible for the acromelalgic syndrome as toxic *Clitocybe ameonolens* and *C. acromelalga* (Konno *et al.*, 1988; Moreau *et al.*, 2001; Saviuc, 2000; Saviuc *et al.*, 2001, 2003).

Although *L. inversa* and *L. flaccida* have similar odours, many differences were found with regard to their volatile pattern. The major compounds found in *L. flaccida* were aromatic aldehydes, i.e., benzaldehyde (43%), phenylacetaldehyde (24%) and *p*-hydroxybenzaldehyde (13.5%) while a chlorinated compound (clitolactone, 35.4%) along with phenylacetic acid (23.5%) were predominant for *L. inversa*. This major chlorinated metabolite was recently identified as a banana slug antifeedant by Wood *et al.* (2004).

The *L. inversa* volatile composition also appears to be more varied than that of *L. flaccida* but neither this observation nor the nature of shikimic derivatives are an unequivocal feature to distinguish them considering natural variations according to stage of development and sampling. Conversely, presence of three chlorinated compounds (more than 40.4%, Table I) in the volatile fraction of *L. inversa* is of interest in this way. Considering little information of their mass spectra, no chemical structure can be suggested by the authors to the chlorinated compounds I and II. Nevertheless, the similarity between mass spectra from the three metabolites lead us to think that the chlorinated components I and II have also a lactonic structure. Thus, the three chlorinated metabolites probably could come from a nonprotein amino acid such as those reported by De Jong and Field (1997).

To our knowledge, these chlorinated natural substances could be of major interest for the chemotaxonomic distinction between *L. inversa* and *L. flaccida*, which is controversially identified as a distinct mushroom. Three chlorinated components including clitolactone were detected from *Lepista inversa* (Scop.) Patouillard growing under coniferous trees in two French locations over two years (Rennes and L'Espérou). Moreover, according to our GC-MS analyses over two years, *Lepista flaccida* (Sow.:Fr.) Patouillard growing under deciduous trees in two French locations has no chlorinated metabolites (Table I) while recent investigation on volatiles from *Clitocybe flaccida* (Fries) Kummer growing "in combination with conifers in western North America" (Wood *et al.*, 2004) demonstrates presence of clitolactone. Different characteristics distinguish humus from softwoods (*Picea*) and hardwoods (*Quercus*); the lowest pH values of natural substrates were particularly reported for softwoods (Scheikl, 1994). A low pH of humus/litter in coniferous forest could explain the transformation from a nonprotein amino acid precursor such as 2-amino-2-methyl-5-chloro-4-pentenoic acid to 5-(chlorome-

thyl)-3-methyl-2(5H)-furanone (clitolactone) for the French *Lepista inversa* or the American *Clitocybe flaccida* species, both specimens growing under spruce.

Occurrence of natural chlorinated compounds was previously detected in Basidiomycota strains. Some wood- and forest litter-degrading fungi are well known to produce chlorinated anisyl metabolites (De Jong *et al.*, 1994; Field and Wijnberg, 2003). This feature has particularly been depicted for *L. nuda* that has ability to biosynthesise organically bound halogens in culture or in field conditions as in coniferous forest (Hjelm *et al.*, 1996, 1999). Moreover, *L. nuda* and three *Clitocybe* species were shown to produce low to moderate amounts of aromatic chlorometabolites among 55% of the 191 fungal strains screened for adsorbable organic halogen production (Verhagen *et al.*, 1996). Only some aliphatic chlorinated structures have been previously found in Basidiomycota, i.e., pinicoliform from *Resinicium pinicola* (Becker *et al.*, 1994), scorodonine from *Marasmius scorodoni*, lepiochlorine from *Lepiota* sp. (Field *et al.*, 1995), along with two aminochloropentenoic acids and two aminochlorohexenoic acids found in some *Amanita* species (in Field *et al.*, 1995; Ohta *et al.*, 1995). Recently, Wood *et al.* (2003) identified 3-chloroindole from *Hygrophorus paupertinus*.

Overall, our findings underlined intraspecific variability in the chlorinated volatile profile for *L. inversa* and *L. flaccida* resulting probably from the fungus/litter combination. It should be noted that correlation between the amanitin distribution and the chemical composition of substrate was statistically validated for *Galerina marginata* (Batsch) Kühner (Enjalbert *et al.*, 2004). However, relationship between either the pH or the chemical composition of the litter and the expression of chlorinated metabolites from *Lepista* or *Clitocybe* species should be ascertained.

On the other hand, with regard to flavour production as well as bioactive molecule production, higher fungi represent an alternative to traditional plant sources. The remarkable metabolic diversity of Basidiomycota obtained through biotechnological processes (without using specific precursors) offers immediate industrial applications (Abraham & Berger, 1994; Giacinti-Martinie, 1999). Extended screenings of mushroom volatiles may lead to improvement in the spectrum of natural-labeled odorous components to be mostly used in food agro-industry as additives, preservatives or bioactive substances.

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