Panfungi

REVIEW

Open Access

https://doi.org/10.48130/panfungi-0025-0005

Panfungi **2026**, 1: e005

The taxonomic distribution of garlic-like flavour in the Agaricales

Ji-Peng Li[1,2] and László G. Nagy[1*]

[1] *Synthetic and Systems Biology Unit, Institute of Biochemistry, Biological Research Centre, Szeged 6726, Hungary*

[2] *Engineering Research Center of Edible and Medicinal Fungi, Ministry of Education, Jilin Agricultural University, Changchun 130118, China*

* Correspondence: lnagy@fungenomelab.com (Nagy LG)

Abstract

Garlic-like flavour is widely appreciated by consumers and has been reported in some plants and mushroom-forming fungi. However, its overall taxonomic distribution within the order Agaricales (Fungi) remains poorly understood. In this review, published reports of garlic-like flavour across taxa are summarised, and its phylogenetic distribution and potential evolutionary explanations are discussed. In total, 75 species representing 14 genera, 7 families, and 6 suborders are recognised. The family Omphalotaceae is a main hub for taxa with a garlic-like flavour, with *Gymnopus* and *Mycetinis* contributing most species. Only a few taxa are scattered in other families. The garlic-like flavour is concentrated in the suborder Marasmiineae but is only sporadically present in the other five suborders, a pattern suggesting multiple independent origins. Within the Omphalotaceae, its genus-level patchiness is most parsimoniously explained by a single origin and several secondary losses. The summary presented here provides an updated overview of garlic-flavoured diversity in the Agaricales and a basis for future studies on the evolution and chemical mechanisms of flavour traits in fungi.

Keywords: Alliaceous, Marasmiineae, Odour, Omphalotaceae, Onion, Rotten cabbage, Shiitake, Smell, Taste

Introduction

Garlic flavour is a pungent sensory experience combining taste and aroma. It is a characteristic feature of many *Allium* species (e.g., garlic and onion) and makes these plants highly valued as foodstuffs[1]. This flavour is not confined to plants, as comparable flavour profiles have also been reported in certain macrofungi, including some species in Agaricales, Boletales, etc. *Lentinula edodes* (Berk.) Pegler, commonly known as "shiitake (香菇)", is noted for its garlic-like aftertaste and aroma[2,3], and has become one of the most extensively cultivated mushrooms worldwide[4]. The garlic-like flavour in *Lentinula* has been described as including notes reminiscent of garlic, onion, rotten cabbage, or radish[4–6]. This feature has also been reported in the phylogenetically related genera *Mycetinis* and *Gymnopus*. Together with *Lentinula*, they form a monophyletic lineage within the Omphalotaceae in one phylogenetic work[2], in which the substances responsible for the flavour have therefore been discussed as an apomorphic character. Species exhibiting a garlic-like flavour have been reported in four additional genera of the family, extending the known taxonomic distribution of this feature[3,7–10]. In China, *Lanmaoa asiatica* G. Wu & Zhu L. Yang and *Butyriboletus roseoflavus* (H.B. Li & H.L. Wei) D. Arora & J.L. Frank are usually called "red garlic (红葱)" and "white garlic (白葱)", respectively, by the local people because of their garlic-like flavour. Unfortunately, such flavour has rarely been clearly documented in the literature. Although these two species are distantly related to the Omphalotaceae, the occurrence of garlic-like flavours in Boletales implies that the trait may be more widespread and potentially under-reported. However, it remains unclear whether this feature has been documented in Agaricales outside Omphalotaceae. It is therefore difficult to determine whether the trait is apomorphic or plesiomorphic within the family. A better understanding of the phylogenetic and taxonomic distribution of this feature is essential for exploring its evolutionary history.

The diversity of garlic-flavoured species across lineages has not yet been systematically reviewed. Historically, these fungi were placed in several genera of marasmioid and collybioid fungi[11] and then reassigned into at least five genera of Omphalotaceae by morphomolecular approaches[2,7,8,12,13]. Some taxa may have been overlooked during previous taxonomic revisions, and their placement requires further evaluation. These unresolved taxonomic and phylogenetic questions constrain current assessments of the taxonomic distribution of garlic-flavoured species.

This review aims to collect and summarise the available records of Agaricales species exhibiting this feature, to advance knowledge of their diversity, to discuss their taxonomic placement, and, on this basis, to elucidate their phylogenetic distribution and evaluate possible evolutionary scenarios.

Methods

Definition of garlic-like flavour

In this review, flavour broadly refers to sensory impressions described as smell or taste, because flavour is a multidimensional experience primarily composed of smell and taste[14]. The term "garlic-like flavour" refers to a smell or taste reminiscent of garlic, rotten cabbage, onion, or radish.

Data collection and processing

Information on Agaricales species reported to possess a garlic-like flavour was collected from published literature. Searches were conducted using scientific databases such as Web of Science and Google Scholar, as well as available taxonomic monographs and reference books. Relevant records were retrieved using combinations of keywords such as "garlic odour/taste", "alliaceous smell/

Dates Received 6 February 2026; Revised 25 February 2026; Accepted 8 March 2026; Published online 30 March 2026

Citation: Li JP, Nagy LG. 2026. The taxonomic distribution of garlic-like flavour in the Agaricales. *Panfungi* 1: e005 https://doi.org/10.48130/panfungi-0025-0005

taste", "rotten cabbage", "onion", and "Agaricales". Records referring to infraspecific taxa (e.g., varieties or subspecies) were treated at the species level to maintain a uniform taxonomic rank. The retained records were considered reliable after applying the following filtering criteria: records derived from monographs (M), records derived from protologues (P), and records derived from taxonomic research publications (C) in which the trait is commonly present in closely related lineages within the family and, if this was not the case, the record had to be supported by at least two independent literature sources. The corresponding letters are used in Table 1 to indicate which criterion each record satisfied. For each valid species, the genus, family, and suborder were recorded according to the latest classification of the Agaricales[15,16]. The backbone topology followed a genome-scale phylogeny of Agaricales[17] and was then pruned to match our taxon set. To increase genus-level coverage, additional genera were incorporated according to published multilocus phylogenies (internal transcribed spacer 1, 5.8S ribosomal RNA gene, internal transcribed spacer 2, and large subunit regions of the nuclear ribosomal DNA)[3], yielding the final hybrid tree used for trait mapping (Fig. 1a). The genus *Rhodocollybia* appeared as two separate lineages in the multilocus phylogenies. The nontype lineage was removed to clarify intergeneric relationships prior to grafting.

Taxonomic distribution of garlic-like flavour in Agaricales

Phylogeny is the foundation for understanding the trait's distribution. A hybrid tree was constructed by combining the robustness of phylogenomic analyses with the broader taxonomic coverage provided by multilocus phylogenetic data. The presence or absence of a garlic-like flavour and its species diversity were mapped onto the hybrid tree to explore the trait's distribution and possible evolutionary pattern.

A garlic-like flavour has been reported in 75 species of Agaricales, spanning 14 genera placed in 7 families across 6 suborders (Table 1, Fig. 1a, b). Its distribution is strongly uneven: Most records are in the Marasmiineae, where the trait is confined to Omphalotaceae and Marasmiaceae (Fig. 1a). Omphalotaceae represents the main hotspot, including 62 of the 75 recorded species and eight of the 14 genera, with the highest numbers in *Gymnopus* (35 species) and *Mycetinis* (15 species). Outside the Marasmiineae, the trait is rare and patchy, accounting for the remaining records being scattered across five suborders, each represented by a single genus. The remaining seven species were distributed among five suborders. Single species were recorded in the genera *Dendrothele* (Schizophyllineae), *Hygrocybe* (Hygrophorineae), and *Phyllotopsis* (Phyllotopsidineae), whereas two species were recorded in *Clavaria* (Clavariineae) and three in *Amanita* (Amanitineae).

This pattern indicates a pronounced phylogenetic clustering within a single lineage, coupled with sporadic occurrences in distant clades (Fig. 1a). At the scale of the Agaricales, the pattern is most consistent with repeated, independent origins. Outside the Marasmiineae, the garlic-like flavour is recorded only as single-genus occurrences in five other suborders. Altogether, these occurrences point to at least seven independent gains at the family level within Agaricales. Within the Omphalotaceae, the flavour is widespread across several genera but is missing from a few lineages nested within the family. If Omphalotaceae is treated as having a single origin of the trait, the genus-level patchiness within the family can be explained parsimoniously by a minimum of four secondary losses or, under a less parsimonious scenario, by eight independent gains, assuming one origin per genus. A single origin of the garlic-like flavour at the base of Agaricales would, by contrast, require losses across most major lineages, which is unlikely, given the observed pattern.

Table 1. Overview of garlic-like flavour reported in Agaricales species

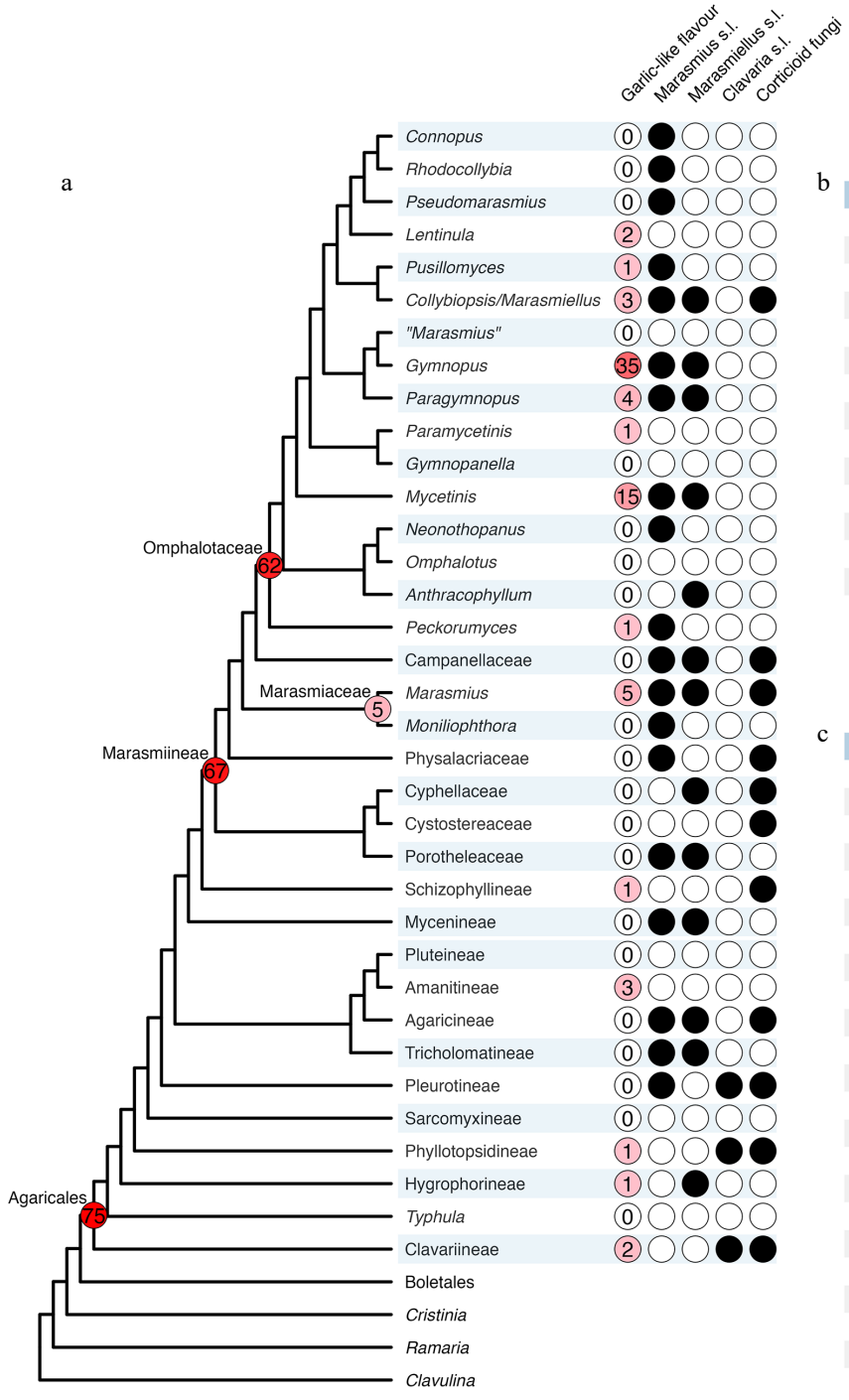
Species name	Odour	Taste	Ref.	Filters
Amanita alliacea (Murrill) Murrill	Decided odour of wild onion	Not recorded	[18]	P
A. alliodora Pat.	Very distinct garlic odour	Not recorded	[19]	P
A. suballiacea (Murrill) Murrill	Strong garlic odour	Not recorded	[18]	P
Clavaria alliacea Corner	Strong garlic	Strong garlic	[20]	P
C. fuscata Oudem.	Strong garlic	Not recorded	[20,21]	C, M
Dendrothele alliacea (Quél.) P.A. Lemke	Garlic-like	Not recorded	[22]	P
Gymnopus alliifoetidissimus T.H. Li & J.P. Li	Strongly alliaceous	Not recorded	[23]	P
G. alpicola (Bon & Ballarà) Esteve-Rav., V. González, Arenal & E. Horak	Strong smell reminiscent of rotten cabbage, with faint a component of garlic	Tastes like the smell	[12]	M
G. brassicolens (Romagn.) Antonín & Noordel.	Foetid smell like rotten cabbage or sewage; sometimes more like garlic	Not recorded	[12]	M
G. ceraceicola J.A. Cooper & P. Leonard	Garlic/rotten cabbage	Not recorded	[24]	P
G. chowii J.P. Li, Chang-Tian Li & Y. Li	Rotten cabbage-like	Not recorded	[7]	P
G. cystidiosus J.J. Hu, B. Zhang & Y. Li	A strong smell reminiscent of rotten cabbage or onion	Not recorded	[25]	P
G. densilamellatus Antonín, Ryoo & Ka	Unpleasant, like rotten cabbage or garlic	Mild or bitterish	[26]	P
G. dysodes (Halling) Halling	Pungent, like old onions or garlic	Onion-like, but not too disagreeable	[27]	P
G. dysosmus Polemis & Noordel.	Strong, unpleasant, foetid, or like garlic	Strong, unpleasant, foetid, or like garlic	[12]	M
G. epiphyllus J.J. Hu, B. Zhang & Y. Li	A strong smell reminiscent of rotten cabbage or onion	Not recorded	[25]	P
G. foetidus (Sowerby) P.M. Kirk	A nasty smell like rotten cabbage	Nasty	[12]	M
G. graveolens (G. Poirault ex Boud.) Antonín & Noordel.	Like rotten cabbage	Distinctly bitter	[12]	M
G. hakaroa J.A. Cooper & P. Leonard	Garlic/rotten cabbage	Not recorded	[24]	P
G. hariolorum (Bull.) Antonín, Halling & Noordel.	A strong, fetid smell, like rotten cabbage or sewage	Very unpleasant	[12]	M
G. herinkii Antonín & Noordel.	Strong, like garlic/onions	Strong, like garlic/onions	[12,28]	M

(to be continued)

Table 1. (continued)

Species name	Odour	Taste	Ref.	Filters
G. imbricatus J.A. Cooper & P. Leonard	Garlic/rotten cabbage	Not recorded	[24]	P
G. impudicus (Fr.) Antonín, Halling & Noordel.	Like rotten cabbage, sometimes with a garlic component	Like rotten cabbage, sometimes with a garlic component	[12]	M
G. iocephalus (Berk. & M.A. Curtis) Halling	Pungent and unpleasant (reported as smelling of garlic, radish, sauerkraut, or gunpowder)	Unpleasant	[27]	M
G. iodes J.P. Li, Chang-Tian Li, Chun Y. Deng & Y. Li	Garlic-like	Not recorded	[29]	P
G. montagnei (Berk.) Redhead	Garlic	Not recorded	[30]	M
G. neobrevipes R.H. Petersen	Negligible	Negligible or weakly alliaceous	[31]	P
G. polyphyllus (Peck) Halling	Garlic	Garlic	[27]	M
G. purpureicollus (Corner) A.W. Wilson, Desjardin & E. Horak	Smell of garlic, not strong	Tasting rancid or rotten	[32,33]	P, C
G. pyrenaeicus (Bon & Ballarà) Antonín & Noordel.	Like cabbage or foetid	Sweet or slightly like cocoa	[12]	M
G. similis Antonín, Ryoo & Ka	Garlic-like	Garlic-like	[26]	P
G. sinopolyphyllus J.P. Li, Chang-Tian Li & Y. Li	Garlic-like	Not recorded	[29]	P
G. spadiceus J.J. Hu, B. Zhang & Y. Li	A strong smell reminiscent of rotten cabbage	Not recorded	[34]	P
G. subdensilamellatus J.J. Hu, Y.L. Tuo, B. Zhang & Y. Li	A strong smell reminiscent of rotten cabbage or onion	Not recorded	[25]	P
G. subpolyphyllus J.J. Hu, B. Zhang & Y. Li	A strong smell reminiscent of rotten cabbage or onion	Not recorded	[25]	P
G. talisiae V. Coimbra, F.G.B. Pinheiro, Wartchow & Gibertoni	Not garlic	Radish-like	[35]	P
G. thiersii (Desjardin) Mešić & Tkalčec	Mild or rarely slightly foetid when old and wet	The taste slowly becomes strongly alliaceous	[36]	P
G. tianbaoyanensis J.P. Li, Chang-Tian Li & Y. Li	Rotten cabbage-like	Not recorded	[7]	P
G. trabzonensis Vizzini, Antonín, Sesli & Contu	Typically and strongly cabbage-like	Indistinct	[37]	P
G. variicolor Antonín, Ryoo, Ka & Tomšovský	Odour foetid and garlic-like with a component of rotten cabbage	Mild and unpleasant	[26]	P
G. violaceigregarius Qasmi, A. Izhar & Khalid	Garlic-like	Not recorded	[38]	P
Hygrocybe helobia (Arnolds) Bon	Garlic	Not recorded	[39,40]	M
Lentinula edodes (Berk.) Pegler	Garlic- or rotten cabbage-like	Garlic-like	[2,3]	C
L. raphanica (Murrill) Mata & R.H. Petersen	Radish-like	Radish-like	[41]	P
Marasmiellus alliiodorus (Mont.) Singer	Strong smell of garlic	Not recorded	[42,43]	P, M
M. osmophorus Dennis	Strong smell of garlic	Not recorded	[43]	M
M. subingratus (Dennis) Singer	Strong of garlic	Not recorded	[43]	M
Marasmius alliifoetidus Corner	Garlic-like, strong, and foetid	Not recorded	[32]	P
Ma. alliipotens Corner	Strong smell of garlic	Not recorded	[32]	P
Ma. edodoides Corner	Slight smell of onions or of meal	Not recorded	[32]	P
Ma. hortorum Corner	Smell of garlic, rather strong	Not recorded	[32]	P
Ma. matangensis Corner	Smell of garlic, not strong	Not recorded	[32]	P
Mycetinis alliaceus (Jacq.) Earle ex A.W. Wilson & Desjardin	Strong smell of garlic	Distinct smell of garlic, sometimes also acrid	[31]	C
My. applanatipes (Desjardin) A.W. Wilson & Desjardin	Strongly alliaceous	Strongly alliaceous	[44]	P
My. arbuscularis J.P. Li, Chang-Tian Li & Y. Li	Garlic-like	Not recorded	[7]	P
My. copelandii (Peck) A.W. Wilson & Desjardin	Strongly alliaceous	Strongly alliaceous	[36]	C
My. curraniae (G. Stev.) J.A. Cooper & P. Leonard	Garlic-like	Garlic-like	[45]	C
My. ignobilis (Berk. & Broome) Desjardin & B.A. Perry	Strong smell of garlic	Strong taste of garlic	[46]	C
My. kallioneus (Huhtinen) Antonín & Noordel.	Strongly alliaceous	Strongly alliaceous	[45]	C
My. olidus (Gilliam) R.H. Petersen	Weakly pleasant to pungent smell of garlic	Garlic or onion, often persisting with drying and storage	[45]	C
My. prasiosmus (Fr.) R.H. Petersen	Strong smell of garlic	Distinct garlic component	[45]	C
My. querceus (Britzelm.) Antonín & Noordel.	Garlic	Not recorded	[47]	C
My. rufodiscus J.P. Li, Chang-Tian Li & Y. Li	Garlic-like	Not recorded	[7]	P
My. salalis (Desjardin & Redhead) Redhead	Strong smell of onion or garlic	Strong taste of onion or sweet garlic	[45]	C
My. scorodonius (Fr.) A.W. Wilson & Desjardin	Weak to strong smell of garlic, rarely lacking	Usually alliaceous	[45]	C
My. subalpinus (P.-A. Moreau) R.H. Petersen	Very powerful of garlic	Alliaceous and sweet	[45]	C
My. virgultorum (Malençon & Bertault) R.H. Petersen	Garlic	Garlic	[45]	C
Paragymnopus foliiphilus (R.H. Petersen) J.S. Oliveira	Usually reported as negligible, occasionally resembling boiled cabbage after drying or mildly foetid	Usually reported as negligible, occasional very weak taste of garlic	[9]	C
Pg. magnisporus J.P. Li, Chang-Tian Li & Y. Li	Garlic-like	Not recorded	[7]	P
Pg. perforans (Hoffm.) J.S. Oliveira	Like rotten cabbage	Often tardily alliaceous	[9]	C
Pg. sequoiae (Desjardin) J.S. Oliveira	Mild or rarely slightly foetid when old and wet	Strongly alliaceous after 1–2 min	[9]	C
Paramycetinis austrobrevipes R.H. Petersen	Negligible	Negligible or weak taste of garlic	[10]	P
Peckorumyces umbonatus (Peck) J.P. Li, J.S. Oliveira & Chang-Tian Li	Garlic-like	Not recorded	[7]	C
Phyllotopsis nidulans (Pers.) Singer	Similar to rotten cabbage	Not recorded	[48,49]	C
Pusillomyces rhizoalliaceus J.P. Li & Chang-Tian Li, nom. prov.	Garlic-like	Not recorded	[3]	C

a



b

Suborder	Family	Genus	Species Count
Clavariineae	Clavariaceae	*Clavaria*	2
Hygrophorineae	Hygrophoraceae	*Hygrocybe*	1
Marasmiineae	Marasmiaceae	*Marasmius*	5
Marasmiineae	Omphalotaceae	*Gymnopus*	35
Marasmiineae	Omphalotaceae	*Lentinula*	2
Marasmiineae	Omphalotaceae	*Marasmiellus*	3
Marasmiineae	Omphalotaceae	*Mycetinis*	15
Marasmiineae	Omphalotaceae	*Paragymnopus*	4
Marasmiineae	Omphalotaceae	*Paramycetinis*	1
Marasmiineae	Omphalotaceae	*Peckorumyces*	1
Marasmiineae	Omphalotaceae	*Pusillomyces*	1
Phyllotopsidineae	Phyllotopsidaceae	*Phyllotopsis*	1
Schizophyllineae	Cyphellopsidaceae	*Dendrothele*	1
Amanitineae	Amanitaceae	*Amanita*	3

c

Current Name	Validation Required
Clavaria alliacea	Phylogenetic Placement
C. fuscata	Phylogenetic Placement
Dendrothele alliacea	Phylogenetic Placement
Gymnopus atlanticus	Garlic-like Flavour
G. barbipes	Garlic-like Flavour
G. bisporiger	Garlic-like Flavour
G. bunerensis	Garlic-like Flavour
G. fuscus	Garlic-like Flavour
G. niveus	Garlic-like Flavour
G. purpureicollus	Phylogenetic Placement
G. pygmaeus	Garlic-like Flavour
G. salakensis	Garlic-like Flavour
G. subfoetidus	Garlic-like Flavour
G. thiersii	Phylogenetic Placement
G. wutaishanensis	Garlic-like Flavour
Marasmiellus alliiodorus	Phylogenetic Placement
M. osmophorus	Phylogenetic Placement
M. subingratus	Phylogenetic Placement
Marasmius alliifoetidus	Phylogenetic Placement
Ma. alliipotens	Phylogenetic Placement
Ma. edodoides	Phylogenetic Placement
Ma. hortorum	Phylogenetic Placement
Ma. matangensis	Phylogenetic Placement

Fig. 1 The taxonomic distribution of garlic-like flavour in the Agaricales. (a) Hybrid tree of Agaricales. Numbers inside open circles indicate the number of species with a garlic-like flavour within each taxon; red fill intensifies with increasing species counts. The "*Marasmius*" lineage was provisionally treated as lacking the garlic-like flavour because no verifiable records were available from literature. Black-filled circles indicate the presence of the corresponding annotation. In columns representing legacy genus concepts (*Marasmius* s. l., *Marasmiellus* s. l., and *Clavaria* s. l.), they mark genera containing species historically placed under those names according to Index Fungorum[50]. In the "Corticioid fungi" column, they indicate genera containing corticioid taxa as documented in Larsson[51]and Dong et al.[52]. Open circles indicate absence. (b) Summary table of taxa with a garlic-like flavour across Agaricales, listing the suborder, family, and genus, with the corresponding number of species recorded as having a garlic-like flavour. (c) List of species records requiring validation, indicating whether verification is needed for phylogenetic placement or for the presence of garlic-like flavour[7,12,33,35,53–57].

Information bias in documenting garlic-like flavour

The distribution of garlic-like flavour in the Agaricales is compiled from published descriptions and may be biased by multiple factors. Barriers to literature access and retrieval limit the records' coverage. Recent studies continue to document new taxa exhibiting a garlic-like flavour, suggesting that additional species likely remain to be discovered and may further reshape the distribution pattern[23,29,38,58]. In addition, detection bias in accessible sources and terminological vagueness make determination of the presence

or absence of a garlic-like flavour uncertain in some cases. These uncertain cases require further clarification and are highlighted in Fig. 1c.

The garlic-like flavour is diagnostic for certain groups, such as *Gymnopus* section *Impudicae*[12]. However, several species within the clade of section *Impudicae* (e.g., *G. barbipes* and *G. salakensis*) were originally characterized as lacking a distinct flavour[33,53]. This discrepancy may reflect either true phenotypic absence or a detection bias, as the lack of recorded flavour could result from sensory limitations. Crushing the basidiomata may be involved in releasing the flavour, and it can intensify the smell[24,45]. This is further exemplified by *Peckorumyces umbonatus*, in which the garlic-like flavour is sometimes negligible but becomes distinct after the stipe is cut longitudinally[7].

Even if they belong to the clade of section *Impudicae*, the descriptions of several species fail to provide flavour traits or specific details. This reporting gap suggests that the apparent lack of recorded garlic-like flavours could stem from incomplete descriptions rather than an actual lack of the flavour. This is largely because several descriptions prioritise broad sensory categories over specific diagnostic traits, and a reliance on generalised terms that can mask the distinct garlic-like components. Specifically, flavour data were not recorded in the original descriptions for several species, including *G. atlanticus*, *G. fuscus*, *G. niveus*, *G. pygmaeus*, and *G. subfoetidus*[7,35,55,56]. Furthermore, the odours of *G. wutaishanensis* and *G. bunerensis* were described only in broad terms as "tangy and unpleasant" or simply "unpleasant"[54,57].

Phylogenetic impact on the distribution patterns of garlic-like flavour

Phylogeny is instrumental in resolving the evolutionary relationships of taxa exhibiting trait convergence. Recent phylogenetic studies assigned taxa with a garlic-like flavour to *Peckorumyces* and *Pusillomyces,* two genera in which the trait had not previously been recognised[3,7]. These studies have significantly expanded the known distribution of garlic-like flavour.

Phylogenetic relationships and morphology-based classifications are not always in agreement, particularly among marasmioid, clavarioid, and corticioid fungi[2,52,59]. Most species that fall outside the core distribution of the garlic-like flavour trait have an unresolved phylogenetic position, largely because most are historical taxa without molecular data. This is compounded by the nomenclatural instability and taxonomic ambiguity that characterise many historical taxa according to Index Fungorum (Fig. 1a, c)[50]. The eventual phylogenetic resolution of species currently assigned to *Clavaria* (two species), *Dendrothele* (*D. alliacea*, one corticioid species), *Marasmiellus* (three species), and *Marasmius* (five species) may reshape the perceived phylogenetic range of garlic-like flavour within the Agaricales. Specifically, the phylogenetic placements of the *Clavaria* species sampled here may define the most phylogenetically distant occurrence of garlic-like flavour within the Agaricales. The phylogenetic placement of species currently assigned to the other three genera may influence whether the distribution of this trait becomes further concentrated within the family Omphalotaceae. According to previous studies, many species of *Marasmiellus* and *Marasmius* exhibiting a garlic-like flavour have been phylogenetically recovered within the Omphalotaceae[2,45]. Furthermore, although corticioid fungi are known to be distributed across multiple suborders within Agaricales, such corticioid lineages have been repeatedly recovered within the Omphalotaceae or in closely related clades in the Marasmiineae[52,60–62]. These findings raise the possibility that many currently unplaced taxa may eventually be resolved within the Marasmiineae or Omphalotaceae, which would further reinforce the concentrated distribution of garlic-like flavour.

Because garlic-like flavour occurs in phylogenetically distant clades, it is a phylogenetically patchy trait. Such traits pose a great challenge in evolution because they can be either explained by a single origin and multiple subsequent losses, or by multiple independent origins. Some similar examples have recently been documented in the Agaricales, such as the evolution of bioluminescence[63]. In the case of garlic-like flavour, its phylogenetic distribution suggests multiple independent origins, though the situation may be more complex in the Omphalotaceae, where species with and without a garlic-like flavour form closely related clades. Another consideration for future studies is clarifying whether its genetics is also convergent, e.g., by the recruitment of the same gene families for the production of garlic-like flavour. However, given that the genetic bases of producing the garlic-like flavour are themselves partially known, their evolution also remains to be clarified in the future.

Summary and perspectives

Garlic-like flavour has been reported in multiple suborders of Agaricales, yet its occurrence is taxonomically and phylogenetically clustered overall rather than broadly dispersed. The available evidence indicates that Omphalotaceae represents the main centre of this trait, showing the highest diversity and record density at both the species and genus levels. However, the current picture is likely to underestimate the true extent of the distribution. Limited access to the literature, continued reports of additional taxa, detection bias in published descriptions, and inconsistent terminology all introduce uncertainty into presence–absence assessments, which, in turn, affects how the continuity and discontinuity of the distribution pattern are interpreted. In addition, the phylogenetic placement of several historically described taxa remains uncertain; once these lineages are robustly resolved, the taxonomic distribution of garlic-like flavour and the degree to which it appears to be concentrated or dispersed may need to be revised.

This review helps clarify how garlic-like flavour is distributed among the existing records and how that distribution aligns with phylogenetic structure. It provides a starting point for exploring the evolutionary history of the trait and raises hypotheses about gains and losses across lineages. The observed phylogenetic clustering offers practical value in prioritizing lineages for aroma-related compound screening, even in the absence of detailed chemical data. Trait-informed targeting can improve the efficiency of identifying strains with desirable volatiles for use in food production or natural product development. In cultivars such as *Lentinula*, where a garlic-like flavour is already present, the identified pathways may support targeted enhancement of aroma intensity through breeding or metabolic regulation. In other lineages where the trait is absent, these findings may enable the introduction of garlic-like flavour via gene transfer or synthetic biology approaches, offering new possibilities for aroma improvement.

Author contributions

The authors confirm contribution to the paper as follows: study conception and design: Nagy LG; data collection: Li JP; analysis and interpretation of results: Nagy LG, Li JP; manuscript preparation: Nagy LG, Li JP. All authors reviewed the results and approved the final version of the manuscript.

Data availability

All data generated or analyzed during this study are included in this published article.

Acknowledgments

The first author thanks Geng-Shen Wang for sharing the phylogenetic tree of Agaricales. LGN acknowledges support by the National Research Development and Innovation Office (Grant No. OTKA 142188). JPL was supported by China Scholarship Council (Grant No. 202308220156). We thank the editor and the anonymous reviewers for their constructive comments, which improved the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

References

[1] Fenwick GR, Hanley AB, Whitaker JR. 1985. The genus *Allium*—part 1. *Critical Reviews in Food Science & Nutrition* 22(3):199–271

[2] Wilson AW, Desjardin DE. 2005. Phylogenetic relationships in the Gymnopoid and Marasmioid fungi (Basidiomycetes Euagarics clade). *Mycologia* 97:667–679

[3] Li JP. 2025. 类脐菇科的分类与系统发育研究 [Studies on the Taxonomy and Phylogeny of Omphalotaceae]. Dissertation. *吉林农业大学* [*Jilin Agricultural University*], China. pp. 1–192. (in Chinese). doi: 10.27163/d.cnki.gjlnu.2025.000010

[4] Sierra-Patev S, Min B, Naranjo-Ortiz M, Looney B, Konkel Z, et al. 2023. A global phylogenomic analysis of the shiitake genus *Lentinula*. *Proceedings of the National Academy of Sciences of the United States of America* 120(10):e2214076120

[5] Liu Q, Hu S, Song Z, Cui X, Kong W, et al. 2021. Relationship between flavor and energy status in shiitake mushroom (*Lentinula edodes*) harvested at different developmental stages. *Journal of Food Science* 86(10):4288–4302

[6] Wu CM, Wang Z. 2000. Volatile compounds in fresh and processed shiitake mushrooms (*Lentinus edodes* Sing.). *Food Science & Technology Research* 6(3):166–170

[7] Li JP, Oliveira JJS, Pan MC, Deng CY, Antonín V, et al. 2024. Notes on all Genera of Omphalotaceae: Expanding the Taxonomic Spectrum in China and Revisiting Historical Type Specimens. *Mycosphere* 15(1):1522–1594

[8] Oliveira JJS, Vargas–Isla R, Cabral TS, Rodrigues DP, Ishikawa NK, et al. 2019. Progress on the phylogeny of the Omphalotaceae: *Gymnopus* s. str., *Marasmiellus* s. str., *Paragymnopus* gen. nov. and *Pusillomyces* gen. nov. *Mycological Progress* 18:713–739

[9] Petersen RH, Hughes KW. 2016. *Micromphale* sect. *Perforantia* (Agaricales, Basidiomycetes); expansion and phylogenetic placement. *MycoKeys* 18:1–122

[10] Petersen RH, Hughes KW. 2020. Two new genera of gymnopoid/marasmioid euagarics. *Mycotaxon* 135(1):1–95

[11] Singer R. 1986. The Agaricales in Modern Taxonomy. 4th Edition. Koenigstein: Koeltz Scientific Books. 981 pp

[12] Antonín V, Noordeloos ME. 2010. A monograph of Marasmioid and Collybioid fungi in Europe. Eching: IHW-Verlag Publisher. 478 pp

[13] Moncalvo JM, Vilgalys R, Redhead SA, Johnson JE, James TY, et al. 2002. One hundred and seventeen clades of euagarics. *Molecular Phylogenetics and Evolution* 23:357–400

[14] Castillo M. 2014. The complicated equation of smell, flavor, and taste. *American Journal of Neuroradiology* 35(7):1243–1245

[15] He MQ, Cao B, Liu F, Boekhout T, Denchev TT, et al. 2024. Phylogenomics, divergence times and notes of orders in Basidiomycota. *Fungal Diversity* 126:127–406

[16] Qu H, Cai Q, Redhead SA, Chen X, Ge ZW, et al. 2025. Exploring criteria forconstructing suprageneric classifications of fungi in the genomic era: acase study of suborders *Agaricineae*, *Pluteineae*, and *Tricholomatineae* (*Agaricales*). *Fungal Diversity* 132:127–150

[17] Wang GS, Cai Q, Hao YJ, Bau T, Chen ZH, et al. 2024. Phylogenetic and taxonomic updates of Agaricales, with an emphasis on *Tricholomopsis*. *Mycology* 15(2):180–209

[18] Murrill WA. 1941. More Florida novelties. *Mycologia* 33:434–448

[19] Patouillard NT. 1924. Basidiomycetes nouveaux de Madagascar. *Bulletin du Muséum d'Histoire Naturelle Paris* 30:526–532

[20] Corner EJH. 1950. A monograph of *Clavaria* and allied genera. *Annals of Botany Memoirs* 1:1–740

[21] Coker WC. 1923. The *Clavarias* of the United States and Canada. North Carolina: The University of North Carolina Press. 206 pp

[22] Quélet L. 1884. Quelques especes critiques ou nouvelles de la Flore Mycologique de France. *Comptes Rendus de la Association Française pour l'Avancement des Sciences* 12:498–512

[23] Li JP, Li Y, Li TH, Antonín V, Hosen, MI, et al. 2021. A preliminary report of *Gymnopus* sect. *Impudicae* (Omphalotaceae) from China. *Phytotaxa* 497(3):263–276

[24] Cooper JA, Leonard P. 2013. Three new species of foetid *Gymnopus* in New Zealand. *MycoKeys* 7:31–44

[25] Hu JJ, Song LR, Tuo YL, Zhao GP, Yue L, et al. 2022. Multiple evidences reveal new species and a new record of smelly *Gymnopus* (Agaricales, Omphalotaceae) from China. *Frontiers in Microbiology* 13:968617

[26] Ryoo R, Antonín V, Ka KH, Tomšovský M. 2016. Marasmioid and gymnopoid fungi of the Republic of Korea. 8. *Gymnopus* section *Impudicae*. *Phytotaxa* 286(2):75–88

[27] Halling RE. 1983. The genus *Collybia* (Agaricales) in the Northeastern United States and adjacent Canada. *Mycologia Memoir* 8:1–148

[28] Antonín V, Noordeloos ME. 1996. *Gymnopus herinkii* spec. nov. : a critical review of the complex of *Agaricus porreus* and *A. prasiosmus*. *Czech Mycology* 48(4):309–313

[29] Li JP, Pan MC, Li Y, Deng CY, Wang XM, et al. 2022. Morpho–molecular evidence reveals four novel species of *Gymnopus* (Agaricales, Omphalotaceae) from China. *Journal of Fungi* 8(4):398

[30] Corner EJH. 1966. *A monograph of cantharelloid fungi*. London: Oxford University Press. 255 pp

[31] Petersen RH, Hughes KW. 2019. Two additional species of *Gymnopus* (Euagarics, Basidiomycotina). *MycoKeys* 45:1–24

[32] Corner EJH. 1996. The agaric genera *Marasmius, Chaetocalathus, Crinipellis, Heimiomyces, Resupinatus, Xerula*, and *Xerulina* in Malesia. *Nova Hedwigia* 111:1–175

[33] Wilson AW, Desjardin DE, Horak E. 2004. Agaricales of Indonesia. 5. The genus *Gymnopus* from Java and Bali. *Sydowia* 56:137–210

[34] Hu JJ, Tuo YL, Qi ZX, Li XF, Jiang DH, et al. 2024. The combination of morphological and phylogenetic evidence reveals four new *Gymnopus* species and new distribution. *Journal of Fungi* 10(10):672

[35] Coimbra VR, Pinheiro FG, Wartchow F, Gibertoni TB. 2015. Studies on *Gymnopus* sect. *Impudicae* (Omphalotaceae, Agaricales) from Northern Brazil: two new species and notes on *G. montagnei*. *Mycological Progress* 14(11):110

[36] Desjardin DE. 1987. New and Noteworthy Marasmioid Fungi from California. *Mycologia* 79(1):123–134

[37] Vizzini A, Antonin V, Sesli E, Contu M. 2015. *Gymnopus trabzonensis* sp. nov. (Omphalotaceae) and *Tricholoma virgatum* var. *fulvoumbonatum* var. nov. (Tricholomataceae), two new white-spored agarics from Turkey. *Phytotaxa* 226(2):119–130

[38] Qasmi AB, Izhar A, Khalid AN. 2025. *Gymnopus violaceigregarius* (Omphalotaceae, Agaricales, Basidiomycota): a new species from Pakistan. *Phytotaxa* 715(3):245–259

[39] Borgen T, Senn-Irlet B. 1995. *Hygrocybe glacialis* spec. nov. and notes on subsection Squamulosae based on collections from Switzerland. *Documents mycologiques* 25(98–100):91–102

[40] Boertmann D. 2010. The Genus *Hygrocybe*. In *Fungi of Northern Europe*. 2nd Revised Edition. Vol. 1. Copenhagen: Svampetryk. 200 pp

[41] Murrill WA. 1943. Some Southern Novelties. *Mycologia* 35(4):422–433

[42] Montagne JPFC. 1835. Prodromus florae fernandesianae. Pars prima sistens enumerationem plantarum cellularium quas in insula Juan Fernandez a Cl. Bertero collectas describi edique curavit. *Annales des Sciences Naturelles Botanique* 2(3):347–356

[43] Singer R. 1973. A monograph of the Neotropical species of *Marasmiellus*. *Beih Nova Hedwigia* 44:1−339
[44] Desjardin DE. 1985. New marasmioid fungi from California. *Mycologia* 77(6):894−902
[45] Petersen RH, Hughes KW. 2017. An investigation on *Mycetinis* (Euagarics, Basidiomycota). *MycoKeys* 24:1−138
[46] Desjardin DE, Perry BA. 2017. The gymnopoid fungi (Basidiomycota, Agaricales) from the Republic of São Tomé and Príncipe, West Africa. *Mycosphere* 8(9):1317−1391
[47] Britzelmayr M. 1896. Materialien zur Beschreibung der Hymenomyceten 7. *Botanisches Centralblatt* 68:137−145
[48] Smith AH, Weber NS. 1980. The Mushroom Hunter's Field Guide. Ann Arbor: University of Michigan Press. 161 pp
[49] Ainsworth M. 2005. Identifying important sites for beech deadwood fungi. *Field Mycology* 6(2):41−61
[50] Index Fungorum. 2025. *Index Fungorum. The Royal Botanic Gardens, Kew*. www.indexfungorum.org (Accessed on October 31, 2025)
[51] Larsson KH. 2007. Re-thinking the classification of corticioid fungi. *Mycological research* 111(9):1040−1063
[52] Dong JH, Chen ML, Chen M, Li Q, Zhu YJ, et al. 2025. Notes, outline, taxonomy and phylogeny of wood-inhabiting Agaricales. *Mycosphere* 16(1):2599−2711
[53] Petersen RH, Hughes KW. 2014. New *Gymnopus* species from North America. *North American Fungi* 9(3):1−22
[54] Manawasinghe IS, Calabon MS, Jones EBG, Zhang YX, Liao CF, et al. 2022. Mycosphere notes 345−386. *Mycosphere* 13(1):454−557
[55] Crous PW, Wingfield MJ, Burgess TI, Hardy G, Crane C, et al. 2016. Fungal Planet description sheets: 469–557. *Persoonia* 37:218−403
[56] Liu S, Pan M, Cui BK, Zhu B. 2025. Catalogue of fungi in China 5. Preliminary survey of macrofungi in Medog, Southwest China. *Mycology* 16(4):1589−1636
[57] Mao N, Liu H, Fan L. 2022. *Gymnopus wutaishanensis* (Omphalotaceae, Agaricales) a new species from North China. *Phytotaxa* 556(1):63−75
[58] Nagy LG, Branco S, Floudas D, Hibbett DS, Lofgren L, et al. 2026. The biodiversity, genomics, ecology and evolution of mushroom-forming fungi. *Nature Reviews Biodiversity* 2:24−39
[59] Birkebak JM, Mayor JR, Ryberg M, Matheny PB. 2013. A systematic, morphological, and ecological overview of the Clavariaceae (Agaricales). *Mycologia* 105:896−911
[60] Koch RA, Lodge DJ, Sourell S, Nakasone K, McCoy AG, et al. 2018. Tying up loose threads: revised taxonomy and phylogeny of an avian-dispersed Neotropical rhizomorph-forming fungus. *Mycological Progress* 17(9):989−998
[61] Nakasone KK, Hibbett DS, Goranova G. 2009. *Neocampanella*, a new corticioid fungal genus, and a note on *Dendrothele bispora*. *Botany* 87(9):875−882
[62] Wu SH, Wang DM, Tschen E. 2007. *Brunneocorticium pyriforme*, a new corticioid fungal genus and species belonging to the euagarics clade. *Mycologia* 99(2):302−309
[63] Ke HM, Lee HH, Lin CYI, Liu YC, Lu MR, et al. 2020. *Mycena* genomes resolve the evolution of fungal bioluminescence. *Proceedings of the National Academy of Sciences of the United States of America* 117(49):31267−31277