

# Taxonomy and phylogeny of the brown-rot fungi: *Fomitopsis* and its related genera

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**Abstract** Taxonomic and phylogenetic studies on the brown-rot fungi, *Fomitopsis* and its related genera, are carried out. On the basis of morphological characters and phylogenetic evidence of DNA sequences of multiple loci including the internal transcribed spacer (ITS) regions, the large subunit nuclear ribosomal RNA gene (nLSU), the small subunit nuclear ribosomal RNA gene (nSSU), the small subunit mitochondrial rRNA gene sequences (mtSSU), the translation elongation factor 1- $\alpha$  gene (*tefl*) and the second subunit of RNA polymerase II (*rpb2*), six new genera, *Fragifomes*, *Niveoporofomes*, *Piptoporellus*, *Rhodofomitopsis*, *Rubellofomes* and *Ungulidaedalea* are established. Four new species, *Buglossoporus eucalypticola*, *Daedalea allantoidea*, *Piptoporellus hainanensis* and *P. triqueter* are described from China. Illustrated descriptions of the novel species are provided. Identification keys to *Fomitopsis* and its related genera, as well as keys to the species of each genus are provided.

**Keywords** Fomitopsidaceae · Multi-marker analysis · Phylogeny · Polypore · Systematics

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Mei-Ling Han and Yuan-Yuan Chen contributed equally to this work.

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## Introduction

*Fomitopsis* P. Karst. was established by Karsten and typified by *F. pinicola* (Sw.) P. Karst. (Karsten 1881a). It is a well-known cosmopolitan genus of polypores belonging to the antrodia clade (Ortiz-Santana et al. 2013) and includes brown rotting fungi with a dimitic hyphal system (Gilbertson and Ryvarden 1986a; Núñez and Ryvarden 2001; Ryvarden and Melo 2014). The genus is characterized by mostly perennial, sessile to effused-reflexed, tough to woody hard basidiocarps, white to tan or pinkish-colored pore surface with mostly small and regular pores, a dimitic hyphal system with clamped generative hyphae, hyaline, thin-walled, smooth, subglobose to cylindrical basidiospores which are negative in Melzer's reagent, and causing a brown rot (Ryvarden and Johansen 1980; Gilbertson and Ryvarden 1986a; Núñez and Ryvarden 2001; Ryvarden and Melo 2014; Han and Cui 2015). More than 40 species have been accepted in the genus worldwide (Ryvarden and Johansen 1980; Gilbertson and Ryvarden 1986a; Rajchenberg 1995a; Núñez and Ryvarden 2001; Hattori 2003; Kim et al. 2007; Hattori and Sotome 2013; Ryvarden and Melo 2014; Han and Cui 2015), of which 14 species are recorded from China (Dai 2012; Zhou and Wei 2012; Li et al. 2013; Han et al. 2014; Han and Cui 2015).

Recently, several studies on the taxonomy and phylogeny of *Fomitopsis* were carried out, phylogenetic studies showed that *Fomitopsis* was embedded in the antrodia clade and closely related to *Daedalea* Pers., *Piptoporus* P. Karst. and some species of *Antrodia* P. Karst. Kim et al. (2005) sequenced the nLSU regions from 10 species of *Fomitopsis* and 15 related species, their phylogenetic analysis indicated that *Fomitopsis* and *Piptoporus* were phylogenetically heterogeneous and members in *Fomitopsis* were divided into three subgroups, among them, *P. betulinus* (Bull.) P. Karst. and *D. quercina* (L.) Pers. were included in *Fomitopsis* core group

and some *Antrodia* species were included in *F. rosea* (Alb. & Schwein.) P. Karst. and *F. cajanderi* (P. Karst.) Kotl. & Pouzar group. Ortiz-Santana et al. (2013) investigated the phylogenetic relationships among members of the antrodia clade by molecular data from ITS and nLSU regions, in their study, *Fomitopsis* were divided into five groups, their study supported the polyphyly of *Fomitopsis* and the transfer of the rosea clade (including *F. rosea* and *F. cajanderi*) into the genus *Rhodofomes*, and confirmed the placement of *P. betulinus* within *Fomitopsis sensu stricto* as reported in previous studies (Hibbett and Binder 2002; Binder et al. 2005; Garcia-Sandoval et al. 2011). However, no comprehensive investigation was carried out on a broad phylogenetic overview of *Fomitopsis* with enough samples from relevant genera, such as *Daedalea* and *Piptoporus*, and taxonomic delimitation of *Fomitopsis* has been controversial and remained insufficiently resolved (Kotlába and Pouzar 1998; Kim et al. 2005, 2007; Ortiz-Santana et al. 2013). So, further phylogenetic analyses sampling more species are needed to clarify the relationships of *Fomitopsis* and its related genera.

## Materials and methods

### Morphological studies

The studied specimens are deposited at the herbaria of the Institute of Microbiology, Beijing Forestry University, China (BJFC), the Institute of Applied Ecology, Chinese Academy of Sciences, China (IFP), the private herbarium of Dr. J. Vlasák of Czech Republic (JV), the Botanical Museum of the University of Oslo, Norway (O), Université Claude Bernard, France (LY), Botanical Museum of University of Helsinki, Finland (H), Royal Botanic Gardens, Kew, UK (K), Botanic Garden Edinburgh, UK (E), Universidad de Buenos Aires, Argentina (BAFC) and the Pennsylvania State University, USA (PAC). The microscopic routines followed Zhao et al. (2013) and Li et al. (2014). Sections were studied at a magnification up to  $\times 1000$  using a Nikon E80i microscope and phase contrast illumination (Nikon, Tokyo, Japan). Drawings were made with the aid of a drawing tube. Microscopic features, measurements and drawings were made from slide preparations stained with Cotton Blue and Melzer's reagent. Spores were measured from sections cut from the tubes. In presenting the variation in the size of the spores, 5 % of measurements were given in parentheses. In the text the following abbreviations were used: IKI = Melzer's reagent, IKI+ = amyloid, IKI- = non-dextrinoid and non-amyloid, KOH = 5 % potassium hydroxide, CB = Cotton Blue, CB+ = cyanophilous, CB- = acyanophilous, L = mean spore length (arithmetic average of all spores), W = mean spore width (arithmetic average of all spores), Q = variation in the L/W ratios between the specimens studied, n = number of

spores measured from given number of specimens. Special color terms followed Petersen (1996).

### Phylogenetic analysis

A cetyl trimethylammonium bromide rapid plant genome extraction kit (Aidlab Biotechnologies Co., Ltd, Beijing) was used to extract total genomic DNA from dried specimens, and performed the polymerase chain reaction (PCR) according to the manufacturer's instructions with some modifications (Chen et al. 2015a; Zhao et al. 2015a). The ITS regions were amplified with primer pairs ITS5 and ITS4 (White et al. 1990). The nLSU regions were amplified with primer pairs LR0R and LR7 (<http://www.biology.duke.edu/fungi/mycolab/primers.htm>). The nSSU regions were amplified with primer pairs NS1 and NS4 (White et al. 1990). The mtSSU regions were amplified with primer pairs MS1 and MS2 (White et al. 1990). Part of *tefl* was amplified with primer pairs EF1-983 F and EF1-1567R (Rehner 2001). *rpb2* was amplified with primer pairs bRPB2-6 F and bRPB2-7R (Matheny 2005). The PCR cycling schedule for ITS, mtSSU, and *tefl* included an initial denaturation at 95 °C for 3 min, followed by 35 cycles at 94 °C for 40 s, 54 °C for ITS and mtSSU, 54–59 °C for *tefl* for 45 s, 72 °C for 1 min, and a final extension at 72 °C for 10 min. The PCR cycling schedule for nLSU and nSSU included an initial denaturation at 94 °C for 1 min, followed by 35 cycles at 94 °C for 30 s, 50 °C for nLSU and 53 °C for nSSU for 1 min, 72 °C for 1.5 min, and a final extension at 72 °C for 10 min. The PCR cycling schedule for *rpb2* followed Kim et al. (2007) with slight modifications: initial denaturation at 95 °C for 10 min, followed by 39 cycles at 94 °C for 1 min, 56 °C for 1 min and 72 °C for 1 min + 3 s/cycle, and a final extension at 72 °C for 10 min. The PCR products were purified and sequenced at Beijing Genomics Institute (China), with the same primers. All newly generated sequences were deposited at GenBank (Table 1).

Additional sequences were downloaded from GenBank (Table 1). All sequences were aligned using ClustalX (Thompson et al. 1997) and manually adjusted in BioEdit (Hall 1999). The missing sequences were coded as "N". Ambiguous nucleotides were coded as "N". The final concatenated sequence alignment was deposited in TreeBase (<http://purl.org/phylo/treebase>; submission ID 18345).

Most parsimonious phylogenies were inferred from the combined 3-gene dataset (ITS + nLSU + *rpb2*) and 6-gene dataset (ITS + nLSU + nSSU + mtSSU + *tefl* + *rpb2*), and their congruences were evaluated with the incongruence length difference (ILD) test (Farris et al. 1994) implemented in PAUP\* 4.0b10 (Swofford 2002), under heuristic search and 1000 homogeneity replicates. Phylogenetic analysis approaches followed Zhao et al. (2014, 2015b). Sequences of *Trametes suaveolens* (L.) Fr. and *Coriolopsis polyzona* (Pers.) Ryvarden

**Table 1** A list of species, specimens and GenBank accession numbers of sequences used in this study

Species name	Sample no.	Locality	GenBank accession numbers					References	
			ITS	nLSU	nSSU	mtSSU	<i>tef1</i>		<i>rpb2</i>
<i>Amylocystis lapponica</i>	HHB-13400-Sp	USA	KC585237	KC585059	–	–	–	–	Ortiz-Santana et al. 2013
<i>A. lapponica</i>	OKM-4418-Sp	USA	KC585238	KC585060	–	–	–	–	Ortiz-Santana et al. 2013
<i>Amyloporia carbonica</i>	Cui 12212	China	KR605816 <sup>a</sup>	KR605755 <sup>a</sup>	KR605917 <sup>a</sup>	KR606017 <sup>a</sup>	KR610745 <sup>a</sup>	–	this study
<i>A. subxantha</i>	Cui 10573	China	KC951150	KT968825 <sup>a</sup>	–	–	–	KT895896 <sup>a</sup>	Cui and Dai 2013
<i>A. subxantha</i>	Cui 10588	China	KC951151	KT968826 <sup>a</sup>	–	–	–	KT895897 <sup>a</sup>	Cui and Dai 2013
<i>A. xantha</i>	Cui 9901	China	KC951168	KT968827 <sup>a</sup>	–	–	–	KT895898 <sup>a</sup>	Cui and Dai 2013
<i>A. xantha</i>	Cui 11544	China	KR605817 <sup>a</sup>	KR605756 <sup>a</sup>	KR605918 <sup>a</sup>	KR606018 <sup>a</sup>	KR610746 <sup>a</sup>	KR610836 <sup>a</sup>	this study
<i>A. xantha</i>	Cui 11677	China	KR605818 <sup>a</sup>	KR605757 <sup>a</sup>	KR605919 <sup>a</sup>	–	KR610747 <sup>a</sup>	KR610837 <sup>a</sup>	this study
<i>Antrodia heteromorpha</i>	CBS 200.91	Canada	DQ491415	–	–	–	–	DQ491388	Kim et al. 2007
<i>A. heteromorpha</i>	Dai 12742	USA	KP715319	–	–	–	–	KT895887 <sup>a</sup>	Chen and Cui 2015
<i>A. heteromorpha</i>	Dai 12755	USA	KP715306	KP715322	KR605908 <sup>a</sup>	KR606009 <sup>a</sup>	KP715336	KR610828 <sup>a</sup>	Chen and Cui 2015
<i>A. juniperina</i>	WM-284 T	Unknown	EU232212	EU232295	–	–	–	–	Ortiz-Santana et al. 2013
<i>A. juniperina</i>	CBS 117.40	USA	DQ491416	AY515346	–	–	–	DQ491389	Kim et al. 2007
<i>A. macra</i>	Eriksson 1967	Unknown	KR605810 <sup>a</sup>	KR605749 <sup>a</sup>	KR605909 <sup>a</sup>	–	KR610739 <sup>a</sup>	–	this study
<i>A. malicola</i>	Cui 9491	China	KT968824 <sup>a</sup>	KT968828 <sup>a</sup>	–	–	–	KT988994 <sup>a</sup>	this study
<i>A. malicola</i>	X1016	China	KC595896	KC595896	–	–	–	–	Ortiz-Santana et al. 2013
<i>A. malicola</i>	X1382	Russia	JQ700282	JQ700282	–	–	–	–	Ortiz-Santana et al. 2013
<i>A. serialis</i>	CBS 306.82	Germany	DQ491417	–	–	–	–	DQ491390	Kim et al. 2007
<i>A. serialis</i>	Cui 9706	China	KR605811 <sup>a</sup>	KR605750 <sup>a</sup>	KR605910 <sup>a</sup>	KR606010 <sup>a</sup>	KR610741 <sup>a</sup>	KR610829 <sup>a</sup>	this study
<i>A. serialis</i>	Cui 10519	China	KP715307	KP715323	KR605911 <sup>a</sup>	KR606011 <sup>a</sup>	KP715337	KR610830 <sup>a</sup>	this study
<i>A. serialis</i>	Dai 7626	China	KR605812 <sup>a</sup>	KR605751 <sup>a</sup>	KR605912 <sup>a</sup>	KR606012 <sup>a</sup>	KR610740 <sup>a</sup>	KR610831 <sup>a</sup>	this study
<i>A. serpens</i>	Dai 7465	China	KR605813 <sup>a</sup>	KR605752 <sup>a</sup>	KR605913 <sup>a</sup>	KR606013 <sup>a</sup>	KR610742 <sup>a</sup>	KR610832 <sup>a</sup>	this study
<i>A. subserpens</i>	Cui 8310	China	KP715310	KP715326	–	–	–	KT895888 <sup>a</sup>	Chen and Cui 2015
<i>A. subserpens</i>	Dai 13233	China	KP715309	KP715325	–	–	–	KT895889 <sup>a</sup>	Chen and Cui 2015
<i>A. tanakae</i>	Cui 9743	China	KR605814 <sup>a</sup>	KR605753 <sup>a</sup>	KR605914 <sup>a</sup>	KR606014 <sup>a</sup>	KR610743 <sup>a</sup>	KR610833 <sup>a</sup>	this study
<i>A. tanakae</i>	Dai 11770	China	KR605815 <sup>a</sup>	KR605754 <sup>a</sup>	KR605915 <sup>a</sup>	KR606015 <sup>a</sup>	KR610744 <sup>a</sup>	KR610834 <sup>a</sup>	this study
<i>A. tanakae</i>	Yuan 1106	China	KP715313	KP715329	KR605916 <sup>a</sup>	KR606016 <sup>a</sup>	KP715343	KR610835 <sup>a</sup>	this study
<i>A. variiformis</i>	CBS 309.82	USA	DQ491418	AY515344	–	–	–	DQ491391	Kim et al. 2007
<i>A. variiformis</i>	FP-90100-SP	USA	KC585311	KC585136	–	–	–	–	Ortiz-Santana et al. 2013
<i>Auriporia aurea</i>	FP-98524	USA	KC585316	KC585141	–	–	–	–	Ortiz-Santana et al. 2013
<i>A. aurulenta</i>	HHB-8864	USA	KC585317	KC585142	–	–	–	–	Ortiz-Santana et al. 2013
<i>Buglossoporus eucalypticola</i>	Dai 13660	China	KR605808 <sup>a</sup>	KR605747 <sup>a</sup>	KR605906 <sup>a</sup>	KR606007 <sup>a</sup>	KR610736 <sup>a</sup>	KR610825 <sup>a</sup>	this study
<i>B. eucalypticola</i>	Dai 13660A	China	KR605809 <sup>a</sup>	KR605748 <sup>a</sup>	KR605907 <sup>a</sup>	KR606008 <sup>a</sup>	KR610737 <sup>a</sup>	KR610826 <sup>a</sup>	this study

Table 1 (continued)

Species name	Sample no.	Locality	GenBank accession numbers							References
			ITS	nLSU	nSSU	mtSSU	<i>tef1</i>	<i>rpb2</i>		
<i>B. quercinus</i>	JV 0906/15-J	USA	KR605800 <sup>a</sup>	KR605739 <sup>a</sup>	KR605898 <sup>a</sup>	KR606001 <sup>a</sup>	KR610729 <sup>a</sup>	KR610819 <sup>a</sup>	this study	
<i>B. quercinus</i>	JV 1406/1	Czech Republic	KR605801 <sup>a</sup>	KR605740 <sup>a</sup>	KR605899 <sup>a</sup>	KR606002 <sup>a</sup>	KR610730 <sup>a</sup>	KR610820 <sup>a</sup>	this study	
<i>B. quercinus</i>	LY BR 2030	France	KR605799 <sup>a</sup>	KR605738 <sup>a</sup>	KR605897 <sup>a</sup>	KR606000 <sup>a</sup>	KR610728 <sup>a</sup>	KR610818 <sup>a</sup>	this study	
<i>Coriopsis polyzona</i>	Cui 11040	China	KR605824 <sup>a</sup>	KR605767 <sup>a</sup>	KR605932 <sup>a</sup>	KR606029 <sup>a</sup>	KR610760 <sup>a</sup>	KR610849 <sup>a</sup>	this study	
<i>Crustoderma dryinum</i>	FP-105487-Sp	USA	KC585320	KC585145	–	–	–	–	Ortiz-Santana et al. 2013	
<i>C. dryinum</i>	HHB-1290-Sp	USA	KC585321	KC585146	–	–	–	–	Ortiz-Santana et al. 2013	
<i>C. dryinum</i>	HHB-7517-Sp	USA	KC585322	KC585147	–	–	–	–	Ortiz-Santana et al. 2013	
<i>Daeryobolus sudans</i>	FP-100190-Sp	USA	KC585331	KC585156	–	–	–	–	Ortiz-Santana et al. 2013	
<i>D. sudans</i>	FP-101996-Sp	USA	KC585332	KC585157	–	–	–	–	Ortiz-Santana et al. 2013	
<i>D. sudans</i>	FP-150381	Jamaica	KC585333	KC585158	–	–	–	–	Ortiz-Santana et al. 2013	
<i>Daedalea africana</i>	O 15372	Kenya	KP171196	KP171216	KR605871 <sup>a</sup>	KR605974 <sup>a</sup>	KR610704 <sup>a</sup>	KR610795 <sup>a</sup>	Han et al. 2015	
<i>D. allantoides</i>	Dai 13612A	China	KR605795 <sup>a</sup>	KR605734 <sup>a</sup>	KR605892 <sup>a</sup>	KR605995 <sup>a</sup>	KR610723 <sup>a</sup>	KR610813 <sup>a</sup>	this study	
<i>D. americana</i>	JV 0312/24-7-J	USA	KP171197	KP171217	KR605872 <sup>a</sup>	KR605975 <sup>a</sup>	KR610705 <sup>a</sup>	KR610796 <sup>a</sup>	Han et al. 2015	
<i>D. americana</i>	JV 0909/19	USA	KP171198	KP171218	KR605873 <sup>a</sup>	KR605976 <sup>a</sup>	KR610706 <sup>a</sup>	KR610797 <sup>a</sup>	Han et al. 2015	
<i>D. americana</i>	JV 0909/20	USA	KP171199	KP171219	KR605874 <sup>a</sup>	KR605977 <sup>a</sup>	KR610707 <sup>a</sup>	KR610798 <sup>a</sup>	Han et al. 2015	
<i>D. circularis</i>	Cui 10125	China	JQ780411	KP171220	KR605875 <sup>a</sup>	KR605978 <sup>a</sup>	KR610708 <sup>a</sup>	KR610799 <sup>a</sup>	Li and Cui 2013	
<i>D. circularis</i>	Cui 10134	China	JQ314352	KP171221	KR605876 <sup>a</sup>	KR605979 <sup>a</sup>	KR610709 <sup>a</sup>	KR610800 <sup>a</sup>	Li and Cui 2013	
<i>D. circularis</i>	Dai 13062	China	KP171200	KP171222	KR605877 <sup>a</sup>	KR605980 <sup>a</sup>	KR610710 <sup>a</sup>	KR610801 <sup>a</sup>	Han et al. 2015	
<i>D. dochmia</i>	CBS 426.84	Thailand	DQ491401	AY515326	–	DQ491428	–	DQ491374	Kim et al. 2007	
<i>D. dickinsii</i>	Yuan 1090	China	KR605790 <sup>a</sup>	KR605729 <sup>a</sup>	KR605878 <sup>a</sup>	KR605981 <sup>a</sup>	KR610711 <sup>a</sup>	KR610802 <sup>a</sup>	this study	
<i>D. dickinsii</i>	Yuan 2685	China	KP171201	KP171223	KR605879 <sup>a</sup>	KR605982 <sup>a</sup>	KR610712 <sup>a</sup>	KR610803 <sup>a</sup>	Han et al. 2015	
<i>D. dickinsii</i>	Yuan 2707	China	KP171202	KP171224	KR605880 <sup>a</sup>	KR605983 <sup>a</sup>	KR610713 <sup>a</sup>	KR610804 <sup>a</sup>	Han et al. 2015	
<i>D. hydroides</i>	O 14083	Costa Rica	KP171203	KP171225	KR605881 <sup>a</sup>	KR605984 <sup>a</sup>	–	–	Han et al. 2015	
<i>D. modesta</i>	Cui 10124	China	KR605791 <sup>a</sup>	KR605730 <sup>a</sup>	KR605882 <sup>a</sup>	KR605985 <sup>a</sup>	KR610715 <sup>a</sup>	KR610805 <sup>a</sup>	this study	
<i>D. modesta</i>	Cui 10151	China	KP171205	KP171227	KR605883 <sup>a</sup>	KR605986 <sup>a</sup>	KR610716 <sup>a</sup>	KR610806 <sup>a</sup>	Han et al. 2015	
<i>D. modesta</i>	Dai 10844	China	KP171206	KP171228	KR605884 <sup>a</sup>	KR605987 <sup>a</sup>	KR610714 <sup>a</sup>	KR610807 <sup>a</sup>	Han et al. 2015	
<i>D. neotropica</i>	DLC04-80	Belize	FJ403217	–	–	–	–	–	Lindner et al. 2011	
<i>D. neotropica</i>	DLC04-100	Belize	FJ403218	–	–	–	–	–	Lindner et al. 2011	
<i>D. neotropica</i>	DLC04-174	Belize	FJ403219	–	–	–	–	–	Lindner et al. 2011	
<i>D. pseudodothmia</i>	10533	China	FJ403210	–	–	–	–	–	Lindner et al. 2011	
<i>D. quercina</i>	Dai 2260	Sweden	KR605792 <sup>a</sup>	KR605731 <sup>a</sup>	KR605885 <sup>a</sup>	KR605988 <sup>a</sup>	KR610718 <sup>a</sup>	KR610808 <sup>a</sup>	this study	
<i>D. quercina</i>	Dai 12152	Czech Republic	KP171207	KP171229	KR605886 <sup>a</sup>	KR605989 <sup>a</sup>	KR610717 <sup>a</sup>	KR610809 <sup>a</sup>	Han et al. 2015	

Table 1 (continued)

Species name	Sample no.	Locality	GenBank accession numbers							References
			ITS	nLSU	nSSU	mtSSU	<i>tefl</i>	<i>rpb2</i>		
<i>D. quercina</i>	Dai 12659	Finland	KP171208	KP171230	KR605887 <sup>a</sup>	KR605990 <sup>a</sup>	KR610719 <sup>a</sup>	KR610810 <sup>a</sup>	Han et al. 2015	
<i>D. radiata</i>	Cui 8575	China	KP171210	KP171233	KR605888 <sup>a</sup>	KR605991 <sup>a</sup>	KR610720 <sup>a</sup>	KR610811 <sup>a</sup>	Han et al. 2015	
<i>D. radiata</i>	Cui 8624	China	KR605793 <sup>a</sup>	KR605732 <sup>a</sup>	KR605889 <sup>a</sup>	KR605992 <sup>a</sup>	KR610721 <sup>a</sup>	–	this study	
<i>D. sprucei</i>	O 10546	Taiwan	KR605794 <sup>a</sup>	KR605733 <sup>a</sup>	KR605890 <sup>a</sup>	KR605993 <sup>a</sup>	KR610722 <sup>a</sup>	KR610812 <sup>a</sup>	this study	
<i>D. stereoides</i>	10551	Ethiopia	FJ403215	–	–	–	–	–	Lindner et al. 2011	
<i>D. stevensonii</i>	O 10543	Borneo	KP171212	KP171235	KR605891 <sup>a</sup>	KR605994 <sup>a</sup>	–	–	Han et al. 2015	
<i>Fibroporia albicans</i>	Cui 9464	China	KC456250	KR605758 <sup>a</sup>	KR605920 <sup>a</sup>	KR606019 <sup>a</sup>	KR610748 <sup>a</sup>	KR610838 <sup>a</sup>	Chen et al. 2015b	
<i>F. albicans</i>	Dai 10595	China	KC456249	KR605759 <sup>a</sup>	KR605921 <sup>a</sup>	KR606020 <sup>a</sup>	KR610749 <sup>a</sup>	KR610839 <sup>a</sup>	Chen et al. 2015b	
<i>F. radiculosa</i>	Cui 2790	China	KC456248	KR605761 <sup>a</sup>	KR605923 <sup>a</sup>	KR606022 <sup>a</sup>	KR610751 <sup>a</sup>	–	Chen et al. 2015b	
<i>F. radiculosa</i>	Cui 11404	China	KP145011	KR605760 <sup>a</sup>	KR605922 <sup>a</sup>	KR606021 <sup>a</sup>	KR610750 <sup>a</sup>	KR610840 <sup>a</sup>	Chen et al. 2015b	
<i>F. vaillantii</i>	Cui 10497	China	KT895886 <sup>a</sup>	KT988993 <sup>a</sup>	–	–	–	KT895903 <sup>a</sup>	this study	
<i>Fomitopsis betulinus</i>	Cui 10309	China	KR605796 <sup>a</sup>	KR605735 <sup>a</sup>	KR605893 <sup>a</sup>	KR605996 <sup>a</sup>	KR610727 <sup>a</sup>	KR610814 <sup>a</sup>	this study	
<i>F. betulina</i>	Cui 10756	China	KR605797 <sup>a</sup>	KR605736 <sup>a</sup>	KR605894 <sup>a</sup>	KR605997 <sup>a</sup>	KR610725 <sup>a</sup>	KR610815 <sup>a</sup>	this study	
<i>F. betulina</i>	Dai 11449	China	KR605798 <sup>a</sup>	KR605737 <sup>a</sup>	KR605895 <sup>a</sup>	KR605998 <sup>a</sup>	KR610726 <sup>a</sup>	KR610816 <sup>a</sup>	this study	
<i>F. betulina</i>	Dai 12665	China	KP171215	KP171238	KR605896 <sup>a</sup>	KR605999 <sup>a</sup>	KR610724 <sup>a</sup>	KR610817 <sup>a</sup>	Han et al. 2015	
<i>F. cana</i>	Cui 6239	China	JX435777	JX435775	KR605826 <sup>a</sup>	KR605934 <sup>a</sup>	KR610661 <sup>a</sup>	KR610761 <sup>a</sup>	Li et al. 2013	
<i>F. cana</i>	Dai 9611	China	JX435776	JX435774	KR605825 <sup>a</sup>	KR605933 <sup>a</sup>	KR610660 <sup>a</sup>	KR610762 <sup>a</sup>	Li et al. 2013	
<i>F. durescens</i>	Overholts 4215	USA	KF937293	KF937295	KR605835 <sup>a</sup>	KR605941 <sup>a</sup>	–	–	Han et al. 2014	
<i>F. durescens</i>	O 10796	Venezuela	KF937292	KF937294	KR605834 <sup>a</sup>	KR605940 <sup>a</sup>	KR610669 <sup>a</sup>	KR610766 <sup>a</sup>	Han et al. 2014	
<i>F. hemitephra</i>	O 10808	Australia	KR605770 <sup>a</sup>	KR605709 <sup>a</sup>	KR605841 <sup>a</sup>	KR605947 <sup>a</sup>	KR610675 <sup>a</sup>	–	this study	
<i>F. iberica</i>	O 10810	Portugal	KR605771 <sup>a</sup>	KR605710 <sup>a</sup>	KR605842 <sup>a</sup>	KR605948 <sup>a</sup>	KR610676 <sup>a</sup>	KR610771 <sup>a</sup>	this study	
<i>F. iberica</i>	O 10811	Italy	KR605772 <sup>a</sup>	KR605711 <sup>a</sup>	KR605843 <sup>a</sup>	–	KR610677 <sup>a</sup>	KR610772 <sup>a</sup>	this study	
<i>F. meliae</i>	Dai 10035	China	KR605774 <sup>a</sup>	KR605713 <sup>a</sup>	KR605847 <sup>a</sup>	KR605952 <sup>a</sup>	KR610683 <sup>a</sup>	–	this study	
<i>F. meliae</i>	Roberts GA863	United Kingdom	KR605775 <sup>a</sup>	KR605714 <sup>a</sup>	KR605848 <sup>a</sup>	KR605953 <sup>a</sup>	KR610682 <sup>a</sup>	–	this study	
<i>F. meliae</i>	Ryvarden 16893	Unknown	KR605776 <sup>a</sup>	KR605715 <sup>a</sup>	KR605849 <sup>a</sup>	KR605954 <sup>a</sup>	KR610681 <sup>a</sup>	KR610775 <sup>a</sup>	this study	
<i>F. nivosa</i>	JV 0509/52-X	China	KR605779 <sup>a</sup>	KR605718 <sup>a</sup>	KR605853 <sup>a</sup>	KR605957 <sup>a</sup>	KR610686 <sup>a</sup>	KR610777 <sup>a</sup>	this study	
<i>F. ostreiformis</i>	BCC 23382	Thailand	DQ491403	–	–	–	–	–	Kim et al. 2007	
<i>F. ostreiformis</i>	Miettinen XI1405	Indonesia	KC595919	–	–	–	–	–	Ortiz-Santana et al. 2013	
<i>F. ostreiformis</i>	Miettinen XI1393	Indonesia	KC595918	–	–	–	–	–	Ortiz-Santana et al. 2013	
<i>F. palustris</i>	Cui 7597	China	KP171213	KP171236	KR605854 <sup>a</sup>	KR605958 <sup>a</sup>	KR610687 <sup>a</sup>	KR610778 <sup>a</sup>	Han et al. 2015	
<i>F. palustris</i>	Cui 7615	China	KR605780 <sup>a</sup>	KR605719 <sup>a</sup>	KR605855 <sup>a</sup>	KR605959 <sup>a</sup>	KR610688 <sup>a</sup>	KR610779 <sup>a</sup>	this study	
<i>F. pinicola</i>	Cui 10312	China	KR605781 <sup>a</sup>	KR605720 <sup>a</sup>	KR605856 <sup>a</sup>	KR605960 <sup>a</sup>	KR610689 <sup>a</sup>	KR610780 <sup>a</sup>	this study	

Table 1 (continued)

Species name	Sample no.	Locality	GenBank accession numbers							References
			ITS	nLSU	nSSU	mSSU	tefl	rpb2		
<i>F. pinicola</i>	Cui 10405	China	KC844852	KC844857	KR605857 <sup>a</sup>	KR605961 <sup>a</sup>	KR610690 <sup>a</sup>	KR610781 <sup>a</sup>	KR610781 <sup>a</sup>	Han and Cui 2015
<i>F. pinicola</i>	Cui 10532	China	KP171214	KP171237	KR605858 <sup>a</sup>	KR605962 <sup>a</sup>	KR610691 <sup>a</sup>	KR610782 <sup>a</sup>	KR610782 <sup>a</sup>	Han et al. 2015
<i>F. subtropica</i>	Cui 10140	China	JQ067651	JX435771	KR605865 <sup>a</sup>	KR605969 <sup>a</sup>	KR610699 <sup>a</sup>	KR610789 <sup>a</sup>	KR610789 <sup>a</sup>	Li et al. 2013
<i>F. subtropica</i>	Cui 10181	China	JQ067653	JX435773	KR605866 <sup>a</sup>	KR605970 <sup>a</sup>	KR610700 <sup>a</sup>	KR610790 <sup>a</sup>	KR610790 <sup>a</sup>	Li et al. 2013
<i>F. subtropica</i>	Cui 10578	China	KR605787 <sup>a</sup>	KR605726 <sup>a</sup>	KR605867 <sup>a</sup>	KR605971 <sup>a</sup>	KR610698 <sup>a</sup>	KR610791 <sup>a</sup>	KR610791 <sup>a</sup>	this study
<i>Fragiomes niveomarginatus</i>	Cui 10108	China	KR605778 <sup>a</sup>	KR605717 <sup>a</sup>	KR605851 <sup>a</sup>	KR605955 <sup>a</sup>	KR610684 <sup>a</sup>	KR610776 <sup>a</sup>	KR610776 <sup>a</sup>	this study
<i>F. niveomarginatus</i>	Wei 5583	China	HQ693994	KC507175	KR605852 <sup>a</sup>	KR605956 <sup>a</sup>	KR610685 <sup>a</sup>	–	–	Han and Cui 2015
<i>Gilbertsonia angulopora</i>	FP-133019	USA	KC585354	KC585182	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>Laetiporus. sulphureus</i>	Dai 12154	China	KF951295	KF951302	KR605924 <sup>a</sup>	KR606023 <sup>a</sup>	KR610752 <sup>a</sup>	KR610841 <sup>a</sup>	KR610841 <sup>a</sup>	Song et al. 2014
<i>L. sulphureus</i>	Dai 12826	China	KR605819 <sup>a</sup>	KR605762 <sup>a</sup>	KR605925 <sup>a</sup>	KR606024 <sup>a</sup>	KR610753 <sup>a</sup>	KR610842 <sup>a</sup>	KR610842 <sup>a</sup>	this study
<i>Laricifomes officinalis</i>	JV 0309/49-J	USA	KR605821 <sup>a</sup>	KR605764 <sup>a</sup>	KR605929 <sup>a</sup>	–	KR610757 <sup>a</sup>	KR610846 <sup>a</sup>	KR610846 <sup>a</sup>	this study
<i>L. officinalis</i>	JV 9010/14	Slovakia	KR605822 <sup>a</sup>	KR605765 <sup>a</sup>	KR605930 <sup>a</sup>	–	KR610758 <sup>a</sup>	KR610847 <sup>a</sup>	KR610847 <sup>a</sup>	this study
<i>Neolentiporus maculatissimus</i>	Rajchenberg 158	Unknown	–	AF318632	AF334921	AF334884	–	AY218497	AY218497	Wang et al. 2004
<i>Niveoporofomes spraguei</i>	4638	France	KR605784 <sup>a</sup>	KR605723 <sup>a</sup>	KR605862 <sup>a</sup>	KR605966 <sup>a</sup>	KR610696 <sup>a</sup>	KR610786 <sup>a</sup>	KR610786 <sup>a</sup>	this study
<i>N. spraguei</i>	Cui 8969	China	KR605785 <sup>a</sup>	KR605724 <sup>a</sup>	KR605863 <sup>a</sup>	KR605967 <sup>a</sup>	KR610695 <sup>a</sup>	KR610787 <sup>a</sup>	KR610787 <sup>a</sup>	this study
<i>N. spraguei</i>	JV 0509/62	USA	KR605786 <sup>a</sup>	KR605725 <sup>a</sup>	KR605864 <sup>a</sup>	KR605968 <sup>a</sup>	KR610697 <sup>a</sup>	KR610788 <sup>a</sup>	KR610788 <sup>a</sup>	this study
<i>Oligoporus rennyi</i>	KEW-57	Unknown	AY218416	AF287876	–	–	–	–	–	Yu et al. 2010
<i>O. rennyi</i>	TN-6645	Finland	KC595929	KC595929	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>Phaeolus schweinitzii</i>	AFTOL-ID 702	USA	–	AY629319	AY705961	JN710740	DQ028602	DQ408119	DQ408119	Matheny et al. 2007
<i>P. schweinitzii</i>	DA-38	USA	EU402585	–	–	–	–	–	–	Lindner and Banik 2008
<i>P. schweinitzii</i>	FP-102447-Sp	USA	KC585368	KC585197	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>P. schweinitzii</i>	FP-133218-Sp	USA	KC585369	KC585198	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>P. schweinitzii</i>	OKM-4435-T	USA	KC585370	KC585199	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>Piptoporellus soloniensis</i>	Cui 11386	China	KR605802 <sup>a</sup>	KR605741 <sup>a</sup>	KR605900 <sup>a</sup>	–	KR610732 <sup>a</sup>	KR610821 <sup>a</sup>	KR610821 <sup>a</sup>	this study
<i>P. soloniensis</i>	Cui 11390	China	KR605803 <sup>a</sup>	KR605742 <sup>a</sup>	KR605901 <sup>a</sup>	KR606003 <sup>a</sup>	KR610733 <sup>a</sup>	KR610822 <sup>a</sup>	KR610822 <sup>a</sup>	this study
<i>P. soloniensis</i>	Dai 11872	China	KR605804 <sup>a</sup>	KR605743 <sup>a</sup>	KR605902 <sup>a</sup>	KR606004 <sup>a</sup>	KR610731 <sup>a</sup>	KR610823 <sup>a</sup>	KR610823 <sup>a</sup>	this study
<i>P. soloniensis</i>	LY BR 5463	France	KR605805 <sup>a</sup>	KR605744 <sup>a</sup>	KR605903 <sup>a</sup>	–	KR610734 <sup>a</sup>	–	–	this study
<i>P. hainanensis</i>	Dai 13714	China	KR605806 <sup>a</sup>	KR605745 <sup>a</sup>	KR605904 <sup>a</sup>	KR606005 <sup>a</sup>	KR610735 <sup>a</sup>	KR610824 <sup>a</sup>	KR610824 <sup>a</sup>	this study
<i>P. triquetra</i>	Dai 13121	China	KR605807 <sup>a</sup>	KR605746 <sup>a</sup>	KR605905 <sup>a</sup>	KR606006 <sup>a</sup>	KR610738 <sup>a</sup>	KR610827 <sup>a</sup>	KR610827 <sup>a</sup>	this study
<i>Postia duplicata</i>	Cui 10366	China	KF699124	KJ684975	KR605927 <sup>a</sup>	KR606026 <sup>a</sup>	KR610755 <sup>a</sup>	KR610844 <sup>a</sup>	KR610844 <sup>a</sup>	Shen et al. 2014
<i>P. duplicata</i>	Dai 13411	China	KF699125	KJ684976	KR605928 <sup>a</sup>	KR606027 <sup>a</sup>	KR610756 <sup>a</sup>	KR610845 <sup>a</sup>	KR610845 <sup>a</sup>	Shen et al. 2014
<i>P. fragilis</i>	Cui 10088	China	KF699120	–	–	–	–	KT893745 <sup>a</sup>	KT893745 <sup>a</sup>	Shen et al. 2014
<i>P. lactea</i>	Cui 12206	China	KR605820 <sup>a</sup>	KR605763 <sup>a</sup>	KR605926 <sup>a</sup>	KR606025 <sup>a</sup>	KR610754 <sup>a</sup>	KR610843 <sup>a</sup>	KR610843 <sup>a</sup>	this study



Table 1 (continued)

Species name	Sample no.	Locality	GenBank accession numbers					References	
			ITS	nLSU	nSSU	mtSSU	tefl		rpb2
<i>Pycnoporellus fulgens</i>	CA-20	USA	KC585385	KC585218	–	–	–	–	Ortiz-Santana et al. 2013
<i>P. fulgens</i>	FP-133367-Sp	USA	KC585386	KC585219	–	–	–	–	Ortiz-Santana et al. 2013
<i>P. fulgens</i>	OKM-7608-T	USA	KC585387	KC585220	–	–	–	–	Ortiz-Santana et al. 2013
<i>Rhodofomes cajanderei</i>	Cui 9879	China	KC507157	KC507167	KR605827 <sup>a</sup>	KR605935 <sup>a</sup>	KR610663 <sup>a</sup>	KR610763 <sup>a</sup>	Han and Cui 2015
<i>R. cajanderei</i>	Cui 9888	China	KC507156	KC507166	KR605828 <sup>a</sup>	KR605936 <sup>a</sup>	KR610662 <sup>a</sup>	KR610764 <sup>a</sup>	Han and Cui 2015
<i>R. cajanderei</i>	JV 0410/14a,b-J	USA	KR605768 <sup>a</sup>	KR605707 <sup>a</sup>	KR605829 <sup>a</sup>	KR605937 <sup>a</sup>	KR610664 <sup>a</sup>	–	this study
<i>R. carneus</i>	O 15519	Tanzania	KC507155	KC507165	KR605830 <sup>a</sup>	–	KR610665 <sup>a</sup>	–	Han and Cui 2015
<i>R. carneus</i>	Ryvarden 10118	Tanzania	KF999921	KF999925	KR605831 <sup>a</sup>	–	KR610666 <sup>a</sup>	–	Han and Cui 2015
<i>R. incarnatus</i>	Cui 10348	China	KC844848	KC844853	KR605844 <sup>a</sup>	KR605949 <sup>a</sup>	KR610679 <sup>a</sup>	KR610773 <sup>a</sup>	Han and Cui 2015
<i>R. incarnatus</i>	Yuan 2653	China	KC844849	KC844854	KR605845 <sup>a</sup>	KR605950 <sup>a</sup>	KR610678 <sup>a</sup>	–	Han and Cui 2015
<i>R. rosea</i>	Cui 10520	China	KC507162	KC507172	KR605859 <sup>a</sup>	KR605963 <sup>a</sup>	KR610692 <sup>a</sup>	KR610783 <sup>a</sup>	Han and Cui 2015
<i>R. rosea</i>	Cui 10633	China	KR605782 <sup>a</sup>	KR605721 <sup>a</sup>	KR605860 <sup>a</sup>	KR605964 <sup>a</sup>	KR610693 <sup>a</sup>	KR610784 <sup>a</sup>	this study
<i>R. rosea</i>	JV 1110/9	Czech Republic	KR605783 <sup>a</sup>	KR605722 <sup>a</sup>	KR605861 <sup>a</sup>	KR605965 <sup>a</sup>	KR610694 <sup>a</sup>	KR610785 <sup>a</sup>	this study
<i>R. subfeei</i>	Cui 9229	China	KR605789 <sup>a</sup>	KR605728 <sup>a</sup>	KR605869 <sup>a</sup>	–	KR610701 <sup>a</sup>	KR610793 <sup>a</sup>	this study
<i>R. subfeei</i>	Dai 10430	China	KR605788 <sup>a</sup>	KR605727 <sup>a</sup>	KR605868 <sup>a</sup>	KR605972 <sup>a</sup>	KR610702 <sup>a</sup>	KR610792 <sup>a</sup>	this study
<i>R. subfeei</i>	Dai 11887	China	KC507160	KC507170	KR605870 <sup>a</sup>	KR605973 <sup>a</sup>	KR610703 <sup>a</sup>	KR610794 <sup>a</sup>	Han and Cui 2015
<i>Rhodofomitopsis africana</i>	MUCL 43284	Cameroon	DQ491422	–	–	DQ491449	–	DQ491395	Kim et al. 2007
<i>R. cupreorosea</i>	CBS 236.87	Costa Rica	DQ491400	AY515325	–	DQ491427	–	DQ491373	Kim et al. 2007
<i>R. feei</i>	JV 0610/K9-Kout	Mexico	KF999922	KF999926	KR605836 <sup>a</sup>	KR605942 <sup>a</sup>	KR610673 <sup>a</sup>	–	Han and Cui 2015
<i>R. feei</i>	Oinonen 6011906	Brazil	KC844851	KC844856	KR605837 <sup>a</sup>	KR605943 <sup>a</sup>	KR610671 <sup>a</sup>	KR610767 <sup>a</sup>	Han and Cui 2015
<i>R. feei</i>	Ryvarden 37603	Venezuela	KC844850	KC844855	KR605838 <sup>a</sup>	KR605944 <sup>a</sup>	KR610670 <sup>a</sup>	KR610768 <sup>a</sup>	Han and Cui 2015
<i>R. feei</i>	Uotila 42928	Australia	KF999924	KF999928	KR605839 <sup>a</sup>	KR605945 <sup>a</sup>	KR610672 <sup>a</sup>	KR610769 <sup>a</sup>	Han and Cui 2015
<i>R. lilacinogilva</i>	Schigel 5193	Australia	KR605773 <sup>a</sup>	KR605712 <sup>a</sup>	KR605846 <sup>a</sup>	KR605951 <sup>a</sup>	KR610680 <sup>a</sup>	KR610774 <sup>a</sup>	this study
<i>Rubellofomes cystidiatus</i>	Cui 5481	China	KF937288	KF937291	KR605832 <sup>a</sup>	KR605938 <sup>a</sup>	KR610667 <sup>a</sup>	KR610765 <sup>a</sup>	Han et al. 2014
<i>R. cystidiatus</i>	Yuan 6304	China	KR605769 <sup>a</sup>	KR605708 <sup>a</sup>	KR605833 <sup>a</sup>	KR605939 <sup>a</sup>	KR610668 <sup>a</sup>	–	this study
<i>R. minutisporus</i>	Rajchenberg 10661	Argentina	KR605777 <sup>a</sup>	KR605716 <sup>a</sup>	KR605850 <sup>a</sup>	–	–	–	this study
<i>Rhodonia placenta</i>	Dietz7E	USA	KC585390	KC585223	–	–	–	–	Ortiz-Santana et al. 2013
<i>Ryvardenia campyla</i>	NZFS 2826	New Zealand	JQ390051	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>R. campyla</i>	NZFS 2828	New Zealand	JQ390052	–	–	–	–	–	Ortiz-Santana et al. 2013
<i>Sarcoporia polyspora</i>	234-36	USA	KC585392	KC585225	–	–	–	–	Ortiz-Santana et al. 2013
<i>S. polyspora</i>	L-14910-Sp	USA	KC585393	KC585226	–	–	–	–	Ortiz-Santana et al. 2013
<i>Sparassis crispa</i>	MBUH-DORISLABER	Germany	AY218442	AY218404	–	–	–	–	Ortiz-Santana et al. 2013
<i>S. crispa</i>	zw-clarku003	USA	AY218430	AY218393	–	–	–	–	Ortiz-Santana et al. 2013

Table 1 (continued)

Species name	Sample no.	Locality	GenBank accession numbers					References
			ITS	nLSU	nSSU	mtSSU	<i>tefl</i>	
<i>S. crispa</i>	X950	Finland	KC595954	KC595954	-	-	-	Ortiz-Santana et al. 2013
<i>Spongiporus leucospongia</i>	OKM-4335	USA	KC585395	KC585228	-	-	-	Ortiz-Santana et al. 2013
<i>S. leucospongia</i>	X1311	USA	KC595955	KC595955	-	-	-	Ortiz-Santana et al. 2013
<i>Taiwanofungus camphoratus</i>	ACT1	Taiwan	EU232205	EU232281	-	-	-	Ortiz-Santana et al. 2013
<i>T. camphoratus</i>	ACT2	Taiwan	EU232204	EU232280	-	-	-	Ortiz-Santana et al. 2013
<i>Trametes suaveolens</i>	Cui 11586	China	KR605823 <sup>a</sup>	KR605766 <sup>a</sup>	KR605931 <sup>a</sup>	KR606028 <sup>a</sup>	KR610759 <sup>a</sup>	this study
<i>Ungulitaedalea fragilis</i>	Cui 10919	China	KF937286	KF937290	KR605840 <sup>a</sup>	KR605946 <sup>a</sup>	KR610770 <sup>a</sup>	Han et al. 2014
<i>Wolfiporia dilatohypha</i>	CS-63-59-13-A-R	USA	KC585400	KC585234	-	-	-	Ortiz-Santana et al. 2013
<i>W. dilatohypha</i>	FP-72162-R	USA	EU402556	KC585235	-	-	-	Ortiz-Santana et al. 2013
<i>W. dilatohypha</i>	FP-94089-R	USA	KC585401	KC585236	-	-	-	Ortiz-Santana et al. 2013

<sup>a</sup> Newly generated sequences for this study

obtained from GenBank were used as outgroups to root trees following Binder et al. (2013). Maximum parsimony analysis was applied to the combined multiple genes datasets and the tree construction procedure was performed in PAUP\* version 4.0b10. All characters were equally weighted and gaps were treated as missing data. Trees were inferred using the heuristic search option with TBR branch swapping and 1000 random sequence additions. Max-trees were set to 5000, branches of zero length were collapsed and all parsimonious trees were saved. Clade robustness was assessed using a bootstrap (BT) analysis with 1000 replicates (Felsenstein 1985). Descriptive tree statistics tree length (TL), consistency index (CI), retention index (RI), rescaled consistency index (RC), and homoplasy index (HI) were calculated for each Most Parsimonious Tree (MPT) generated. RAxML v.7.2.8 was used to construct a maximum likelihood (ML) tree with GTR+G+I model of site substitution including estimation of Gamma-distributed rate heterogeneity and a proportion of invariant sites (Stamatakis 2006). The branch support was evaluated with bootstrapping method of 1000 replicates (Hillis and Bull 1993). Phylogenetic trees were visualized using Treeview (Page 1996).

MrModeltest 2.3 (Posada and Crandall 1998; Nylander 2004) was used to determine the best-fit evolution model for the combined multi-gene dataset for Bayesian inference (BI). Bayesian inference was calculated with MrBayes 3.1.2 with a general time reversible (GTR) model of DNA substitution and a gamma distribution rate variation across sites (Ronquist and Huelsenbeck 2003). Four Markov chains were run for 2 runs from random starting trees for 8.2 million generations (ITS + nLSU + *rpb2*), for 10 million generations (ITS + nLSU + nSSU + mtSSU + *tefl* + *rpb2*) and trees were sampled every 100 generations. The first one-fourth generations were discarded as burn-in. A majority rule consensus tree of all remaining trees was calculated. Branches that received bootstrap support for maximum parsimony (MP), maximum likelihood (BS) and Bayesian posterior probabilities (BPP) greater than or equal to 75 % (MP and BS) and 0.95 (BPP) were considered as significantly supported, respectively.

## Results

The combined ITS + nLSU + *rpb2* dataset included sequences from 170 fungal samples representing 80 taxa. The dataset had an aligned length of 2790 characters, of which 1503 characters are constant, 138 are variable and parsimony-uninformative, and 1149 are parsimony-informative. Maximum parsimony analysis yielded 234 equally parsimonious trees (TL = 8307, CI = 0.285, RI = 0.778, RC = 0.221, HI = 0.715). Best model for the combined ITS + nLSU + *rpb2* dataset estimated and applied in the Bayesian analysis: GTR+I+G, lset nst = 6, rates = invgamma; prset statefreq = dirichlet (1,1,1,1).



Bayesian analysis and ML analysis resulted in a similar topology as MP analysis, with an average standard deviation of split frequencies = 0.009184 (BI).

The phylogeny (Fig. 1) inferred from ITS + nLSU + *rpb2* sequences demonstrates 34 major lineages (including six new genera) for the sampled 80 species of the antrodia clade, and *Fomitopsis s. l.* and the previously so-called *Piptoporus* are polyphyletic.

The combined six gene (ITS, nLSU, nSSU, mtSSU, *tef1*, *rpb2*) sequences dataset had an aligned length of 4789 characters, of which 2874 characters were constant, 257 were variable and parsimony-uninformative, and 1658 were parsimony-informative. Maximum parsimony analysis yielded 14 equally parsimonious trees (TL = 11,070, CI = 0.305, RI = 0.740, RC = 0.225, HI = 0.695). Best model for the combined ITS + nLSU + nSSU + mtSSU + *tef1* + *rpb2* sequence dataset estimated and applied in the Bayesian analysis was: GTR + I + G with equal frequency of nucleotides. ML analysis resulted in a similar topology as MP and Bayesian analysis, and the ML topology was shown in Fig. 2.

A further phylogeny (Fig. 2) inferred from multiple genes of the combined ITS + nLSU + nSSU + mtSSU + *tef1* + *rpb2* sequences was obtained from 114 fungal samples representing 59 taxa in the antrodia clade and demonstrated that 23 species previously belong to *Fomitopsis sensu lato* are embedded in seven lineages: *Fomitopsis s. s.* (including the type species, *F. pinicola*), *Fragifomes* gen. nov., *Niveoporofomes* gen. nov., *Rhodofomes*, *Rhodofomitopsis* gen. nov., *Rubellofomes* gen. nov. and *Ungulidaedalea* gen. nov. The previously so-called *Piptoporus* includes species belonging to three distinct lineages: *Fomitopsis betulina* (= *P. betulinus*), *Buglossoporus* and *Piptoporellus* gen. nov. *Piptoporus* is treated as a synonym of *Fomitopsis*. Four new species, *Buglossoporus eucalypticola*, *Daedalea allantoidea*, *Piptoporellus hainanensis* and *P. triqueter*, are described from China (Figs. 1 and 2).

## Taxonomy

***Buglossoporus*** Kotl. & Pouzar, Česká Mykol. 20: 82, 1966.

*Type species. Buglossoporus quercinus* (Schrad.) Kotl. & Pouzar.

Basidiocarps annual, pileate, sessile to substipitate or stipitate, corky to fragile when dry. Pileal surface pink, cinnamon, orange to brown, velutinate or glabrous, azonate. Pore surface white, cream, buff to brown; pores small, round to angular. Context white, cream, buff, orange to brown, corky, thicker than tubes, sometimes with a pellicle at the upper surface. Tubes fragile, thin. Hyphal system dimitic in context, monomitic in trama; generative hyphae with clamp connections, skeletal hyphae thick-walled, IKI–, CB–. Cystidia absent, thin-walled cystidioles usually present. Basidiospores

ellipsoid, cylindrical to fusiform, hyaline, thin-walled, smooth, IKI–, CB–. Usually grows on angiosperm wood and causes a brown rot.

*Remarks.* *Buglossoporus* was proposed by Kotlába and Pouzar (1966), it was treated as a synonym of *Piptoporus* (Ryvarden 1991; Hattori 2000). In our study, *Piptoporus* is treated as a synonym of *Fomitopsis*, and *Buglossoporus* is an independent genus. Phylogenetically, *B. quercinus* and *B. eucalypticola* formed a well-supported lineage (Figs. 1 and 2), which was distant from *Fomitopsis betulina* (= *P. betulinus*), and closely related to *Neolentiporus* Rajchenb. However, *Neolentiporus* has a dimitic hyphal system in trama with irregularly thick-walled generative hyphae and metachromatic skeletal hyphae (Rajchenberg 1995b).

***Buglossoporus eucalypticola*** M.L. Han, B.K. Cui & Y.C. Dai, sp. nov. (Figs. 3a and 4)

Mycobank no.: MB 812644

*Holotype.* CHINA. Hainan Prov., Danzhou, Danzhou Tropical Botanical Garden, on dead tree of *Eucalyptus*, 15 June 2014, Y.C. Dai 13660 (BJFC 017399).

*Etymology.* *eucalypticola* (Lat.): refers to growth on *Eucalyptus*.

*Diagnosis.* Differing from other *Buglossoporus* species by its clay-pink to cinnamon pileal surface usually with a pellicle, pinkish buff or clay-buff to dark brown pore surface, and cylindrical to fusiform basidiospores (4.5–6.8 × 2–2.8 μm), and exclusively growing on *Eucalyptus*.

*Fruiting body.* Basidiocarps annual, solitary, pileate, usually with a central to lateral stipe. Pileus appanate to slightly convex, flabelliform or semicircular with a series of inward-pointing notches, projecting up to 10 cm, 6.5 cm wide, 7 mm thick at base. Pileal surface peach to brownish orange when fresh, becoming clay-pink to cinnamon when dry, usually with a pellicle, glabrous, azonate, rugose; margin flesh-pink when fresh, becoming cinnamon to dark brown when dry, acute. Pore surface white when fresh, turning pinkish buff or clay-buff to dark brown upon drying, sterile margin indistinct; pores round to angular, 2–6 per mm; dissepiments thin, entire. Context distinctly thicker than tubes, cream to pinkish buff, corky, up to 6.5 mm. Tubes concolourous with pore surface, fragile, very short, up to 0.5 mm long. Stipe glabrous, often with a pellicle, cream to dark brown, up to 16 cm long and 2.7 cm thick, fleshy and flexible when fresh, fragile and light in weight when dry.

*Hyphal structure.* Hyphal system dimitic in context, monomitic in trama; generative hyphae with clamp connections; skeletal hyphae IKI–, CB–; tissues becoming orange in KOH.

*Context.* Generative hyphae dominant, hyaline, thin- to slightly thick-walled, occasionally branched, interwoven, 3–9 μm in diam.; skeletal hyphae infrequent, thick-walled with a wide lumen, more or less straight, interwoven, 3–4 μm in diam.

**Tubes.** Generative hyphae hyaline, thin-walled, moderately branched, more or less parallel along the tubes, 2–4 µm in diam. Cystidia absent, fusoid cystidioles present, hyaline, thin-walled, 11–34 × 3–4 µm. Basidia clavate, bearing four sterigmata and a basal clamp connection, 15–36 × 4–6.5 µm; basidioles in shape similar to basidia, but slightly smaller.

**Spores.** Basidiospores cylindrical to fusiform, tapering at the apex, hyaline, thin-walled, smooth, mostly bearing 1 or 2 guttules, IKI–, CB–, (4–)4.5–6.8(–7) × 2–2.8 µm, L = 5.44 µm, W = 2.35 µm, Q = 2.23–2.4 (n = 60/2).

**Additional specimen (paratype) examined. CHINA.** Hainan Prov., Danzhou, Danzhou Tropical Botanical Garden, on dead tree of *Eucalyptus*, 15 June 2014, Y.C. Dai 13660A (BJFC 017400).

**Remarks.** *Buglossoporus malesianus* Corner and *B. quercinus* also produce annual and pileate basidiocarps, a dimitic hyphal system in context and monomitic in trama, and cylindrical to fusiform basidiospores, but *B. malesianus* differs from *B. eucalypticola* by its dark brown pileal surface without a pellicle, light brown pore surface, and bigger basidiospores (5.5–7 × 2.5–3.2 µm; Hattori 2000); while *B. quercinus* is separated by its whitish brown pileal surface without a pellicle, bigger basidiospores (6–8 × 2.5–3.5 µm) and grows on *Quercus* exclusively (Ryvarden and Melo 2014).

***Buglossoporus malesianus*** Corner, Beihefte zur Nova Hedwigia 78: 165, 1984. (Fig. 3b)

= *Piptoporus malesianus* (Corner) T. Hatt., Mycoscience 41: 343, 2000.

= *Buglossoporus matangensis* Corner, Beihefte zur Nova Hedwigia 78: 172, 1984.

= *Buglossoporus rufescens* Corner, Beihefte zur Nova Hedwigia 78: 178, 1984.

**Remarks.** Hattori (2000) studied the type specimens of *Buglossoporus malesianus*, *B. matangensis* and *B. rufescens* described by Corner and considered the type specimens of *B. matangensis* and *B. rufescens* represent *B. malesianus*, and the former two were treated as synonyms of *Piptoporus malesianus*. We also examined the types of these three species, and confirmed the identifications of *B. matangensis* and *B. rufescens* as Hattori (2000). We tried to extract DNA from materials of *Buglossoporus malesianus*, *B. matangensis* and *B. rufescens*, but did not succeed. However, *Piptoporus malesianus* has annual, pileate, substipitate basidiocarps, a dimitic hyphal system in context and monomitic in trama, and cylindrical to fusiform basidiospores, which are similar to *Buglossoporus quercinus*. Therefore, we keep this species in *Buglossoporus* although without phylogenetic support. Hattori (2000) supplied detailed description for the species.

**Specimens examined. *Buglossoporus malesianus*.** MALAYSIA. Borneo, Mt. Kinabalu, Mesilau, 11 March 1964, RSNB 5747 (holotype, E 00159734). ***Buglossoporus matangensis*.** MALAYSIA. Borneo,

**Fig. 1** Maximum likelihood tree illustrating the phylogeny of *Fomitopsis* and its related genera in the antrodia clade based on the combined sequences dataset of ITS + nLSU + *rpb2*. Branches are labeled with maximum likelihood bootstrap higher than 50 %, parsimony bootstrap proportions higher than 50 % and Bayesian posterior probabilities more than 0.95

Sarawak, Gunong Matang, 20 August 1972 (holotype, E 00159655). ***Buglossoporus rufescens*.** MALAYSIA. Borneo, Mt. Kinabalu, Mesilau, 19 April 1964, RSNB 8361 (holotype, E 00159656).

***Buglossoporus quercinus*** (Schrad.) Kotl. & Pouzar, Česká Mykol. 20: 84, 1966. (Fig. 3c)

= *Boletus quercinus* Schrad., Spicil. fl. germ. 1: 157, 1794.

= *Piptoporus quercinus* (Schrad.) P. Karst., Meddn Soc. Fauna Flora fenn. 6: 9, 1881.

**Remarks.** Karsten (1881a) transferred *Boletus quercinus* Schrad. into *Piptoporus*, later Kotlába and Pouzar (1966) established *Buglossoporus* with *B. quercinus* as the type species. However, *Buglossoporus* was treated as a synonym of *Piptoporus* (Ryvarden 1991; Hattori 2000), and *B. quercinus* was accepted as *P. quercinus*. In our study, *Piptoporus* is treated as a synonym of *Fomitopsis*, *B. quercinus* was formed in the *Buglossoporus* lineage (Figs. 1 and 2), For a detailed description, see Ryvarden and Melo (2014) as *Piptoporus quercinus*.

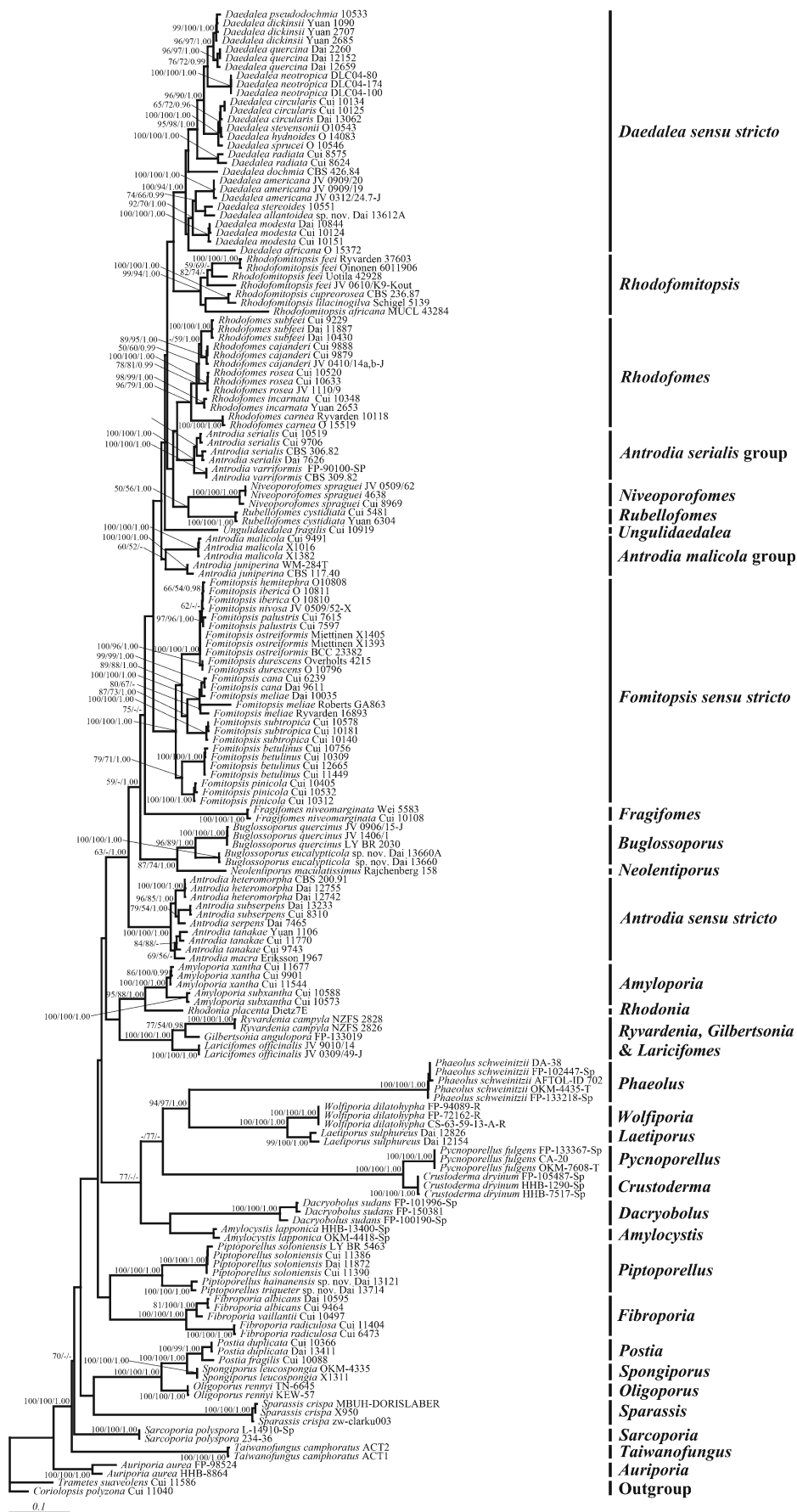
**Specimens examined. CZECH REPUBLIC.** Hluboka, Bezdrev pond dam, *Quercus*, 16 June 2014, J. Vlasák 1406/1 (JV). **FRANCE.** Fontainebleau, Gros-Foutreau, *Quercus*, 15 September 2001, LY BR 2030 (LY). **USA.** Cayo District, Pennsylvania, Norristown, Valley Forge, *Quercus*, 28 June 2009, J. Vlasák 0906/15-J (JV).

***Daedalea*** Pers., Syn. meth. fung. (Göttingen) 2: 500, 1801.

**Type species.** *Daedalea quercina* (L.) Pers.

Basidiocarps mostly perennial, effuse-reflexed or most often pileate, broadly sessile, coriaceous to corky or hard corky when dry. Pileal surface smooth to velutinate, often concentrically zonate and sulcate. Hymenophore surface ochraceous to dark-brown or grey, hymenophores irregular, labyrinthine/daedaleoid to lamellate, hydroid or poroid. Context more or less brownish, sometimes with a cuticle or crust at the upper surface. Tubes coriaceous to corky or hard corky. Hyphal system dimitic with more or less branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless to pale yellow or pale brown, thick-walled, IKI–, CB–. Catahymenium present or not. Cystidia occasionally present, thin-walled cystidioles usually present. Basidiospores cylindrical to ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Usually grows on angiosperm wood and causes a brown rot.

**Remarks.** *Daedalea*, typified by *D. quercina*, was originally established by Persoon (1801), then it was treated as a



the antrodia clade

*Daedalea sensu stricto*

*Rhodofomitopsis*

*Rhodofomes*

*Antrodia serialis* group

*Niveoporofomes*

*Rubellofomes*

*Ungulidaedalea*

*Antrodia malicola* group

*Fomitopsis sensu stricto*

*Fragifomes*

*Buglossoporus*

*Neolentiporus*

*Antrodia sensu stricto*

*Amyloporia*

*Rhodonia*

*Ryvardenia, Gilbertsonia & Laricifomes*

*Phaeolus*

*Wolfiporia*

*Laetiporus*

*Pycnoporellus*

*Crustoderma*

*Dacryobolus*

*Amylocystis*

*Piptoporellus*

*Fibroporia*

*Postia*

*Spongiporus*

*Oligoporus*

*Sparassis*

*Sarcoporia*

*Taiwanofungus*

*Auriporia*

*Outgroup*



**Fig. 2** Maximum likelihood tree illustrating the phylogeny of *Fomitopsis* and its related genera in the antrodia clade based on the combined sequences dataset of ITS + nLSU + nSSU + mtSSU + *tef1* + *rpb2*.

collective genus for all species with a daedaleoid to labyrinthine hymenophore (Fries 1821). During the last century, more microscopic and chemical characters were applied in taxonomy, many *Daedalea* species have been transferred to other genera (Singer 1944; Donk 1966; Ryvarden 1984). Recently, a few species were described in the genus based

on morphological characters and molecular data (Lindner et al. 2011; Li and Cui 2013; Han et al. 2015). Currently, the genus is restricted to species with the above definition.

In our six-loci phylogenetic study (Fig. 2), *Daedalea dickinsii* Yasuda, *D. quercina*, *D. circularis* B.K. Cui & Hai J. Li, *D. sprucei* Berk., *D. hydnoidea* I. Lindblad & Ryvarden





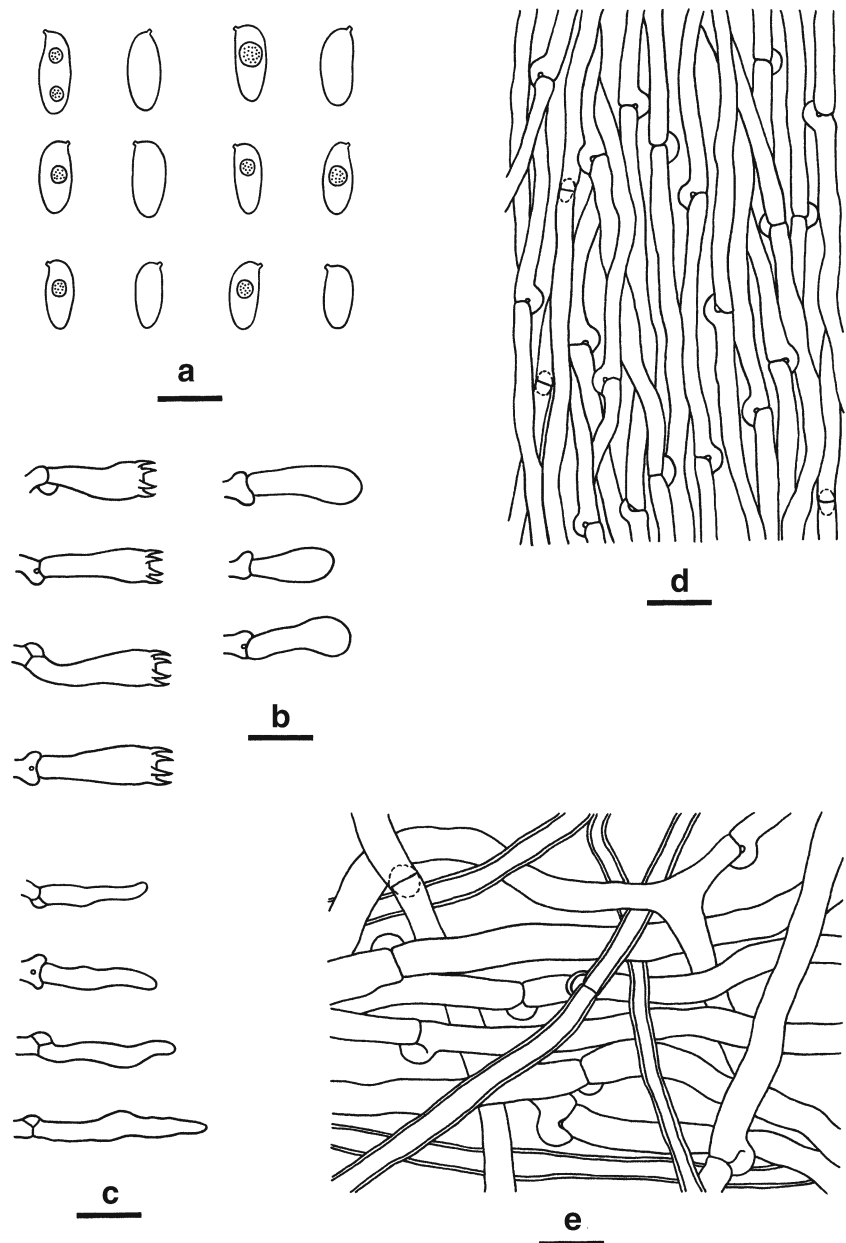
**Fig. 3** Basidiocarps of new species and new combinations. **a.** *Buglossoporus eucalypticola* (Dai 13660); **b.** *Buglossoporus malesianus* (RSNB 5747); **c.** *Buglossoporus quercinus* (Vlasák 0906/15-J); **d, e.** *Daedalea allantoidea* (Dai 13612A); **f.** *Fomitopsis betulina* (Dai 1953); **g.** *Fragifomes niveomarginatus* (Dai 9175); **h.** *Niveoporofomes spraguei* (Dai 9260); **i, j.** *Piptoporellus hainanensis* (Dai 13714); **k.** *Piptoporellus triquetter* (Dai 13121); **l.** *Piptoporellus soloniensis* (Cui 11390); **m.** *Rhodofomes cajanderi* (Dai 9024); **n.**

*Rhodofomes carneus* (Ryvarden 10118); **o.** *Rhodofomes incarnatus* (Cui 10348); **p.** *Rhodofomes rosea* (Cui 9278); **q.** *Rhodofomes subfeei* (Uotila 42928); **r.** *Rhodofomitopsis cupreoreosa* (Ryvarden 44394); **s.** *Rhodofomitopsis feei* (Uotila 42928); **t, u.** *Rhodofomitopsis lilacinogilva* (Ratkowsky 0562); **v.** *Rubellofomes cystidiatus* (Dai 10355); **w.** *Rubellofomes minutisporus* (Rajchenberg 10666); **x.** *Ungulidaedalea fragilis* (Cui 10919). Bars: **x** = 0.5 cm; **i, j, k, n, p, s–u, w** = 1 cm; **a, d, e, g, l, m, o, q, r, v** = 2 cm; **f, h** = 3 cm; **b, c** = 4 cm

and *D. stevensonii* Petr. grouped together with high support (100 % BS, 100 % MP, 1.00 BPP); *D. allantoidea*, a new species described from China, clustered with *D. americana*

M.L. Han, Vlasák & B.K. Cui and *D. modesta* (Kunze ex Fr.) Aoshima (77 % BS, 98 % MP, 1.00 BPP); two samples of *D. radiata* B.K. Cui & Hai J. Li formed a separate lineage

**Fig. 4** Microscopic structures of *Buglossoporus eucalypticola* (drawn from the holotype). **a.** Basidiospores; **b.** Basidia and basidioles; **c.** Cystidioles; **d.** Hyphae from trama; **e.** Hyphae from context. Bars: **a** = 5  $\mu$ m; **b**–**e** = 10  $\mu$ m



(100 % BS, 100 % MP, 1.00 BPP). These ten species together with *D. dochmia* (Berk. & Broome) T. Hatt. and *D. africana* I. Johans. & Ryvar den share similar morphological characters and form the core group of *Daedalea sensu stricto* (98 % BS, 86 % MP, 1.00 BPP).

Another three species, *Daedalea neotropica* D.L. Lindner, Ryvar den & T.J. Baroni, *D. pseudodochmia* (Corner) T. Hatt. and *D. stereoides* Fr. also produce pileate, mostly perennial, coriaceous to corky or hard corky basidiocarps, irregular, labyrinthine/daedaleoid to poroid hymenophores, ochraceous to pale cinnamon or cork-colored hymenophore surface, brownish context, a dimitic hyphal system with clamped generative hyphae and more or less branched skeletal hyphae and cylindrical to broadly ellipsoid basidiospores (Ryvar den and

Johansen 1980; Núñez and Ryvar den 2001; Lindner et al. 2011). These species were not included in our phylogeny (Fig. 2) because of lacking of multi-gene sequences of ITS + nLSU + nSSU + mtSSU + *tefl* + *rpb2*. However, they clustered into *Daedalea s. s.* inferred from sequences data of ITS + nLSU + *rpb2* sequences (Fig. 1). Therefore, *D. neotropica*, *D. pseudodochmia* and *D. stereoides* are also recognized in *Daedalea s. s.*

**Specimens examined.** *Daedalea africana*. KENYA. Kwale Distr. Shimba Hills, Makadara Forest, 14 February 1973, L. Ryvar den 16485 (holotype, O); Buda Forest, 25 August 1966, R. Cain, H.D. Griffin, J.C. Krug (O 15372). *Daedalea americana*. COSTA RICA. Rincon de la Vieja, Las Pilas Ranger Station, on angiosperm trunk, 1 August 2014,



*J. Vlasák 1408/3* (paratype, BJFC 018299; JV). USA. Florida, Miami, Matheson Hammock, on angiosperm trunk, 19 April 2009, *J. Vlasák 0904/20* (holotype, BJFC 015575; JV) & *J. Vlasák 0904/19* (paratype, BJFC 15574; JV); 24 December 2003, *J. Vlasák 0312/24.7-J* (paratype, BJFC 015573; JV). **Daedalea circularis**. CHINA. Guangdong Prov., Heyuan, Daguishan Forest Park, on angiosperm stump, 18 August 2011, *B.K. Cui 10125* (paratype, BJFC 011019) & *B.K. Cui 10134* (paratype, BJFC 011028); Yunnan Prov., Mengla County, Wangtianshu Park, on fallen angiosperm trunk, 2 November 2009, *B.K. Cui 8488* (holotype, BJFC 006977). **Daedalea dickinsii**. CHINA. Shanxi Prov., Qinshui County, Lishan Nature Reserve, on fallen angiosperm trunk, 20 October 2004, *H.S. Yuan 1090* (BJFC 000525); Zhouzhi County, Taibaishan Nature Reserve, on fallen angiosperm trunk, 24 October 2006, *H.S. Yuan 2685* (BJFC 000526) & *H.S. Yuan 2707* (BJFC 000527). **Daedalea hydroides**. COSTA RICA. Guanacaste, Guanacaste National Park, Cacao, on dead deciduous wood, 3 November 1997, *I. Lindblad 3679* (isotype, O 14083). **Daedalea modesta**. CHINA. Guangdong Prov., Heyuan, Daguishan Forest Park, on fallen angiosperm trunk, 18 August 2011, *B.K. Cui 10124* (BJFC 011018); Guangzhou, Tianluhu Forest Park, on fallen angiosperm trunk, 19 August 2011, *B.K. Cui 10151* (BJFC 011046); Hainan Prov., Ledong County, Jianfengling Nature Reserve, on fallen trunk of *Cyclobalanopsis*, 11 May 2009, *Y.C. Dai 10844* (BJFC 005086). MALAYA. Pahang, Tembeling, on a fallen dead trunk in secondary forest, 18 November 1930, *Record No. 194261* (type, E). **Daedalea pseudodochmia**. MALAYSIA. Borneo, Mt. Kinabalu, on a living tree in montane forest, 14 June 1961 (type, E 00430837). **Daedalea quercina**. CZECH REPUBLIC. Lednice Vallage Castle Park, on fallen trunk of *Quercus*, 6 May 2011, *Y.C. Dai 12152* (BJFC 012670). FINLAND. Helsinki, Vantaa, Tamisto Nature Reserve, on fallen trunk of *Quercus*, 5 November 2011, *Y.C. Dai 12659* (BJFC 012240). SWEDEN. Göteborg, Ryvaskog Nat. Park, on stump of *Quercus*, 21 August 1996, *Y.C. Dai 2260* (BJFC 000536). **Daedalea radiata**. CHINA. Yunnan Prov., Mengla County, Wangtianshu Park, on fallen angiosperm trunk, 16 September 2007, *H.S. Yuan 3629* (holotype, IFP 013864; BJFC 012960); 2 November 2009, *B.K. Cui 8575* (paratype, BJFC 007064); 3 November 2009, *B.K. Cui 8624* (paratype, BJFC 007113). **Daedalea sprucei**. CHINA. Taiwan, Kuraru in Keshun, January 1909, *Kusano* (O 10546). CUBA. Pinar del Rio, Sierra del Rosario, on *Guazuma*, 18 February 1976, *L. Ortiz* (O 10547). **Daedalea stereoides**. COSTA RICA. Guanacaste, Finca Rio Naranjo, in bosque ripario, 10 April 2000, *I. Lopez 1243* (O 14081). **Daedalea stevensonii**. MALAYSIA. Borneo, Mt. Kinabalu, 29 April 1932 (O 10543).

**Daedalea allantoides** M.L. Han, B.K. Cui & Y.C. Dai, sp. nov. (Figs. 3d, e and 5)

Mycobank no.: MB 812643

**Holotype**. CHINA. Yunnan Prov., Jinghong, Forest Park, on fallen angiosperm trunk, 22 October 2013, *Y.C. Dai 13612A* (BJFC 015075).

**Etymology**. *allantoidea* (Lat.): refers to the allantoid basidiospores.

**Diagnosis**. Differing from other *Daedalea* species by its annual, pileate basidiocarps, pinkish buff to cinnamon buff or pale mouse-grey pileal surface, light clay-buff to fawn pore surface with large pores (1–3 per mm), a catayahmenium formed by skeletal hyphae and allantoid basidiospores.

**Fruiting body**. Basidiocarps annual, pileate, imbricate, corky, without odor or taste when fresh, hard corky and light in weight upon drying. Pileus conchate or triquetrous, projecting up to 4.4 cm, 2.5 cm wide, 9 mm thick at base. Pileal surface pinkish buff to cinnamon buff or pale mouse-grey, glabrous to tuberculate, slightly zonate and radially streaked; margin pinkish buff to clay-buff, acute. Pore surface light clay-buff to fawn; pores round to angular or elongated, 1–3 per mm; dissepiments thin, entire. Context cream, hard corky, up to 5 mm thick. Tubes pinkish buff to salmon, corky, up to 4 mm long.

**Hyphal structure**. Hyphal system dimitic; generative hyphae with clamp connections; skeletal hyphae IKI–, CB–; tissues becoming brown in KOH.

**Context**. Generative hyphae hyaline, thin- to slightly thick-walled, moderately branched, 2–3.5 µm in diam.; skeletal hyphae dominant, colorless, thick-walled with a wide or narrow lumen, sometimes subsolid, occasionally branched, interwoven, 2–5 µm in diam.

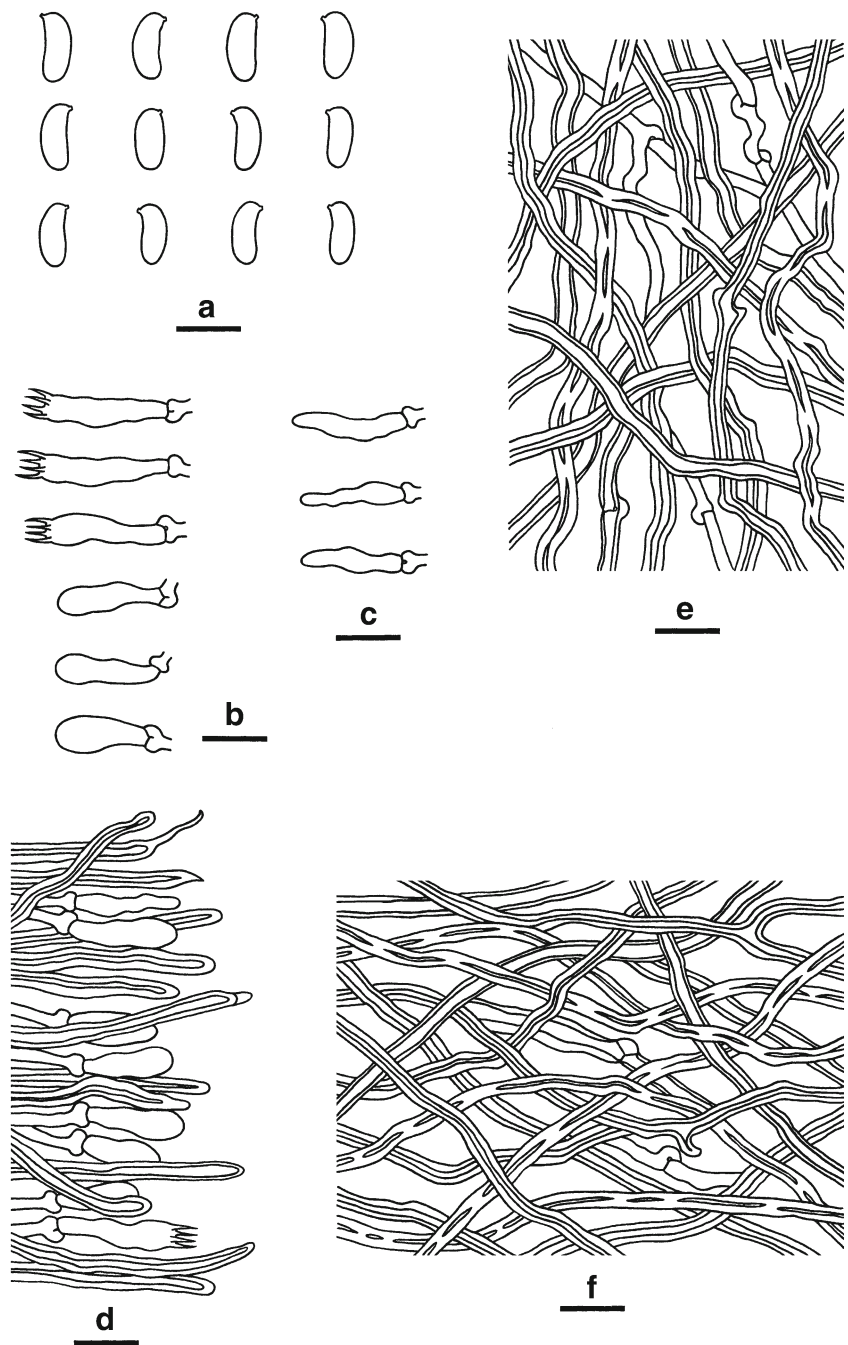
**Tubes**. Generative hyphae hyaline, thin- to slightly thick-walled, moderately branched, 1.5–3.5 µm in diam.; skeletal hyphae dominant, colorless, thick-walled with a wide or narrow lumen, sometimes subsolid, occasionally branched, interwoven, 2–4 µm in diam. Cystidia absent, sometimes skeletal hyphae penetrating into the hymenium, and forming a catayahmenium with cystidia-like, thinning out or rounded and thick-walled apices; fusoid cystidioles present, hyaline, thin-walled, 13–19 × 3.5–4.5 µm. Basidia infrequent, clavate, with four sterigmata and a basal clamp connection, 18–21 × 4.5–5 µm; basidioles dominant, in shape similar to basidia, but smaller.

**Spores**. Basidiospores allantoid, hyaline, thin-walled, smooth, IKI–, CB–, (4.5–)4.6–6(–6.2) × (1.9–)2–2.8(–3.2) µm, L = 5.15 µm, W = 2.32 µm, Q = 2.22 (n = 50/1).

**Additional specimen (paratype) examined**. CHINA. Yunnan Prov., Jinghong, Forest Park, on fallen angiosperm trunk, 16 August 2005, *H.S. Yuan 1710A* (IFP 012955).

**Remarks**. *Daedalea dickinsii* produce pileate basidiocarps, similar colored pileal surface and pore surface, similar sized pores and basidiospores with *D. allantoides*, but *D. dickinsii* differs by a perennial growth habit, broadly concentrically sulcate pileal surface and cylindrical basidiospores, and it

**Fig. 5** Microscopic structures of *Daedalea allantoidea* (drawn from the holotype). **a.** Basidiospores; **b.** Basidia and basidioles; **c.** Cystidioles; **d.** Section of hymenium; **e.** Hyphae from trama; **f.** Hyphae from context. Bars: **a** = 5  $\mu$ m; **b**–**f** = 10  $\mu$ m



grows mostly on wood of *Quercus* in temperate areas (Núñez and Ryvarden 2001).

*Daedalea quercina* resembles *D. allantoidea* by having a catahymenium formed by skeletal hyphae and similar sized basidiospores ( $5.5\text{--}6 \times 2.5\text{--}3.5 \mu\text{m}$ ), but it differs by a perennial growth habit, poroid to daedaleoid or almost lamellate hymenophore and more or less ellipsoid basidioapores (Niemelä 2005).

*Daedalea modesta* and *D. americana* also have annual, pileate basidiocarps and poroid hymenophore, but *D. modesta* has smaller pores (6–10 per mm) and smaller

and cylindrical basidioapores ( $4.5\text{--}6 \times 1.5\text{--}2 \mu\text{m}$ ; Ryvarden and Johansen 1980), *D. americana* differs in smaller pores (4–5 per mm), and smaller and ellipsoid basidiospores ( $4\text{--}5.1 \times 2.1\text{--}3 \mu\text{m}$ ; Han et al. 2015).

***Fomitopsis*** P. Karst., Meddelanden af Societas pro Fauna et Flora Fennica 6: 9, 1881.

*Type species. Fomitopsis pinicola* (Sw.) P. Karst.

Basidiocarps annual to perennial, mostly sessile, occasionally effused-reflexed or substipitate, soft, corky, tough to woody. Pileal surface white to greyish, yellowish or brown, velutinate to glabrous, concentrically sulcate or not. Pore

surface white, cream to greyish or tan; pores mostly small, round to angular. Context white to greyish or straw, fibrous to corky, sometimes with a thin crust or cuticle at the upper surface. Hyphal system mostly dimitic with more or less branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless to pale grey, thick-walled with a narrow lumen to subsolid, IKI–, CB–. Cystidia occasionally present, thin-walled cystidioles usually present. Basidiospores cylindrical to ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Grows on angiosperm wood or gymnosperm wood, and causes a brown rot.

**Remarks.** In our six-loci phylogenetic study (Fig. 2), *Fomitopsis durescens* (Overh.) Gilb. & Ryvarden, *F. nivos*a (Berk.) Gilb. & Ryvarden, *F. palustris* (Berk. & M.A. Curtis) Gilb. & Ryvarden, *F. iberica* Melo & Ryvarden and *F. hemitephra* (Berk.) G. Cunn. grouped together forming a fully supported subgroup (100 % BS, 100 % MP, 1.00 BPP). *Fomitopsis cana* B.K. Cui, Hai J. Li & M.L. Han, *F. meliae* (Underw.) Gilb and *F. subtropica* B.K. Cui, Hai J. Li & M.L. Han formed a subgroup with only weak support (56 % BS). Four samples of *Piptoporus betulinus* from China and Finland formed a highly supported subgroup (100 % BS, 100 % MP, 1.00 BPP), and then grouped with *Fomitopsis pinicola*. The above species subsequently clustered together forming a monophyletic lineage, namely *Fomitopsis s. s.*, with high support (91 % BS, 96 % MP, 1.00 BPP). These ten species share similar morphological characters and form the core group of *Fomitopsis*. We did not get any sample of *F. ostreiformis* (Berk.) T. Hatt., but *F. ostreiformis* has annual, sessile or effuse-reflexed basidiocarps, greyish pileal surface, white or greyish white pore surface, white to brownish and fibrous-corky context, a dimitic hyphal system with more or less branched skeletal hyphae, and cylindrical basidiospores (De 1981; Hattori 2003). In addition, *F. ostreiformis* clustered with *F. durescens*, *F. iberica*, *F. nivos*a, *F. hemitephra* and *F. palustris* in *Fomitopsis s. s.* based on phylogeny of ITS + nLSU + *rpb2* sequences (Fig. 1). Therefore, *F. ostreiformis* is also included in *Fomitopsis s. s.*

**Specimens examined.** *Fomitopsis cana*. CHINA. Hainan Prov., Qiongzong County, Limushan Forest Park, on fallen angiosperm trunk, 24 May 2008, Y.C. Dai 9611 (holotype, BJFC 013033); Chengmai County, on dead part of living *Delonix*, 6 May 2009, B.K. Cui 6239 (paratype, BJFC 004095). *Fomitopsis durescens*. USA. West Elkton, Ohio, on *Fagus* stump, 28 July 1917, L.O. Overholts 4215 (type, PAC). VENEZUELA. Esta. Aragua Rancho Grande res. Station, Parque Nac. Henri Pittier, 14 April 1999, L. Ryvarden 41410 (O 10796). *Fomitopsis hemitephra*. AUSTRALIA. New South Wales, on trunk of living tree in rainforest, 11 February 1984, R. Covering 18 (O 10808); Victoria, Tarra Valley, on indet wood, 29 February 1976, D.A. Reid (K 88939). *Fomitopsis iberica*. ITALY. Parco della Calabria, on *Pinus*, 7 November 1988, A. Bernicchia n4937

(O 10811). PORTUGAL. Beira Litoral, Pinhal do Urso, Lago de Evredeira, 9 November 1999, on *Pinus*, A. Hausknecht & R. Reinwald (O 10810). *Fomitopsis meliae*. BRITAIN. Virgin Island (British), Tortola, Sage Mountain, main trail to National Park, on trunk, 6 October 2001, P.J. Roberts GA863 (K 109430). CHINA. Hainan Prov., Ledong County, Jianfengling Nature Reserve, on angiosperm, 3 June 2008, Y.C. Dai 10035 (IFP 008212). *Fomitopsis nivos*a. BRAZIL. Paraibo, João Pessoa, on wood, 11 July 1960, R. singer B3372 (K 8422). CHINA. Guangxi Autonomous Region, Yangshuo County, on *Prunus*, September 2005, J. Vlasák 0509/52-X (JV). GUATEMALA. Laguna Chicabal, hardwood, 19 November 2006, J. Vlasák 0611/6B-Kout (JV). USA. Florida, Pinelands Trail, Everglades National Park, on hardwood, 21 December 2003, J. Vlasák 0312/21.8-J (JV). *Fomitopsis palustris*. CHINA. Guangdong Prov., Ruyang County, Nanling Nature Reserve, on living angiosperm tree, 16 September 2009, B.K. Cui 7597 (BJFC 006085) & B.K. Cui 7615 (BJFC 006103). USA. Louisiana, Louisiana State University campus, on *Ligustrum*, 6 July 1986, R.L. Gilbertson 14757 (O 16323). *Fomitopsis pinicola*. BELGIUM. Louvain, Louvain-la-Neuve, on dead tree of *Betula*, 3 December 2005, Y.C. Dai 7454 (BJFC 015595). CHINA. Yunnan Prov., Lanping County, Changyanshan Nature Reserve, on fallen trunk of *Picea*, 18 September 2011, B.K. Cui 10312 (BJFC 011207). FINLAND. Helsinki, Vantaa, Tamisto Nature Reserve, on fallen trunk of *Picea*, 16 August 2012, Y.C. Dai 12870 (BJFC 013150). ITALY. Roma, Trentino Altoadige, Trento, Molveno, on stump of *Picea*, 28 April 2005, Y.C. Dai 6553 (IFP 002353). *Fomitopsis subtropica*. CHINA. Guangdong Prov., Guangzhou, Tianluhu Forest Park, on fallen trunk of *Castanopsis*, 19 August 2011, B.K. Cui 10154 (holotype, BJFC 011049); Maofengshan Forest Park, on fallen angiosperm trunk, 19 August 2011, B.K. Cui 10140 (paratype, BJFC 011035); Guangxi Autonomous Region, Jinxiu County, Lianhua Mountain, on fallen angiosperm trunk, 24 August 2011, B.K. Cui 10578 (paratype, BJFC 011473); Zhejiang Prov., Taishun County, Wuyanling Nature Reserve, on fallen angiosperm branch, 22 August 2011, B.K. Cui 10181 (paratype, BJFC 011076).

*Fomitopsis betulina* (Bull.) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3f)

Mycobank no.: MB 812646

Basionym. *Boletus betulinus* Bull., *Herbier de la France* 7: t. 312, 1787.

= *Piptoporus betulinus* (Bull.) P. Karst., *Revue Mycologique Toulouse* 3: 17, 1881.

*Piptoporus betulinus* is the type species of *Piptoporus* (Karsten 1881b), it shares the morphological characters with *Fomitopsis s. s.*: annual, pileate basidiocarps, white to cream or tan pore surface with regular pores and context, a thin cuticle at the upper surface, a dimitic hyphal systems with clamped



generative hyphae and more or less branched skeletal hyphae, cylindrical to slightly allantoid, hyaline and smooth basidiospores which are negative in Melzer's reagent (Gilbertson and Ryvarden 1986b; Ryvarden and Melo 2014). In our study, it is closely related to *Fomitopsis pinicola* and grouped into the *Fomitopsis s. s.* clade. Therefore, *Piptoporus betulinus* is transferred to *Fomitopsis*. For a detailed description of *P. betulinus*, see Ryvarden and Melo (2014).

**Specimens examined.** *Fomitopsis betulina*. CHINA. Jilin Prov., Tumen County, Xiaohelong Forest Farm, on living tree of *Betula*, 10 October 2009, Y.C. Dai 11449 (BJFC 007319); Sichuan Prov., Xiaojin County, Jiajin Mountains, on fallen trunk of *Betula*, 17 October 2012, B.K. Cui 10756 (BJFC 013678); Yunnan Prov., Lanping County, Changyanshan Nature Reserve, on fallen trunk of *Betula*, 18 September 2011, B.K. Cui 10309 (BJFC 011204). FINLAND. Helsinki, Vantaa, Tamisto Nature Reserve, on fallen trunk of *Betula*, 5 November 2011, Y.C. Dai 12665 (BJFC 012246); Pohjois Karjala, Patvinsuo Nat. Park, on fallen trunk of *Betula*, 2 August 1995, Y.C. Dai 1953 (BJFC 001941).

**Fragifomes** B.K. Cui, M.L. Han & Y.C. Dai, gen. nov.

Mycobank no.: MB 812649

**Type species.** *Fragifomes niveomarginatus* (L.W. Zhou & Y.L. Wei) B.K. Cui, M.L. Han & Y.C. Dai.

**Etymology.** *Fragifomes* (Lat.): refers to the fragile and layered basidiocarps.

**Diagnosis.** Differing from *Fomitopsis s. s.* by its soft corky to fragile basidiocarps.

Basidiocarps perennial, sessile, soft corky when fresh, fragile upon drying. Pileal surface white, greyish white or greyish brown, smooth, indistinctly sulcate or zoned. Pore surface white when fresh, becoming yellowish brown upon drying, shinning; pores small, round. Context cream, fragile, usually with a thin crust at the upper surface. Tubes fragile, distinctly stratified. Hyphal system dimitic with more or less branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless to yellowish, IKI–, CB–. Cystidia absent, thin-walled cystidioles present. Basidiospores oblong-ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Usually grows on angiosperm wood and causes a brown rot.

**Remarks.** In our study, two samples of *F. niveomarginata* formed a single lineage (Figs. 1 and 2), which was distant from *Fomitopsis s. s.* Morphologically, *Fragifomes* differs from *Fomitopsis s. s.* by its soft corky to fragile basidiocarps.

**Fragifomes niveomarginatus** (L.W. Zhou & Y.L. Wei) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3g)

Mycobank no.: MB 812650

Basionym. *Fomitopsis niveomarginata* L.W. Zhou & Y.L. Wei, Mycological Progress 11: 437, 2012.

For a detailed description of *Fomitopsis niveomarginata*, see Zhou and Wei (2012).

**Specimens examined.** CHINA. Jinlin Prov., Antu County, Changbaishan Nature Reserve, Huangsongpu, on rotten wood

of *Tilia*, 14 September 2007, Y.C. Dai 9175 (holotype, IFP 015643); on fallen angiosperm branch, 24 August 2007, Y.L. Wei 3072 (paratype, IFP 015647); on fallen branch of *Acer*, 14 July 2010, Y.L. Wei 5583 (paratype, IFP 015648); Fusong County, Lushuihe Forest Farm, on fallen angiosperm trunk, 11 August 2011, B.K. Cui 10108 (BJFC 011001).

**Niveoporofomes** B.K. Cui, M.L. Han & Y.C. Dai, gen. nov.

Mycobank no.: MB 812651

**Type species.** *Niveoporofomes spraguei* (Berk. & M.A. Curtis) B.K. Cui, M.L. Han & Y.C. Dai.

**Etymology.** *Niveoporofomes* (Lat.): refers to the white pore surface and layered basidiocarps.

**Diagnosis.** Differing from *Fomitopsis s. s.* by its annual basidiocarps, ovoid to broadly ellipsoid basidiospores.

Basidiocarps annual, sessile, tough when fresh and hard corky upon drying. Pileal surface ivory white to ochraceous or black brown, azonate, appressed-strigose to glabrous, smooth or rugose. Pore surface white when fresh, becoming cream to buff or pale buff brown upon drying; pores round to angular. Context white to ochraceous, tough-corky. Hyphal system dimitic with frequently branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless, IKI–, CB–. Cystidia absent, thin-walled cystidioles present. Basidiospores ovoid to broadly ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Grows on angiosperm wood and causes a brown rot.

**Remarks.** Three samples of *Niveoporofomes spraguei* from France, USA and China formed a single lineage with a high support (Figs. 1 and 2), and was distinct from *Fomitopsis s. s.* Morphologically, *Niveoporofomes* differs from *Fomitopsis s. s.* in its annual growth habit and ovoid to broadly ellipsoid basidiospores.

**Niveoporofomes spraguei** (Berk. & M.A. Curtis) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3h)

Mycobank no.: MB 812652

Basionym. *Polyporus spraguei* Berk. & M.A. Curtis, Grevillea 1: 50, 1872.

= *Fomitopsis spraguei* (Berk. & M.A. Curtis) Gilb. & Ryvarden, Mycotaxon 22: 364, 1985.

For a detailed description of *Fomitopsis spraguei*, see Ryvarden and Melo (2014).

**Specimens examined.** CHINA. Guangdong Prov., Zhaoqing, Dinghushan Nature Reserve, on fallen angiosperm trunk, 30 June 2010, B.K. Cui 8969 (BJFC 007907); Hunan Prov., Zhangjiajie Forest Park, on dead tree of *Castanea*, 17 August 2010, Y.C. Dai 11676 (BJFC 008800). FRANCE. Lons, 27 September 2012, 4638 (BJFC 013985). USA. Pennsylvania, Little Falls, Promised Land State Park, on *Quercus*, 19 September 2010, J. Vlasák 1009/46 (JV); Schwenksville, Spring Mountain, on *Quercus*, 4 September 2008, J. Vlasák 0809/20 (JV); Tennessee, Cove Hardwood Nature Trail,

Great Smoky Mountain, on angiosperm, 6 September 2005, *J. Vlasák 0509/62* (JV).

***Piptoporellus*** B.K. Cui, M.L. Han & Y.C. Dai, gen. nov.  
Mycobank no.: MB 812653

*Type species. Piptoporellus soloniensis* (Dubois) B.K. Cui, M.L. Han & Y.C. Dai.

*Etymology. Piptoporellus* (Lat.): resembling *Piptoporus*.

*Diagnosis.* Differing from *Piptoporus* by its thick-walled with a distinct wide lumen skeletal hyphae, and cylindrical to ellipsoid basidiospores.

Basidiocarps annual, pileate, substipitate, corky or soft fibrous upon drying. Pileal surface cream, buff, cinnamon to orange, velutinate or glabrous, azonate. Pore surface cream, buff, yellow to light brown; pores small, round to angular. Context cream to pinkish buff, corky or soft fibrous, thicker than tubes. Tubes fibrous to fragile. Hyphal system dimitic, generative hyphae with clamp connections, skeletal hyphae thick-walled with a distinctly wide lumen, occasionally branched, IKI–, CB–; generative hyphae and skeletal hyphae mostly dissolved in KOH. Cystidia absent, thin-walled cystidioles present or absent. Basidiospores cylindrical to ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Usually grows on angiosperm wood and causes a brown rot.

*Remarks.* In our study, *Piptoporus soloniensis* (Dubois) Pilát was clustered with two new species from China and formed a highly supported lineage (Figs. 1 and 2) in the antrodia clade. *Piptoporus* is treated as a synonym of *Fomitopsis*, therefore, *Piptoporellus* gen. nov. is proposed to accommodate *P. soloniensis* and the two new species from China, described below.

*Piptoporellus* resembles *Laetiporus* Murrill by sharing annual, pileate to stipitate, corky to fragile basidiocarps, orange pileal surface, cream to yellow pore surface, a dimitic hyphal system and thin-walled basidiospores (Núñez and Ryvarden 2001). But *Laetiporus* differs in simple-septate generative hyphae and ovoid to broadly ellipsoid basidiospores (Núñez and Ryvarden 2001).

***Piptoporellus hainanensis*** M.L. Han, B.K. Cui & Y.C. Dai, sp. nov. (Figs. 3i, j and 6)

Mycobank no.: MB 812654

*Holotype. CHINA.* Hainan Prov., Ledong County, Jianfengling Nature Reserve, on angiosperm stump, 17 June 2014, *Y.C. Dai 13714* (BJFC 017451).

*Etymology. hainanensis* (Lat.): refers to the type locality, Hainan Province in China.

*Diagnosis.* Differing from other *Piptoporellus* species by its cream to buff pileal surface and lacking cystidia or other sterile hymenial elements.

*Fruiting body.* Basidiocarps annual, pileate, with a lateral base, solitary, corky, without odor or taste when fresh, hard corky and light in weight upon drying. Pileus dimidiate, flabelliform or semicircular, applanate to convex, projecting up to 9 cm, 7.8 cm wide, 1.7 cm thick at base. Pileal surface

cream to buff, glabrous, azonate, radially streaked; margin cream, acute, incurved. Pore surface cream to buff or yellow, shining; sterile margin indistinct; pores round to angular or irregular, 4–5 per mm; dissepiments thin, entire. Context cream, hard corky, up to 1.1 cm thick. Tubes paler than or concolourous with pore surface, fragile, up to 6 mm long.

*Hyphal structure.* Hyphal system dimitic; generative hyphae bearing clamp connections, mostly dissolved in KOH; skeletal hyphae IKI–, CB–, mostly dissolved in KOH; tissues becoming orange in KOH.

*Context.* Generative hyphae infrequently, hyaline, thin-walled, occasionally branched, 2.5–4 µm in diam.; skeletal hyphae dominant, colorless, thick-walled with a distinctly wide lumen, occasionally branched, flexuous, interwoven, 2–9 µm in diam.

*Tubes.* Generative hyphae hyaline, thin-walled, occasionally branched, 2.5–4 µm in diam.; skeletal hyphae dominant, colorless, thick-walled with a wide lumen, rarely branched, flexuous, interwoven, 2–4 µm in diam. Cystidia or other sterile hymenial structures absent. Basidia clavate, bearing four sterigmata and a basal clamp connection, 10–17 × 4–5 µm; basidioles in shape similar to basidia, but distinctly smaller.

*Spores.* Basidiospores cylindrical to oblong-ellipsoid, tapering at apiculus, hyaline, thin-walled, smooth, IKI–, CB–, 4–5 × 2–2.8(–3) µm, L=4.51 µm, W=2.37 µm, Q=1.87–1.91 (n=60/2).

*Additional specimen (paratype) examined. CHINA.* Hainan Prov., Ledong County, Jianfengling Nature Reserve, on fallen angiosperm trunk, 17 June 2014, *Y.C. Dai 13725* (BJFC 017462).

*Remarks.* Three species in the genus so far, *Piptoporellus triqueter* differs from *P. hainanensis* by buff-yellow or salmon to brownish orange pileal surface and presence of cystidioles, *P. soloniensis* differs by cream to cinnamon or light orange pileal surface and presence of cystidioles.

***Piptoporellus soloniensis*** (Dubois) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3l)

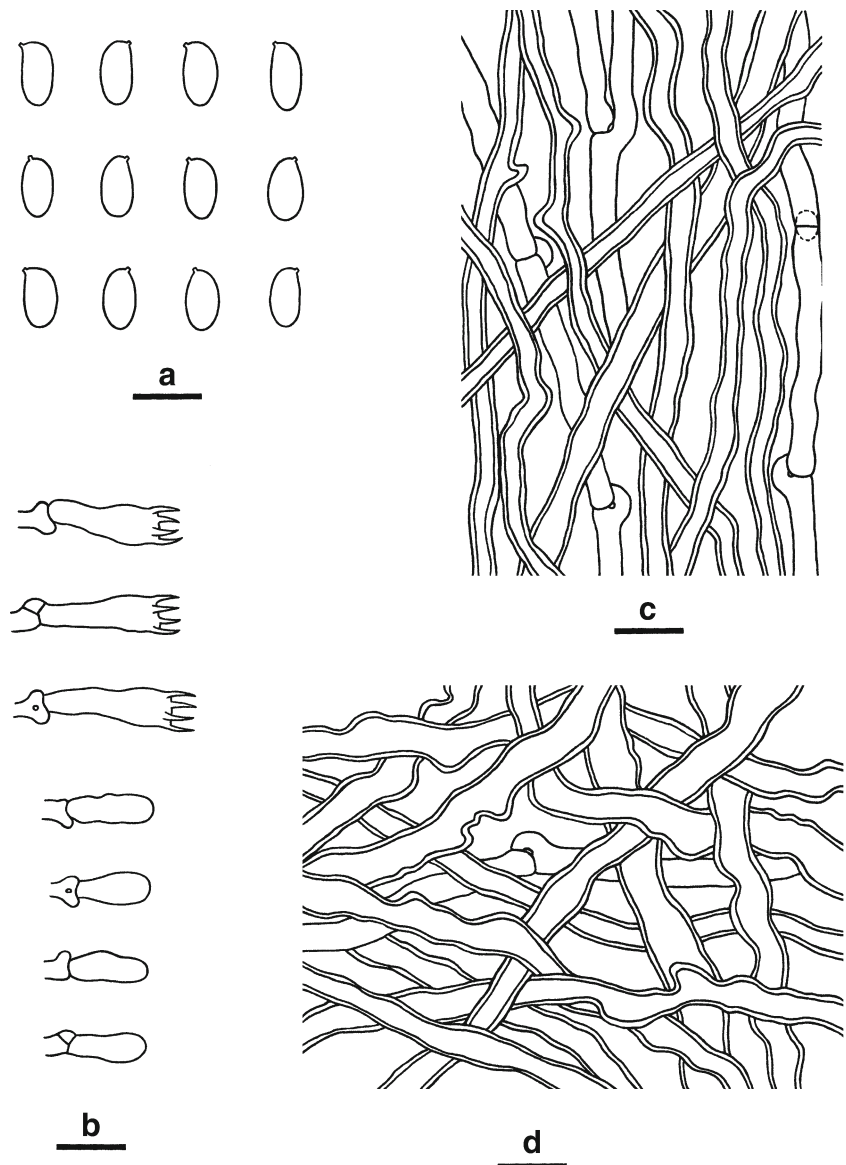
Mycobank no.: MB 812656

Basionym. *Agaricus soloniensis* Dubois, Méth. éprouv. (Orleans): 177, 1803.

= *Piptoporus soloniensis* (Dubois) Pilát, in Kavina & Pilát, Atlas Champ. l'Europe (Praha) 3: 126, 1937.

*Remarks.* One specimen of *Piptoporellus soloniensis* (LY BR 5463), which was collected from the type locality in France was examined. It is characterized by cream to cinnamon or light orange pileal surface, cream to buff or honey-yellow, shining pore surface with large pores (2–4 per mm), a dimitic hyphal system with narrower contextual generative hyphae (2–5 µm) and skeletal hyphae (2–5 µm), thin-walled, fusoid cystidioles and cylindrical to oblong-ellipsoid basidiospores (4–6 × 2.5–3.5 µm). While the Chinese specimens have relatively

**Fig. 6** Microscopic structures of *Piptoporellus hainanensis* (drawn from the holotype). **a.** Basidiospores; **b.** Basidia and basidioles; **c.** Hyphae from trama; **d.** Hyphae from context. Bars: **a** = 5  $\mu\text{m}$ ; **b–d** = 10  $\mu\text{m}$



smaller pores (3–6 per mm) and smaller basidiospores (4.5–5.5  $\times$  2–3  $\mu\text{m}$ ). For a detailed description of *P. soloniensis*, see Ryvarden and Melo (2014).

**Specimens examined.** CHINA. Anhui Prov., Huangshan Mountain, on stump of *Castanopsis*, 21 October 2010, *Y.C. Dai 11872* (BJFC 008975); Fujian Prov., Fuzhou, Fuzhou Botanical Garden, on dead angiosperm tree, 28 October 2013, *Y.C. Dai 11386* (BJFC 015502); Jiangxi Prov., Yingtan, Longhu Mountain, on living tree of *Castanea*, 5 October 2008, *B.K. Cui 5952* (BJFC 003808); Zhejiang Prov., Longquan, Tiantang Mountain, on fallen angiosperm trunk, 29 August 2013, *B.K. Cui 11389* (BJFC 015505); Qingyuan County, Baishanzu Nature Reserve, on fallen angiosperm trunk, 14 September 2013, *B.K. Cui 11390* (BJFC 015506). FRANCE. Montirac, Lagarde Viaur rive gauche du Viaur, on *Castanea*, 27 May 2014, *LY BR 5463* (LY).

*Piptoporellus triqueter* M.L. Han, B.K. Cui, & Y.C. Dai, sp. nov. (Figs. 3k and 7)

Mycobank no.: MB 812655

**Holotype.** CHINA. Yunnan Prov., Yingjiang County, Tongbiguan Nature Reserve, on fallen trunk of *Castanopsis*, 29 October 2012, *Y.C. Dai 13121* (BJFC 013339).

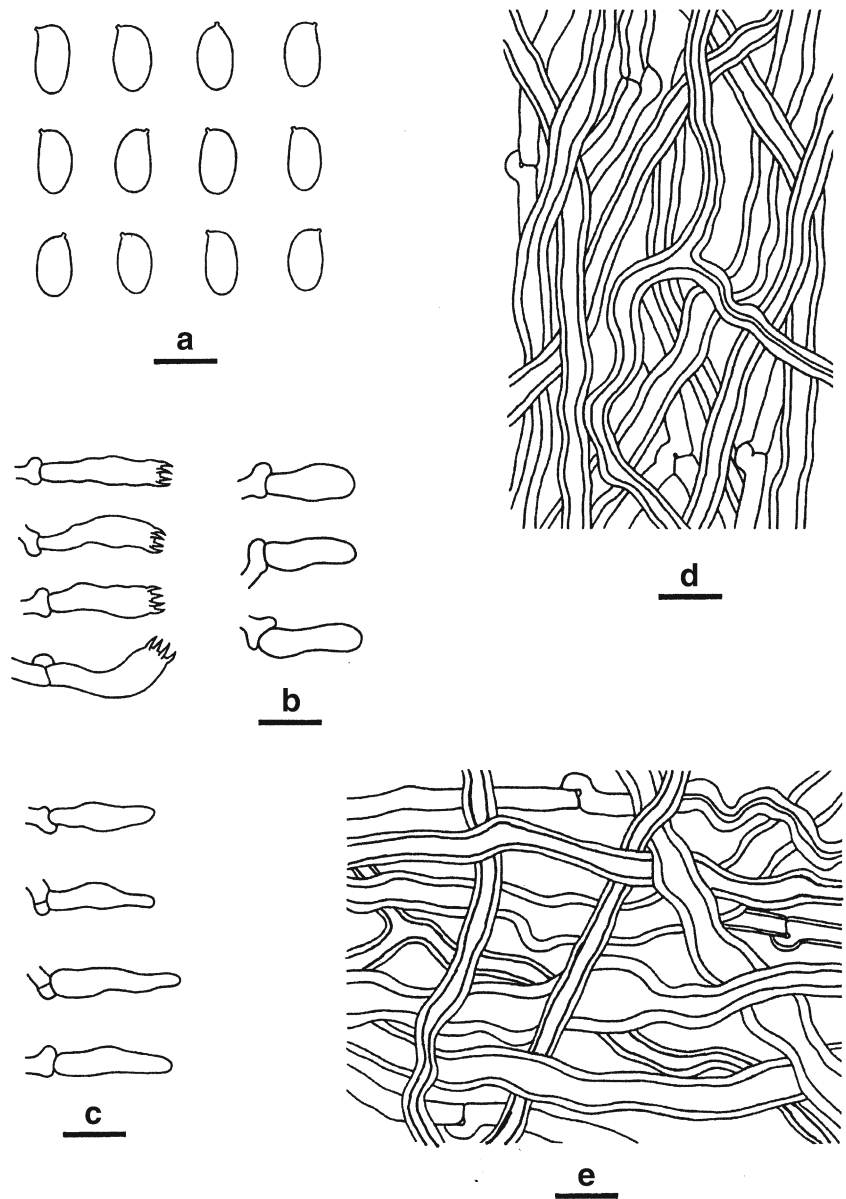
**Etymology.** *triqueter* (Lat.): refers to the triquetrous shape of longitudinal section of fruiting body.

**Diagnosis.** Differing from other *Piptoporellus* species by buff-yellow or salmon to brownish orange pileal surface, wide skeletal hyphae (2.5–7  $\mu\text{m}$  in trama, 3–11  $\mu\text{m}$  in context), and ellipsoid basidiospores (4–6  $\times$  2.8–3.1  $\mu\text{m}$ ).

**Fruiting body.** Basidiocarps annual, pileate, sessile, solitary, corky, without odor or taste when fresh, fragile and light in weight upon drying. Pileus triquetrous, projecting up to 3.5 cm, 2.3 cm wide, 1.5 cm thick at base. Pileal surface



**Fig. 7** Microscopic structures of *Piptoporellus triqueter* (drawn from the holotype). **a.** Basidiospores; **b.** Basidia and basidioles; **c.** Cystidioles; **d.** Hyphae from trama; **e.** Hyphae from context. Bars: **a** = 5  $\mu\text{m}$ ; **b–e** = 10  $\mu\text{m}$



buff-yellow or salmon to brownish orange, glabrous, azonate; margin salmon to brownish orange, acute. Pore surface cream or buff to light brown; sterile margin distinct, up to 7 mm wide, cream to brownish orange; pores round to angular, 3–4 per mm; dissepiments thin, entire. Context distinctly thicker than tubes, cream to pinkish buff, corky, up to 1.45 cm thick. Tubes concolourous with pore surface, fragile, up to 0.5 mm long.

**Hyphal structure.** Hyphal system dimitic; generative hyphae bearing clamp connections, mostly dissolved in KOH; skeletal hyphae IKI–, CB–, mostly dissolved in KOH; tissues becoming reddish brown in KOH.

**Context.** Generative hyphae hyaline, thin- to slightly thick-walled, rarely branched, 3–7  $\mu\text{m}$  in diam.; skeletal hyphae dominant, colorless, thick-walled with a wide lumen,

occasionally with a narrow lumen to subsolid, rarely branched, flexuous, interwoven, 3–11  $\mu\text{m}$  in diam.

**Tubes.** Generative hyphae hyaline, thin- to slightly thick-walled, occasionally branched, 2–5  $\mu\text{m}$  in diam.; skeletal hyphae dominant, colorless, thick-walled with a distinctly wide or narrow lumen, occasionally branched, flexuous, interwoven, 2.5–7  $\mu\text{m}$  in diam. Cystidia absent, fusoid cystidioles present, hyaline, thin-walled, 13–21  $\times$  3–4  $\mu\text{m}$ . Basidia clavate, bearing four sterigmata and a basal clamp connection, 15–26  $\times$  4.8–7  $\mu\text{m}$ ; basidioles in shape similar to basidia, but slightly smaller.

**Spores.** Basidiospores ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–, 4–6  $\times$  (2.5–)2.8–3.1(–3.2)  $\mu\text{m}$ , L = 4.92  $\mu\text{m}$ , W = 2.96  $\mu\text{m}$ , Q = 1.66 (n = 60/1).

*Remarks.* *Piptoporellus soloniensis* may be confused with *P. triqueter* by sharing similar sized pores, a dimitic hyphal system, and similar sized ellipsoid basidiospores, but *P. soloniensis* differs in cream to cinnamon or light orange pileal surface and narrower skeletal hyphae (2–5 µm) in context.

*Additional specimen (paratype) examined.* CHINA. Guangdong Prov., Fengkai County, Heishiding Nature Reserve, on rotten angiosperm wood, 21 October 2014, *F. Li 1896* (BJFC 019281).

*Rhodofomes* Kotl. & Pouzar, Česká Mykol. 44: 235, 1990.

*Type species.* *Rhodofomes rosea* (Alb. & Schwein.) Kotl. & Pouzar.

Basidiocarps perennial, mostly sessile, leathery when fresh, hard corky when dry. Pileal surface rose-pink, brown or black, velutinate or glabrous, mostly strongly zonate and sulcate. Pore surface pinkish to vinaceous when fresh, clay-pink to brownish vinaceous when dry; pores small, round to angular. Context whitish pink, pinkish brown or brown, hard corky, sometimes with a thin crust at the upper surface. Tubes distinctly stratified. Hyphal system dimitic with more or less branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless to pale yellow or pale brown, thick-walled with a narrow lumen to subsolid, IKI–, CB–. Cystidia absent, thin-walled cystidioles usually present. Basidiospores cylindrical to ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Grows on both gymnosperm and angiosperm wood, and causes a brown rot.

*Remarks.* According to Nobles (1971), *Fomitopsis cajanderi* was closely related to the species of *Daedalea* s. s. sharing several important morphological characters. After Nobles' view, Donk (1974) suggested the removal of *F. cajanderi* from *Fomitopsis* and its inclusion into *Daedalea* or any other related group. Subsequently, a new genus, *Rhodofomes* Kotl. & Pouzar, was proposed by Kotlába and Pouzar (1990, 1998) with *R. rosea* (Alb. & Schwein.) Kotl. & Pouzar as type species. But the concept of the genus has been controversial and remained insufficiently resolved (Kim et al. 2005, 2007; Ortiz-Santana et al. 2013; Han et al. 2014; Ryvarden and Melo 2014). In our study, species of *Rhodofomes* formed a well-supported lineage (Figs. 1 and 2), which was distant from *Fomitopsis* s. s., and closely related to species of *Antrodia serialis* (Fr.) Donk group *Rubellofomes* and *Niveoporofomes*. However, *Antrodia serialis* group has mostly resupinate to effused-reflexed basidiocarps, white, cream to wood-colored pore surface and a dimitic hyphal system with mostly unbranched skeletal hyphae (Núñez and Ryvarden 2001; Ryvarden and Melo 2014); *Rubellofomes* has white to cream or purple pink pore surface when fresh, which becoming straw yellow to cinnamon brown when dry; *Niveoporofomes* has soft coky to fragile basidiocarps, white pore surface when fresh, which

becoming yellowish brown upon drying and cream context. Thus, *Rhodofomes* is recognized as an independent genus, and five species including four new combinations are proposed in the genus.

*Rhodofomes cajanderi* (P. Karst.) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3m)

Mycobank no.: MB 812657

Basionym. *Fomes cajanderi* P. Karst., Finl. Basidsvamp. 46: 8, 1904.

= *Fomitopsis cajanderi* (P. Karst.) Kotl. & Pouzar, Česká Mykol. 11: 157, 1957.

For a detailed description of *Fomitopsis cajanderi*, see Carranza-Morse and Gilbertson (1986) and Ryvarden and Melo (2014).

*Specimens examined.* CHINA. Heilongjiang Prov., Yichun, Fenglin Nature Reserve, on fallen trunk of *Picea*, 2 August 2011, *B.K. Cui 9879* (BJFC 010772); *B.K. Cui 9888* (BJFC 010781); Jilin Prov., Antu County, Changbaishan Nature Reserve, on fallen trunk of *Picea*, 12 December 2007, *Y.C. Dai 9024* (BJFC 000701). USA. Virginia, Woodbrige, Mason Neck State Park, on *Pinus*, October 2004, *J. Vlasák 0410/14a,b-J* (JV).

*Rhodofomes carneus* (Blume & T. Nees) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3n)

Mycobank no.: MB 812658

Basionym. *Fomes carneus* Blume & T. Nees, Nova Acta Academiae Caesareae Leopoldino-Carolinae Germanicae Naturae Curiosorum 13: 15, 1826.

= *Fomitopsis carnea* (Blume & T. Nees) Imazeki, Bull. Tokyo Sci. Mus. 6: 92, 1943.

For a detailed description of *Fomitopsis carnea*, see Ryvarden and Johansen (1980) and Carranza-Morse and Gilbertson (1986).

*Specimens examined.* JAPAN. Mt. Fujii, on *Prunus*, 19 October 1947, *Imazeki 1836* (O 10789). TANZANIA. Arusha Province, Arusha National Park, Ngurdoto crater, 10 August 1966 (O 15519); Mountain Meru E, 8 February 1973, *L. Ryvarden 10118* (O 15520).

*Rhodofomes incarnatus* (K.M. Kim, J.S. Lee & H.S. Jung) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3o)

Mycobank no.: MB 812659

Basionym. *Fomitopsis incarnatus* K.M. Kim, J.S. Lee & H.S. Jung, Mycologia 99: 835, 2007.

For a detailed description of *Fomitopsis incarnatus*, see Kim et al. (2007).

*Specimens examined.* CHINA. Henan Prov., Neixiang County, Baotianman Nature Reserve, on rotten wood of *Quercus*, 23 September 2009, *Y.C. Dai 11325* (BJFC 007471); Shaanxi Prov., Zhouzhi County, Taibaishan Nature Reserve, on fallen trunk of *Quercus*, 24 October 2006, *H.S. Yuan 2653* (IFP 001823); Yunnan Prov., Lanping County, Tongdian, Luoguqing, on fallen trunk of *Quercus*, 19 September 2011, *B.K. Cui 10348* (BJFC 011243).

***Rhodofomes rosea*** (Alb. & Schwein.) Kotl. & Pouzar, Česká Mykol. 44: 235, 1990. (Fig. 3p)

Basionym. *Boletus roseus* Alb. & Schwein., Consp. fung. (Leipzig): 251, 1805.

= *Fomitopsis rosea* (Alb. & Schwein.) P. Karst., Meddn Soc. Fauna Flora fenn. 6: 9, 1881.

For a detailed description of *Fomitopsis rosea*, see Carranza-Morse and Gilbertson (1986) and Ryvarden and Melo (2014).

**Specimens examined.** CHINA. Sichuan Prov., Jiuzhaigou County, Jiuzhaigou Nature Reserve, on fallen trunk of *Picea*, 12 October 2012, B.K. Cui 10633 (BJFC 013558); Xinjiang Autonomous Region, Jimusa'er County, Tianchi Nature Reserve, on fallen trunk of *Picea*, 25 August 2004, Y.L. Wei 1689 (IFP 001906); Xizang Autonomous Region, Linzhi County, Lulang, on fallen trunk of *Abies*, 16 September 2010, B.K. Cui 9278 (BJFC 008217); Yunnan Prov., Xianggelila County, Pudacuo national park, on fallen trunk of *Abies*, 24 September 2011, B.K. Cui 10520 (BJFC 011415). CZECH REPUBLIC. Cervene Blato, Bor, on *Picea*, 22 October 2011, J. Vlasák 1110/9 (JV). FINLAND. Helsinki, Vantaa, Tamisto Nature Reserve, on fallen trunk of *Picea*, 3 November 2011, Y.C. Dai 12613 (BJFC 012199).

***Rhodofomes subfeei*** (B.K. Cui & M.L. Han) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3q)

Mycobank no.: MB 812672

Basionym. *Fomitopsis subfeei* B.K. Cui & M.L. Han, Mycoscience 56: 170, 2015.

For a detailed description of *Fomitopsis subfeei*, see Han and Cui (2015).

**Specimens examined.** CHINA. Anhui Prov., Huangshan Mountain, on rotten wood of *Cunninghamia*, 21 October 2010, Y.C. Dai 11887 (paratype, BJFC 008989); Jiangxi Prov., Fenyi County, Dagang Mountain, on rotten wood of *Cunninghamia*, 18 September 2008, Y.C. Dai 10430 (BJFC 004679); Sichuan Prov., Dujiangyan, Qingcheng Mountain, on stump of *Cunninghamia*, 13 September 2010, B.K. Cui 9231 (holotype, BJFC 008169); on angiosperm stump, 13 September 2010, B.K. Cui 9229 (BJFC 008167); B.K. Cui 9226 (paratype, BJFC 008164).

***Rhodofomitopsis*** B.K. Cui, M.L. Han & Y.C. Dai, gen. nov.

Mycobank no.: MB 812660

Type species. *Rhodofomitopsis feei* (Fr.) B.K. Cui, M.L. Han & Y.C. Dai.

**Etymology.** *Rhodofomitopsis* (Lat.): resembling *Fomitopsis* but with violaceous pore surface.

**Diagnosis.** Differing from *Fomitopsis s. s.* by its rose, violaceous to pinkish-brown pore surface and context, round, angular, or slightly labyrinthiform, subdaedaleoid to sinuous-daedaleoid pores and absence of cystidia or other sterile hymenial elements.

Basidiocarps annual to perennial, mostly sessile, coriaceous to woody hard when dry. Pileal surface straw, tan, brownish pink, rosy brown to blackish brown, velutinate or glabrous, slightly zonate, weakly or strongly sulcate, mostly strongly radially streaked. Pore surface rose, lilac, violaceous, pinkish-brown or dirty brown, pores round, angular, or slightly labyrinthiform, subdaedaleoid to sinuous-daedaleoid. Context rose, lilac, or pinkish-brown. Tubes indistinctly stratified. Hyphal system dimitic with more or less branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless to pale yellow or pale brown, contextual vegetative hyphae thick-walled with a distinctly wide lumen, IKI–, CB–. Cystidia or other sterile hymenial structures absent. Basidiospores cylindrical, ellipsoid or navicular, hyaline, thin-walled, smooth, IKI–, CB–. Grows on angiosperm wood and causes a brown rot.

**Remarks.** In our phylogenetic analysis, species of *Rhodofomitopsis* formed a single lineage (Figs. 1 and 2), and it was distant from *Fomitopsis s. s.* Morphologically, *Rhodofomitopsis* differs from *Fomitopsis s. s.* by its rose, violaceous to pinkish-brown pore surface and context, absence of cystidioles and living on angiosperm wood. Four new combinations are proposed in *Rhodofomitopsis*.

***Rhodofomitopsis africana*** (Mossebo & Ryvarden) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov.

Mycobank no.: MB 812661

Basionym. *Fomitopsis africana* Mossebo & Ryvarden, Sydowia 49: 148, 1997.

**Remarks.** *Rhodofomitopsis africana* was originally described from Cameroon as *Fomitopsis africana* (Mossebo and Ryvarden 1997), it has strongly radially streaked pileal surface, dirty brown with pink shades pore surface, absence of cystidia or other sterile hymenial structures, cylindrical to navicular basidiospores and grows on angiosperm wood; these characters fit *Rhodofomitopsis* well. Moreover, the sequence of *R. africana* from Cameroon (type locality) fell into *Rhodofomitopsis* in our phylogeny (Figs. 1 and 2). Therefore, *F. africana* is transferred to *Rhodofomitopsis*. For a detailed description of *F. africana*, see Mossebo and Ryvarden (1997).

***Rhodofomitopsis cupreorosea*** (Berk.) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3r)

Mycobank no.: MB 812662

Basionym. *Polyporus cupreoroseus* Berk., Hooker's J. Bot. Kew Gard. Misc. 8: 233, 1856.

= *Fomitopsis cupreorosea* (Berk.) J. Carranza & Gilb., Mycotaxon 25: 476, 1986.

For a detailed description of *Fomitopsis cupreorosea*, see Carranza-Morse and Gilbertson (1986).

**Specimens examined.** BELIZE. Cayo District, Five sisters, Nature trail, on angiosperm, 19 November 2001, L. Ryvarden 44394 (O 17632); on angiosperm, 2 November 2002, L. Ryvarden 45383 (O 18277).

**BRAZIL.** Pernambuco, Camaragibe, on angiosperm, 07 June 1960, *R. Singer B3106* (K 8405).

*Rhodofomitopsis feei* (Fr.) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3s)

Mycobank no.: MB 812663

Basionym. *Polyporus feei* Fr., *Linnaea* 5: 518, 1830.

= *Fomitopsis feei* (Fr.) Kreisel, *Ciencias Biológicas*, Cuba 16: 83, 1971.

For a detailed description of *Fomitopsis feei*, see Carranza-Morse and Gilbertson (1986) and Gilbertson and Ryvarden (1986a).

*Specimens examined.* **AUSTRALIA.** Darwin, Bicentennial Park, on angiosperm stump, 6 June 1999, *P. Uotila 42928* (H). **BRAZIL.** Bahia, Municipality of Itaberaba, Serra do Orobó, Haberaba, Fazenda gameleira, on fallen angiosperm trunk, 19 January 2006, *P. Oinonen 60119006* (H). **MEXICO.** Semuc Champey, on angiosperm, October 2006, *J. Vlasák 0610/K9-Kout* (JV). **VENEZUELA.** Estado Bolívar, Las Nieves, on angiosperm, 12 January 1995, *L. Ryvarden 37603* (O 10804).

*Rhodofomitopsis lilacinogilva* (Berk.) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3t, u)

Mycobank no.: MB 812664

Basionym. *Polyporus lilacinogilvus* Berk., *Ann. nat. Hist., Mag. Zool. Bot. Geol.* 3: 324, 1839.

= *Fomitopsis lilacinogilva* (Berk.) J.E. Wright & J.R. Deschamps, *Revta Investnes agrop.* 12: 143, 1975.

For a detailed description of *Fomitopsis lilacinogilva*, see Carranza-Morse and Gilbertson (1986).

*Specimens examined.* **ARGENTINA.** Rios Palmar de Colen, September 1979, *D. Cubral* (O 10820). **AUSTRALIA.** Queensland, Lake Barrine, on angiosperm, 19 August 2006, *D.S. Schigel 5193* (H); Tasmania, Mt. Wellington, Pipeline track, 18 January 1996, *A.V. Ratkowsky 0564* (K 141868); Myrtle Gulley, on wood, 25 May 1996, *A.V. Ratkowsky 0562* (K 141881).

*Rubellofomes* B.K. Cui, M.L. Han & Y.C. Dai, gen. nov.

Mycobank no.: MB 812665

*Type species.* *Rubellofomes cystidiatus* (B.K. Cui & M.L. Han) B.K. Cui, M.L. Han & Y.C. Dai.

*Etymology.* *Rubellofomes* (Lat.): resembling *Fomes* but with pinkish context.

*Diagnosis.* Differing from *Fomitopsis s. s.* by its purple pink to light pinkish brown context.

Basidiocarps annual or perennial, resupinate to pileate, coriaceous to woody when dry. Pileal surface orange brown to dark brown, glabrous, mostly strongly zonate and sulcate. Pore surface white to cream or purple pink when fresh, straw yellow to cinnamon brown when dry. Context purple pink to light pinkish brown, corky or woody hard. Hyphal system dimitic with occasionally branched skeletal hyphae, generative hyphae with clamp connections, skeletal hyphae colorless to pale yellow or light brown, IKI–, CB–. Cystidia present or

absent, thin-walled cystidioles present. Basidiospores cylindrical to ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Grows on angiosperm wood and causes a brown rot.

*Remarks.* In the combined six gene phylogenetic tree (Fig. 2), two species previously included in *Fomitopsis*, *F. cystidiata* B.K. Cui & M.L. Han and *F. minutispora* Rajchenb., grouped together and formed a moderately supported lineage, these two species were distant from *Fomitopsis s. s.*, and they were related to species of the *Antrodia serialis* group and *Niveoporofomes*; in the combined three gene phylogenetic tree (Fig. 1), *Rubellofomes* was closely related to species of *Niveoporofomes* and *Ungulidaedalea*. However, *A. serialis* group mostly grows on gymnosperm wood and has mostly resupinate to effused-reflexed basidiocarps and white, cream to wood-colored context (Núñez and Ryvarden 2001; Ryvarden and Melo 2014); *Niveoporofomes* has ivory white to ochraceous pileal surface, white to ochraceous context and ovoid to broadly ellipsoid basidiospores; *Ungulidaedalea* has annual, unguulate, fragile basidiocarps and a dimitic hyphal system with densely septated skeletal hyphae. Therefore, *Rubellofomes* gen. nov. is proposed to accommodate *F. cystidiata* and *F. minutispora*.

*Rubellofomes cystidiatus* (B.K. Cui & M.L. Han) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3v)

Mycobank no.: MB 812666

Basionym. *Fomitopsis cystidiata* B.K. Cui & M.L. Han, *Mycological Progress* 13: 908, 2014.

For a detailed description of *Fomitopsis cystidiata*, see Han et al. (2014).

*Specimens examined.* **CHINA.** Guangxi Autonomous Region, Shangsi County, Shiwandashan National Forest Park, on fallen angiosperm trunk, 26 July 2012, *H.S. Yuan 6304* (paratype, BJFC 015623), *H.S. Yuan 6328* (paratype, BJFC 015624); Hainan Prov., Baoting County, Qixianling National Forest Park, on fallen angiosperm trunk, 27 November 2007, *B.K. Cui 5481* (holotype, BJFC 003522); Lingshui County, Diaoluoshan National Forest Park, on angiosperm stump, 30 May 2008, *Y.C. Dai 9872* (paratype, IFP 012400).

*Rubellofomes minutisporus* (Rajchenb.) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3w)

Mycobank no.: MB 812667

Basionym. *Fomitopsis minutispora* Rajchenb., *Mycotaxon* 54: 441, 1995.

For a detailed description of *Fomitopsis minutispora*, see Rajchenberg (1995a).

*Specimens examined.* **ARGENTINA.** Nenquén, Parque Nacional Lanín, on fallen trunk of *Nothofagus*, 10 April 1992, *M. Rajchenberg 10661* (BAFC 015543), *M. Rajchenberg 10666* (BAFC 015544); 19 May 1999, *M. Rajchenberg 11930* (BAFC 015542).

*Ungulidaedalea* B.K. Cui, M.L. Han & Y.C. Dai, gen. nov.

Mycobank no.: MB 814711



*Type species.* *Ungulidaedalea fragilis* (B.K. Cui & M.L. Han) B.K. Cui, M.L. Han & Y.C. Dai.

*Etymology.* *Ungulidaedalea* (Lat.): resembling *Daedalea* but with unguulate basidiocarps.

*Diagnosis.* Differing from *Fomitopsis s. s.* and *Daedalea s. s.* by its annual, unguulate, fragile basidiocarps, a dimitic hyphal system with densely septated skeletal hyphae and oblong-ellipsoid basidiospores.

Basidiocarps annual, pileate, fragile when dry. Pileus unguulate. Pileal surface brown to dark fuscous, concentrically zonate. Pore surface white to cream when fresh, becoming clay-buff to brown when burnished or dry, pores large, angular. Context buff to clay-buff, fragile, upper surface usually with a crust. Tubes fragile. Hyphal system dimitic, generative hyphae bearing clamp connections; skeletal hyphae frequently simple septate, IKI–, CB–. Cystidia absent, but thin-walled cystidioles occasionally present. Basidiospores oblong-ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–. Grows on angiosperm wood and causes a brown rot.

*Remarks.* *Fomitopsis fragilis* B.K. Cui & M.L. Han was recently described from China based on the rDNA sequences of ITS and nLSU regions, and it formed a separated lineage in *Fomitopsis s. l.* (Han et al. 2014). In the combined six gene phylogenetic analysis (Fig. 2), *F. fragilis* formed a single lineage sister to the species of *Daedalea s. s.* In the combined three gene phylogenetic tree (Fig. 1), *F. fragilis* also formed a single lineage and closely related to the species of *Antrodia malicola* (Berk. & M.A. Curtis) Donk group. Morphologically, it differs from species of *Daedalea s. s.* and *Antrodia malicola* group by unguulate, fragile basidiocarps and a dimitic hyphal system with frequently simple septate skeletal hyphae. Thus, *Ungulidaedalea* gen. nov. is proposed to include this species.

*Ungulidaedalea fragilis* (B.K. Cui & M.L. Han) B.K. Cui, M.L. Han & Y.C. Dai, comb. nov. (Fig. 3x)

Mycobank no.: MB 814712

Basionym. *Fomitopsis fragilis* B.K. Cui & M.L. Han, Mycological Progress 13: 909, 2014.

For a detailed description of *Fomitopsis fragilis*, see Han et al. (2014).

*Specimens examined.* CHINA. Hainan Prov., Ledong County, Jianfengling National Nature Reserve, on fallen angiosperm trunk, 7 November 2012, B.K. Cui 10919 (holotype, BJFC 013841); 17 November 2007, Y.C. Dai 9292 (paratype, BJFC 010337; IFP 007452); on wood, 18 November 2007, H.S. Yuan 4081 (IFP 016598).

## Discussions

Recently, several phylogenetic studies were focused on *Fomitopsis*, and species of *Fomitopsis s. l.* were included in different clades (Kim et al. 2005, 2007; Zhou and Wei 2012; Li

et al. 2013; Ortiz-Santana et al. 2013; Han et al. 2014). Our phylogenetic analysis confirmed that *Fomitopsis s. l.* is polyphyletic based on multiple loci, and it is clustered with other brown-rot genera in the antrodia clade (Binder et al. 2005; Ortiz-Santana et al. 2013).

The segregation of *Fragifomes*, *Niveoporofomes*, *Rhodofomes*, *Rhodofomitopsis*, *Rubellofomes* and *Ungulidaedalea* from *Fomitopsis s. s.* was strongly supported by phylogenetic analysis inferred from the combined datasets of ITS+nLSU+*rpb2* sequences (Fig. 1) and ITS+nLSU+nSSU+mtSSU+*tef1*+*rpb2* sequences (Fig. 2). Morphologically, *Rhodofomes*, *Rhodofomitopsis* and *Rubellofomes* all have pinkish context and a dimitic hyphal system with branched skeletal hyphae, but *Rhodofomitopsis* differs from *Rhodofomes* and *Rubellofomes* by its round, angular, or slightly labyrinthiform, subdaedaleoid to sinuous-daedaleoid pores and thick-walled contextual skeletal hyphae with a distinctly wide lumen; *Rubellofomes* differs from *Rhodofomes* by white to cream or purple pink pore surface when fresh, which becoming straw yellow to cinnamon brown when dry. *Fragifomes* and *Niveoporofomes* share similar pore surface, but *Niveoporofomes* differs from *Fragifomes* by its annual, tough and corky basidiocarps and ovoid to broadly ellipsoid basidiospores.

Morphologically, *Daedalea s. s.* is different from *Fomitopsis s. s.* by irregular, poroid, labyrinthine/daedaleoid to lamellate or hydroid hymenophores and catahymenium formed by skeletal hyphae penetrated into the hymenia; moreover, species in *Daedalea s. s.* grow on angiosperm wood, while species in *Fomitopsis s. s.* occur on both angiosperm and gymnosperm wood (Ryvarden and Johansen 1980; Gilbertson and Ryvarden 1986a; Núñez and Ryvarden 2001; Ryvarden and Melo 2014). In the current study, species of *Daedalea s. s.* formed a monophyletic lineage, which was distant from *Fomitopsis s. s.* (Figs. 1 and 2).

*Piptoporus*, typified with *P. betulinus* (Bull.) P. Karst., was established by Karsten (1881a). The genus is characterized by annual, pileate basidiocarps, white to ochraceous salmon or pale brownish pileal surface, white to pale buff pore surface with regular pores and context, a dimitic hyphal system with clamped generative hyphae, hyaline, thin-walled, smooth, cylindrical or ellipsoid basidiospores (Gilbertson and Ryvarden 1986b; Núñez and Ryvarden 2001; Ryvarden and Melo 2014). These morphological characters are consistent with *Fomitopsis s. s.* and support *Piptoporus* as a synonym of *Fomitopsis* as phylogenetic results suggested in our study. The placement of *P. betulinus* in *Fomitopsis s. s.* and the segregation of *Buglossoporus* and *Piptoporellus* from *Piptoporus* (a synonym of *Fomitopsis*) were strongly supported by the phylogenetic analysis (Figs. 1 and 2). Morphologically, *Buglossoporus* can be easily distinguished from *Fomitopsis s. s.* and *Piptoporellus* by its monomitic tramal hyphal system. *Piptoporellus* differs from *Fomitopsis*

*s. s.* by annual, pileate, corky or soft-fibrous basidiocarps, cream to pinkish buff context without a pellicle or crust at the upper surface, moreover, its skeletal hyphae are thick-walled with a distinctly wide lumen and mostly dissolved in KOH. *Piptoporus roseovinaceus* Choeyklin, T. Hatt. & E.B.G. Jones, living on dead bamboo culms and collected from Thailand, has annual, pileate, sessile basidiocarps, light orange to greyish orange pileus surface, sordid white to greyish orange pore surface, white to pale orange context, a dimitic hyphal system in context and monomitic in trama with clamped generative hyphae, and thin-walled, short ellipsoid to ellipsoid basidiospores (Choeyklin et al. 2009). These characters fit well with *Buglossoporus*. But unfortunately, no sequences data were available for *P. roseovinaceus*, therefore, the taxonomic position of *P. roseovinaceus* remained uncertain.

Kotlába and Pouzar (1990) suggested a narrow concept of *Fomitopsis* and proposed a new genus, *Pilatoporus* Kotl. & Pouzar, and transferred *F. palustris* into it as a type species based on the presence of pseudoskeletal hyphae with conspicuous clamp connections. However, the main morphological characters of *F. palustris* fit well with *Fomitopsis s. s.* Moreover, in our phylogenetic tree (Figs. 1 and 2), *F. palustris* was strongly clustered within *Fomitopsis s. s.* Therefore, we prefer to keep *F. palustris* in *Fomitopsis*, which coincides with Kim et al. (2005, 2007).

*Fomitopsis officinalis* (Vill.) Bondartsev & Singer is used as medicinal mushroom in China (Dai et al. 2009). It was accepted in *Fomitopsis* by Bondartsev and Singer (1941), Núñez and Ryvarden (2001) and Zhou and Wei (2012). Kotlába and Pouzar (1957) established the genus *Laricifomes* Kotl. & Pouzar, and transferred *F. officinalis* to *Laricifomes* according to its chalky context, crumbly consistency, pileal surface without a resinous crust and presence of inflated, strongly thick-walled sclerids (Kotlába and Pouzar 1957, 1998). Recent phylogenetic studies demonstrated that *L. officinalis* formed a separate lineage and was distant from *Fomitopsis s. s.* (Kim et al. 2005; Ortiz-Santana et al. 2013; Han and Cui 2015). Our study confirmed that *Laricifomes* is monophyletic, and it is distant from *Fomitopsis s. s.*

In our phylogenetic analyses, *Antrodia sensu stricto*, *A. serialis* group, *A. malicola* group, *Neolentiporus*, *Amyloporia* Singer, *Rhodon* Niemelä, *Ryvardenia* Rajchenb., *Gilbertsonia* Parmasto, *Phaeolus* (Pat.) Pat., *Wolfiporia* Ryvarden & Gilb., *Laetiporus*, *Pycnoporellus* Murrill, *Crustoderma* Parmasto, *Dacryobolus* Fr., *Amylocystis* Bondartsev & Singer, *Fibroporia* Parmasto, *Postia* Fr., *Spongiporus* Murrill, *Oligoporus* Bref., *Sparassis* Fr., *Sarcoporia* P. Karst., *Taiwanofungus* Sheng H. Wu, Z.H. Yu, Y.C. Dai & C.H. Su and *Auriporia* Ryvarden fell in the antrodia clade. But these 23 groups are distant from *Fomitopsis s. s.*

phylogenetically in the antrodia clade. Moreover, *Antrodia s. s.*, *A. serialis* group and *A. malicola* group are different from *Fomitopsis s. s.* by having mostly resupinate to effused-reflexed basidiocarps and a dimitic hyphal system with mostly unbranched skeletal hyphae in morphology (Núñez and Ryvarden 2001; Ryvarden and Melo 2014); *Neolentiporus* is separated from *Fomitopsis s. s.* by producing annual, pileate and stipitate basidiocarps, a dimitic hyphal system with irregularly thick-walled generative hyphae and metachromatic, unbranched skeletal hyphae (Rajchenberg 1995b); *Amyloporia* differs from *Fomitopsis s. s.* in its mostly resupinate and more or less chalky basidiocarps with a perennial growth habit, a dimitic hyphal system with skeletal hyphae either swollen in KOH or amyloid in Melzer's reagent (Rajchenberg et al. 2011; Cui and Dai 2013); *Rhodon* is different from *Fomitopsis s. s.* by its annual basidiocarps and monomitic hyphal system (Niemelä et al. 2005); *Ryvardenia* is distinguished from *Fomitopsis s. s.* by having annual basidiocarps and a monomitic hyphal system (Rajchenberg 1994); *Gilbertsonia* is different from *Fomitopsis s. s.* by its annual, mostly resupinate basidiocarps and dimitic hyphal system with generative hyphae and well developed binding hyphae (Parmasto 2001); *Phaeolus* differs from *Fomitopsis s. s.* by its monomitic hyphal system with gloeopleurous tramal hyphae and simple septate hyphae (Ryvarden and Melo 2014); *Wolfiporia* separates from *Fomitopsis s. s.* by having annual, resupinate to effused-reflexed basidiocarps and a dimitic hyphal system with simple septated generative hyphae (Ryvarden and Gilbertson 1984); *Laetiporus* is distinguished from *Fomitopsis s. s.* in having a dimitic hyphal system with simple septated generative hyphae (Ryvarden and Melo 2014; Song et al. 2014); *Pycnoporellus* differs from *Fomitopsis s. s.* in its monomitic hyphal system with mostly encrusted and simple septated generative hyphae (Ryvarden and Melo 2014); *Crustoderma* separates from *Fomitopsis s. s.* by having annual, mostly resupinate basidiocarps and a monomitic hyphal system (Eriksson and Ryvarden 1975); *Dacryobolus* is distinguished from *Fomitopsis s. s.* in having annual, resupinate to effused-reflexed basidiocarps, and allantoid basidiospores (Eriksson and Ryvarden 1975; Maekawa 1993); *Amylocystis* differs from *Fomitopsis s. s.* in its tomentose to hispid upper surface, monomitic hyphal system with amyloid and thick-walled generative hyphae, and amyloid, apically encrusted cystidia (Ryvarden and Melo 2014); *Fibroporia* separates from *Fomitopsis s. s.* by its fimbriate to rhizomorphic basidiocarps, and ellipsoid and slightly thick-walled basidiospores (Chen et al. 2015b); *Postia* is different from *Fomitopsis s. s.* in producing annual basidiocarps and a monomitic hyphal system



(Wei and Dai 2006; Shen et al. 2015); *Spongiporus* is separated from *Fomitopsis s. s.* by producing annual, mostly resupinate basidiocarps and a monomitic hyphal system (Spirin et al. 2006); *Oligoporus* is different from *Fomitopsis s. s.* by its monomitic hyphal system (Ryvarden and Melo 2014); *Sparassis* is distinguished from *Fomitopsis s. s.* by having a monomitic hyphal system (Light and Woehrel 2009); *Sarcoporia* separates from *Fomitopsis s. s.* by its monomitic hyphal system and dextrinoid, thick-walled basidiospores (Ryvarden and Melo 2014); *Taiwanofungus* differs from *Fomitopsis s. s.* by producing dimitic to trimitic hyphal system with slightly amyloid skeletal hyphae (Wu et al. 2004); *Auriporia* is different from *Fomitopsis s. s.* by having annual, mostly resupinate basidiocarps and thick-walled, apically encrusted cystidia (Ryvarden and Melo 2014).

23 species of *Fomitopsis s. l.* were divided into seven genera based on morphological characters and phylogenetic evidence in our study. However, another idea to use of a single generic name (the “new” *Fomitopsis*) for *Fomitopsis s. l.* and related genera altogether is not accepted. Because in our phylogenetic analysis (Figs. 1 and 2), *Fomitopsis s. l.* together with its related genera are polyphyletic, which was also confirmed by Kim et al. (2005, 2007) and Ortiz-Santana et al. (2013). If a single generic name (*Fomitopsis*) for *Fomitopsis s. l.*, *Daedalea*, *Piptoporus* and *Antrodia* was used, the morphological concept of the “new” *Fomitopsis* needs to be expanded to allow species with irregular and daedaleoid hymenophores (*Daedalea*, *Rhodofomitopsis*), a cataphenium formed by skeletal hyphae and / or cystidia (*Daedalea*), mostly resupinate to effused-reflexed basidiocarps (*Antrodia*) and substipitate or stipitate and fragile basidiocarps (*Piptoporus*); and many new combinations should be proposed. This solution is straightforward, but it is not totally free of problems. Species of *Antrodia* embed into the antrodia clade forming at least three clades, and *Buglossoporus* and *Neolentiporus* were also included in this “new” *Fomitopsis*, however, *Buglossoporus* has a monomitic hyphal system in trama and *Neolentiporus* has irregularly thick-walled generative hyphae and metachromatic, unbranched skeletal hyphae, these characters were quite different from this “new” *Fomitopsis* and cannot be suitable for the inclusion of *Buglossoporus* and *Neolentiporus* in this “new” *Fomitopsis*. Therefore, we prefer to set up new genera for different monophyletic clades.

In summary, we performed a comprehensive study on *Fomitopsis s. l.* and its related genera. On the basis of morphological characters and phylogenetic evidence, six new genera, *Fragifomes*, *Niveoporofomes*, *Rhodofomitopsis*, *Rubellofomes*, *Ungulidaedalea* and *Piptoporellus* are proposed, four new species, *Buglossoporus eucalypticola*, *Daedalea allantoidea*, *Piptoporellus hainanensis* and *P. triqueter* are described, and 16 new combinations are proposed. However, the DNA sequences data of ca. 20 species of

*Fomitopsis s. l.* are not available, and the systematic and phylogenetic position of those species remains uncertain.

#### Key to *Fomitopsis* and its related genera in the antrodia clade

1. Hyphal system monomitic in trama.....2
1. Hyphal system dimitic or trimitic in trama.....15
2. Generative hyphae with simple septa.....3
2. Generative hyphae with clamp connections.....4
3. Basidiocarps yellow to dark brown.....*Phaeolus*
3. Basidiocarps reddish to bright orange.....*Pycnoporellus*
4. Cystidia thick-walled, encrusted.....5
4. Cystidia absent, or when present, thin-walled, not encrusted.....6
5. Generative hyphae and cystidia IKI+ .....*Amylocystis*
5. Generative hyphae and cystidia IKI- .....*Auriporia*
6. Hyphal system dimitic in context.....*Buglossoporus*
6. Hyphal system monomitic in context.....7
7. Basidiocarps stipitate.....*Sparassis*
7. Basidiospores sessile.....8
8. Basidiospores thick-walled,  $\geq 0.4 \mu\text{m}$  thick.....9
8. Basidiospores thin-walled,  $\leq 0.2 \mu\text{m}$  thick.....10
9. Basidiospores cylindrical.....*Sarcoporia*
9. Basidiospores ellipsoid.....*Ryvardenia*
10. Basidiocarps mostly pileate, or occasionally resupinate.....11
10. Basidiospores resupinate to effused-reflexed.....12
11. Basidiospores allantoid to cylindrical, usually CB-.....*Postia*
11. Basidiospores short cylindrical to ellipsoid, usually CB+ .....*Oligoporus*
12. Basidiospores CB+ .....*Crustoderma*
12. Basidiospores CB-.....13
13. Basidiocarps subceraceous.....*Dacryobolus*
13. Basidiocarps soft to brittle.....14
14. Basidiospores ellipsoid.....*Rhodonia*
14. Basidiospores cylindrical to allantoid.....*Spongiporus*
15. Generative hyphae with simple septa.....16
15. Generative hyphae with clamp connections.....17
16. Basidiocarps resupinate to effused-reflexed.....*Laetiporus*
16. Basidiocarps sessile, stipitate.....*Wolfiporia*
17. Sclerids present in context.....*Laricifomes*
17. Sclerids absent in context.....18
18. Margin fimbriate to rhizomorphic.....*Fibroporia*
18. Margin even.....19
19. Skeletal hyphae frequently simple septate.....*Ungulidaedalea*
19. Skeletal hyphae without septa.....20
20. Basidiocarps more or less chalky.....21
20. Basidiocarps not chalky.....22
21. Basidiocarps tender to fragile.....*Gilbertsonia*

21. Basidiocarps corky.....*Amyloporia*  
 22. Generative hyphae irregularly thick-walled.....*Neolentiporus*  
 22. Generative hyphae regularly thick-walled.....23  
 23. Hymenophores irregular, poroid, hydroid, lamellate or daedaleoid / labyrinthiform.....24  
 23. Hymenophores regular, poroid.....26  
 24. Basidiocarps subceraceous; basidiospores allantoid.....*Dacryobolus*  
 24. Basidiocarps coriaceous to corky or hard corky; basidiospores cylindrical, ellipsoid or navicular.....25  
 25. Context brownish; cystidioles present...*Daedalea s. s.*  
 25. Context rose, lilac, or pinkish-brown; cystidioles absent.....*Rhodofomitopsis*  
 26. Skeletal hyphae thick-walled with a distinctly wide lumen.....*Piptoporellus*  
 26. Skeletal hyphae thick-walled with a narrow lumen to subsolid.....27  
 27. Context whitish pink, purple pink, pinkish brown or brown.....28  
 27. Context white, cream, greyish, straw or ochraceous..29  
 28. Pore surface white to cream or purple pink when fresh, straw yellow to cinnamon brown when dry.....*Rubellofomes*  
 28. Pore surface pinkish to vinaceous when fresh, clay-pink to brownish vinaceous when dry.....*Rhodofomes*  
 29. Basidiospores ovoid to broadly ellipsoid.....*Niveoporofomes*  
 29. Basidiospores cylindrical to oblong-ellipsoid or ellipsoid.....30  
 30. Taste bitter; skeletal hyphae slightly IKI + .....*Taiwanofungus*  
 30. Taste mild; skeletal hyphae IKI-.....31  
 31. Basidiocarps mostly respinate to effused-reflexed. *Antrodia s. s.* / *Antrodia serialis* group / *Antrodia malicola* group  
 31. Basidiocarps mostly sessile.....32  
 32. Basidiocarps soft corky to fragile.....*Fragifomes*  
 32. Basidiocarps mostly tough to woody...*Fomitopsis s. s.*

#### Key to species of *Buglossoporus*

1. Pileal surface usually with a pellicle....*B. eucalypticola*  
 1. Pileal surface without a pellicle.....2  
 2. Grows exclusively on *Quercus*; distributes in temperate areas.....*B. quercinus*  
 2. Grows on other trees rather than *Quercus*; distributes in tropical areas.....*B. malesianus*

#### Key to species of *Daedalea sensu stricto*

1. Cystidia present.....2  
 1. Cystidia absent.....3

2. Hymenophore hydroid; basidiospores 6–7  $\mu\text{m}$  long.....*D. hydroides*  
 2. Hymenophore daedaleoid, labyrinthine to lamellate or irpicoid; basidiospores 4–5.5  $\mu\text{m}$  long.....*D. sprucei*  
 3. Pileal surface with a cuticle or crust when mature.....4  
 3. Pileal surface without a cuticle or crust when mature...7  
 4. Pileus with violet spots or zones.....*D. neotropica*  
 4. Pileus without violet spots or zones.....5  
 5. Pores 0.5–1 per mm.....*D. stevensonii*  
 5. Pores > 1 per mm.....6  
 6. Basidiospores broadly ellipsoid, 3–3.5  $\mu\text{m}$  wide.....*D. pseudodochmia*  
 6. Basidiospores oblong-ellipsoid, 2–2.5  $\mu\text{m}$  wide.....*D. dochmia*  
 7. Hymenophore irregular, poroid, daedaleoid / labyrinthine, lamellate or hydroid.....8  
 7. Hymenophore regular, poroid.....11  
 8. Basidiospores broadly ellipsoid.....9  
 8. Basidiospores cylindrical.....10  
 9. Basidiospores 2.5–5  $\mu\text{m}$  wide.....*D. africana*  
 9. Basidiospores 2–2.5  $\mu\text{m}$  wide.....*D. stereoides*  
 10. Basidiocarps annual to biennial; basidiospores 4.5–5  $\mu\text{m}$  long.....*D. radiata*  
 10. Basidiocarps perennial; basidiospores 5.5–6  $\mu\text{m}$  long.....*D. quercina*  
 11. Pores 8–10 per mm.....*D. modesta*  
 11. Pores < 8 per mm.....12  
 12. Basidiospores cylindrical.....13  
 12. Basidiospores allantoid to ellipsoid.....14  
 13. Pores 1–2 per mm.....*D. dickinsii*  
 13. Pores 4–6 per mm.....*D. circularis*  
 14. Pores 4–5 per mm; basidiospores ellipsoid.....*D. americana*  
 14. Pores 1–3 per mm; basidiospores allantoid.....*D. allantoidea*

#### Key to species of *Fomitopsis sensu stricto*

1. Basidiocarps perennial.....2  
 1. Basidiocarps annual to biennial.....3  
 2. Basidiospores 6–9  $\times$  3.5–4.5  $\mu\text{m}$ .....*F. pinicola*  
 2. Basidiospores 4–6  $\times$  2–2.5  $\mu\text{m}$ .....*F. hemitephra*  
 3. Cystidioles absent.....*F. palustris*  
 3. Cystidioles present.....4  
 4. Pileal surface with a cuticle or a pellicle.....5  
 4. Pileal surface without a cuticle or a pellicle.....6  
 5. Pores 6–8 per mm; basidiospores 6–9  $\times$  2–3  $\mu\text{m}$ .....*F. nivosa*  
 5. Pores 3–5 per mm; basidiospores 5–6  $\times$  1.5–1.7  $\mu\text{m}$ .....*F. betulina*  
 6. Basidiospores < 4  $\mu\text{m}$  long.....*F. subtropica*  
 6. Basidiospores > 4  $\mu\text{m}$  long.....7

7. Pore surface mouse-grey to dark grey.....*F. cana*  
 7. Pore surface white to ochraceous.....8  
 8. Basidiospores 4–5.6 µm long.....*F. ostreiformis*  
 8. Basidiospores > 5.6 µm long.....9  
 9. Pores 5–7 per mm; context pale buff.....*F. meliae*  
 9. Pores < 5 per mm; context white to ivory or cream....10  
 10. Basidiospores 1.5–2.5 µm wide.....*F. durescens*  
 10. Basidiospores 2.8–3.7 µm wide.....*F. iberica*

### Key to species of *Piptoporellus*

1. Cystidioles absent; basidiospores cylindrical to oblong-ellipsoid.....*P. hainanensis*  
 1. Cystidioles present; basidiospores ellipsoid.....2  
 2. Pileal surface cream to cinnamon or light orange; contextual skeletal hyphae 2–5 µm in diam.....*P. soloniensis*  
 2. Pileal surface buff-yellow or salmon to brownish orange; contextual skeletal hyphae 3–11 µm in diam.....*P. triquetra*

### Key to species of *Rhodofomes*

1. Cystidioles absent.....2  
 1. Cystidioles present.....3  
 2. Pileal surface strongly radially streaked, strongly zonate; grows on gymnosperm wood.....*R. rosea*  
 2. Pileal surface without radially streaked, azonate; grows on angiosperm wood.....*R. carneus*  
 3. Basidiospores allantoid.....*R. cajanderi*  
 3. Basidiospores ellipsoid or cylindrical to oblong-ellipsoid.....4  
 4. Pores 6–8 per mm; basidiospores ellipsoid...*R. incarnatus*  
 4. Pores 4–6 per mm; basidiospores cylindrical to oblong-ellipsoid.....*R. subfeei*

### Key to species of *Rhodofomitopsis*

1. Pores 1–3 per mm.....*R. cupreorosea*  
 1. Pores > 3 per mm.....2  
 2. Context pale pink.....*R. africana*  
 2. Context dark rose.....3  
 3. Pores 5–6 per mm; basidiospores 4.5–5.2 × 2–3 µm.....*R. feei*  
 3. Pores 3–5 per mm; basidiospores 6–10 × 3–3.5 µm.....*R. lilacinogilva*

### Key to species of *Rubellofomes*

1. Pores 0.5–1 per mm; cystidia present.....*R. cystidiatus*  
 1. Pores 6–7 per mm; cystidia absent.....*R. minutisporus*

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