
A revision of *Sinotermitomyces*, a synonym of *Termitomyces* (*Agaricales*)

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The taxonomic status of *Sinotermitomyces* is revised on the basis of type material examination of all the five species described in the genus. Full descriptions of the holotypes and other relevant specimens for all of these species are given. The results show that holotypes of the five *Sinotermitomyces* names are representatives of known *Termitomyces* species. *Sinotermitomyces cavus* is synonymous with *T. heimii*, and *S. taiwanensis* with *T. clypeatus*. The other three, *S. carnosus*, *S. griseus* and *S. rugosiceps*, are conspecific with *T. mammiformis*. Therefore, *Sinotermitomyces* is reduced as a synonym of *Termitomyces*. Problems in species identification of some recent molecular phylogenetic studies of *Termitomyces* and *Sinotermitomyces* are also discussed.

Key words: holotype, nomenclature, *Sinotermitomyces*, *Termitomyces*

Introduction

Sinotermitomyces M. Zang is a genus introduced in 1981, based on a few collections from Yunnan Province, China. The genus is currently placed in *Tricholomataceae* R. Heim ex Pouzar (Kirk *et al.*, 2001), and includes five species, namely *S. carnosus* M. Zang, *S. cavus* M. Zang, *S. griseus* M. Zang, *S. rugosiceps* M. Zang and *S. taiwanensis* M. Zang & C.M. Chen. *Sinotermitomyces griseus* and *S. rugosiceps* are known only from Myanmar and the other three are reported from Yunnan, Xizang and Taiwan of China (Zang, 1981, 1992; Zang and Chen, 1998).

According to Zang (1981), *Sinotermitomyces* was considered related to *Termitomyces* R. Heim by virtue of the termite symbiosis and morphological characters, but distinguished from the latter by the small basidiome, papillate perforatorium, persistent velar remains on the stipe and pileus, leathery and

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hollow stipe, and cystidia with protuberances. However, all these characters can also be found in *Termitomyces*. Among the *Termitomyces* species, *T. heimii* Natarajan and *T. mammiformis* R. Heim are most similar to *Sinotermitomyces*. These two species have firm velar remains on the surfaces of pileus and stipe, and moreover, their pseudorhiza is leathery and hollow as seen on the type material of the former. *Sinotermitomyces taiwanensis* was proposed by Zang and Chen (1998) as having a spiniform perforatorium, which is also a distinct character of *T. clypeatus* R. Heim (Heim, 1977; Pegler and Vanhaecke, 1994).

Questions on the taxonomic status of *Sinotermitomyces* have been raised since the genus was published. From the illustration and description provided by Zang (1981), Pegler and Vanhaecke (1994) suspected that *S. carnosus* was a representative of *T. heimii* and that *S. cavus* should be compared with *T. radicans* Natarajan. Based on sequence analysis of large subunit of ribosomal RNA gene (LSU-nrDNA), Frøslev *et al.* (2003) concluded that two *Sinotermitomyces* samples, under the names of *S. cavus* and *S. rugosiceps* respectively, should be treated as species of *Termitomyces* and suggested combining *Sinotermitomyces* species within *Termitomyces*. However, morphological study for the generic status of *Sinotermitomyces* is limited and the taxonomic position of the other species has not been addressed. Consequently, further morphological study based on observation of the type specimen is necessary to elucidate the relationships between *Sinotermitomyces* and *Termitomyces*.

In an investigation of *Termitomyces* in the southwest of China, specimens under *Sinotermitomyces* in the Herbarium of Kunming Botanic Institute, Chinese Academy of Sciences (HKAS), including all the holotypes of the five species of the genus, were studied to determine the species relationships between the two genera. The results are presented in this paper with full descriptions of the holotypes and other relevant specimens previously identified as *Sinotermitomyces* species. Discussion on species identification of *Termitomyces* and *Sinotermitomyces* in recent molecular phylogenetic studies is also provided.

Materials and methods

All collections of *Sinotermitomyces* in the HKAS, from Taiwan, Xizang and Yunnan in China, and from the Mandalay division of Burma, were examined. Additional collections of *Termitomyces* housed in the Mycological Herbarium, Institute of Microbiology, Chinese Academy of Sciences (HMAS), were also observed. Thin sections were prepared by hand, using a razor. The sections of dried basidiomes, including lamellae, cutis, pileal context and

partial veil, were mounted in 5% KOH solution for microscopic examination. Size range of basidiospores, basidia, tramal hyphae, pileal context and cutis were measured using an ocular micrometer. At least 30 basidiospores and 20 basidia of each mature specimen were measured. The microscopic characters were drawn with the aid of a camera lucida.

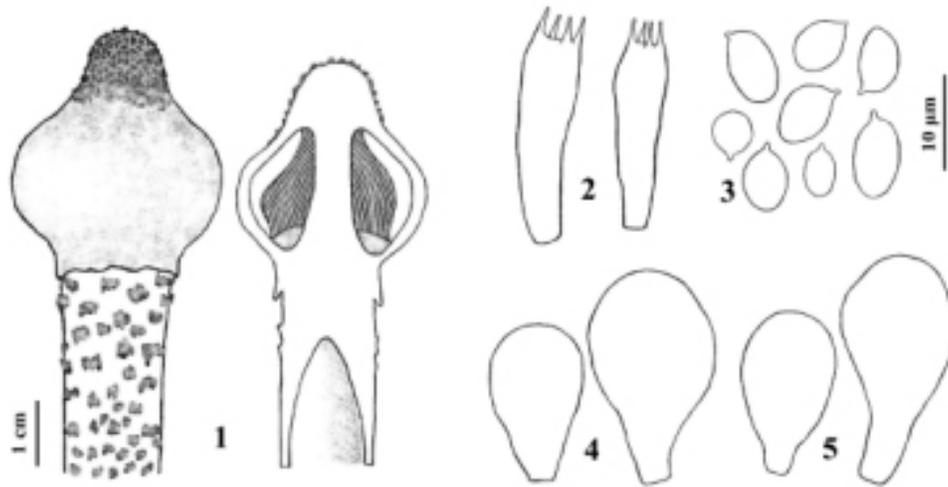
Taxonomy

Sinotermitomyces carnosus M. Zang in *Mycotaxon* 13: 172 (1981) (Figs. 1-5)

Synonym of *Termitomyces mammiformis* R. Heim in *Arch. Mus. Nat. Hist. sér. 6*, 18: 147 (1942).

Pileus 1.5-5.5 cm diam., subglobose or campanulate at first, and then appanate with a mammiform, scrobiculate perforatorium when mature; surface pale brown to dark brown at centre, white to creamy elsewhere, covered by firm creamy partial veil when young, attached with some persistent pale grey or pale brown velar squamules when mature; surface or margin with radial fine stripes. *Lamellae* free, up to 4 mm wide, white to pinkish, crowded with lamellulae. *Stipe* 2-6 × 0.6-1.9 cm, central, cylindrical or occasionally slightly enlarged at ground level; surface white and glabrous above annulus, cream-coloured and with pale brown squamules below; solid, fibrous. *Pseudorhiza* up to 40 cm long, cylindrical, terminal with a disk connected to the surface of the termite comb, leathery, hollow; surface creamy. *Partial veil* membranous, at first covering the whole surface of the pileus and the stipe, then broken into membranous squamules (or occasionally granules) and forming the persistent double annulus on the upper surface; of narrow hyphae 2-2.5 µm diam., with parallel palisadic arrangement and perpendicular to the surface of the pileus and the stipe. *Context* white, fleshy and soft, of inflated, hyaline, thin-walled hyphae, 3-8 µm diam., inflated to 28 µm. *Basidiospore deposit* cream. *Basidiospores* 5-8.5 × 3.5-6 µm, ovoid to ellipsoid, subhyaline and thin-walled. *Basidia* 16-22 × 6-7 µm, subhyaline, thin-walled, clavate, with four sterigmata. *Lamella-edge* heterogenous, with cheilocystidia. *Cheilocystidia* 15-25 × 10.5-14.5 µm, clavate to pyriform, hyaline, thin-walled, occasionally with small protuberances. *Pleurocystidia* 14-25 × 9-15 µm, similar to cheilocystidia, occasional. *Hymenophoral trama* regular, 80-100 µm wide, of hyaline, thin-walled, cylindric hyphae, 5-20 µm diam. *Subhymenial layer* narrow, of branched hyphae, 2-5 µm diam. *Pileipellis* a repent epicutis of narrow, radial hyphae, 3-3.5 µm diam.

Specimens examined: CHINA, Yunnan, Tengchong, on a nest of termite, 30 Aug. 1980, M. Zang (HKAS 6752, **holotype**); Longchuan, 24 May 1992, M. Zang (HKAS 25361); Dehong, alt. 800 m, 9 May 1992, M. Zang 11907 (HKAS 25359); Dehong, alt. 820 m, 19 May 1992, M. Zang 11908 (HKAS 25360). Xizang, Muotuo, on a nest of termite, alt. 1250 m, 3 Sep. 1982, Y.G. Su 1080 (HKAS 15983).



Figs. 1-5. *Sinotermitomyces carnosus*. 1. Habit. 2. Basidia. 3. Basidiospores. 4. Pleurocystidia. 5. Cheilocystidia. Fig. 1 is from HKAS 6752 (holotype) and Figs. 2-5 from HKAS 25361.

This species based on a single collection, HKAS 6752, was proposed by Zang (1981), with further descriptions by Zang (1992) and Ying and Zang (1994), but no additional collections. The above description of morphological characters was based on the holotype and other four collections determined by Zang. All of the collections showed remarkable resemblance with *T. mammiformis*, as described by Heim (1941, 1942, 1977), in having creamy coloured basidiomes, mammiform and scrobiculate perforatorium, and the persistent annulus. The observed microscopic characters (e.g. size and form of basidiospores, basidia and cystidia) agree with that of *T. mammiformis*. The uppermost layer of perforatorium of *T. mammiformis*, described by Heim (1958, 1977) as having narrow, longitudinally palisadic hyphae, 3-3.7 µm in diameter, is very similar to the partial veil as observed in the present study but the diameter of hyphae may be slightly different (as 2-2.5 µm diam. in the above description). Based on the mammiform perforatorium, persistent annulus and microscopic character of partial veil, the Chinese collections were determined as *T. mammiformis* although there are a few inconsistencies between them and the descriptions of Heim (1942, 1958, 1977); e.g. squamules are membranous and only broken occasionally into very small granules in Chinese collections but they were described as pustular on the surfaces of pileus and stipe by Heim who did not mention the hollow pseudorhiza. Two collections identified as *T. mammiformis* in HMAS, i.e. HMAS 76625 (China, Yunnan, Xishuangbanna, 12 Aug. 1999, X.L. Mao, H.A. Wen, S.X. Sun 141) and HMAS 76553 (China, Yunnan, Mengla, on ground associated with

termites' nest, 10 Aug. 1999, X.L. Mao, H.A. Wen, S.X. Sun 58), were also examined for comparison, and they displayed similar characters to those of *S. carnosus* as described above.

The present study showed that the stipe was solid in all of the collections observed (see Fig. 1), but the pseudorhiza was hollow inside. Pseudorhiza is usually referred to the subterranean part of basidiome in *Termitomyces* and is actually the extension of the stipe, although there is no strict boundary between the stipe and the pseudorhiza. The stipe of *S. carnosus* was described as up to 20 cm long in Zang (1981), remarkably longer than that of the present observation (up to 6 cm long), and no pseudorhiza was mentioned in the protologue. Apparently, the hollow stipe described by Zang (1981) is referable to the hollow pseudorhiza.

The small protuberances on the cystidia were emphasised by Zang (1981) as the distinctive character of *S. carnosus*. The present study revealed that most of the cystidia in the above listed specimens were obtusely rounded, occasionally with small protuberances.

Termitomyces mammiformis was proposed by Heim (1941) based on the material from Guinea, but the Latin description was provided later (Heim, 1942). According to descriptions of Heim (1941, 1942, 1958, 1977), the pileus of *T. mammiformis* is cream coloured, but the illustration in Heim (1958), i.e. Plate 25I of BR-MYC 032902, 19 (Democratic Republic of Congo, Equateur, Binga, 10 October 1928, Goossens-Fontana no 821), showed a dark coloured pileus disagreeing with his own descriptions. Unfortunately, the type material of *T. mammiformis* was not available to the present authors for study, thus pileus colour, pustular squamules on pileus and the consistency of pseudorhiza of *T. mammiformis* cannot be confirmed. If the type material of *T. mammiformis* has the same characters as described by Heim (1941, 1942, 1958, 1977), the collection of BR-MYC 032902, 19 may be a different species. However, a new combination in *Termitomyces* may be needed, if the type of *T. mammiformis* proves to be different from that of *S. carnosus* and other similar collections from China (see also below).

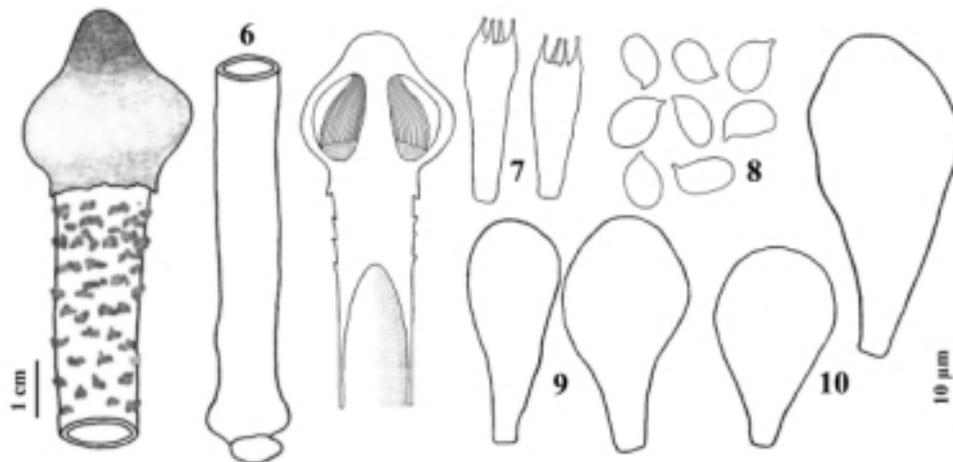
Sinotermitomyces cavus M. Zang in *Mycotaxon* 13: 172 (1981) (Figs. 6-10)

Synonym of *Termitomyces heimii* Natarajan in *Mycologia* 71: 853 (1979).

Pileus 1.8-6 cm diam., convex or campanulate at first, then expanding to plano-umbonate with a coarse, obtuse perforatorium; surface pale brown to dark brown at centre, white to cream-coloured elsewhere, covered at first by a firm partial veil, which disrupts to form persistent velar squamules at maturity; margin radially striate, often splitting. *Lamellae* free, up to 5 mm wide, surface white to pinkish cream, crowded, with lamellulae. *Stipe* 2-7 × 0.7-2 cm, central, cylindrical, surface white and smooth above annulus, with pale

brownish velar squamules below; solid, fibrous. *Pseudorhiza* up to 46 cm long, cylindrical, terminated by a disk connected to the termite comb; leathery, hollow, surface cream. *Partial veil* membranous, at first covering whole surface of the pileus and the stipe, then broken into tough squamules and forming a persistent double annulus on the upper part of the stipe; of narrow hyphae, 2 μm diam, parallel and perpendicular to the surface of the pileus and the stipe. *Context* white, fleshy, soft; of inflated, hyaline, thin-walled hyphae; 3-7.5 μm diam., inflated to 20 μm . *Basidiospore deposit* pinkish cream. *Basidiospores* 5.5-7.5 \times 3.5-4.5 μm , ovoid to ellipsoid, subhyaline and thin-walled. *Basidia* 17-20 \times 6-8 μm , subhyaline and thin-walled, clavate, with four sterigmata. *Lamellae-edge* heterogenous, with cheilocystidia. *Cheilocystidia* 20-43 \times 9.5-20 μm , clavate to pyriform, hyaline and thin-walled. *Pleurocystidia* 20-34 \times 10-18 μm , similar to cheilocystidia, rare. *Hymenophoral trama* regular, 50-60 μm wide, of hyaline, thin-walled, cylindric hyphae 5-20 μm diam. *Subhymenial layer* narrow, of branched and repent hyphae 2-5 μm diam. *Pileipellis* a repent epicutis of narrow, radial hyphae 3-5 μm diam.

Specimens examined: CHINA, Yunnan, Tengchong, on a nest of termite, alt. 2100, 8 Aug. 1980, X.J. Li 11 (HKAS 6533, **holotype**); Tengchong, 17 Jul. 1979, S.X. Ma (HKAS 4613); Ruili, 13 Aug. 1980, X.J. Li 22 (HKAS 6568); Longling, 2 Jul. 1977, X.J. Li 73 (HKAS 3664); Mangshi, 10 Aug. 1980, M. Zang (HKAS 6545); Simao, on a nest of termite, alt. 1500 m, 14 Jun. 2000, M. Zang 13287 (HKAS 36153); Simao, on a nest of termite, alt. 1400 m, 17 Jun. 2000, M. Zang 13372 (HKAS 36154); Jinggu, 10 Jul. 1985, K.Y. Guan 1 (HKAS 14626). Xizang, Muotuo, 25 Sep. 1983, Y.G. Su 1343 (HKAS 16253).



Figs. 6-10. *Sinotermitomyces cavus*. **6.** Habit. **7.** Basidia. **8.** Basidiospores. **9.** Pleurocystidia. **10.** Cheilocystidia. Fig. 6 is from HKAS 6533 (holotype) and Figs. 7-10 from HKAS 6568.

Sinotermitomyces cavus is the type species of the genus and was described on the basis of five collections (HKAS 6533, 4612, 4613, 6545, 6568) from Yunnan, China (Zang, 1981). Two further records (HKAS 14626, 16253) were mentioned in Zang (1992). The above description was based on the collections identified by Zang as *S. cavus* in the HKAS. The white to cream-coloured basidiomes, coarse and bluntly round perforatorium, double annulus, brownish squamules on the surfaces of pileus and stipe, and hollow pseudorhiza are the characters of *T. heimii*. The microscopic characters of the collections examined also confirmed this determination.

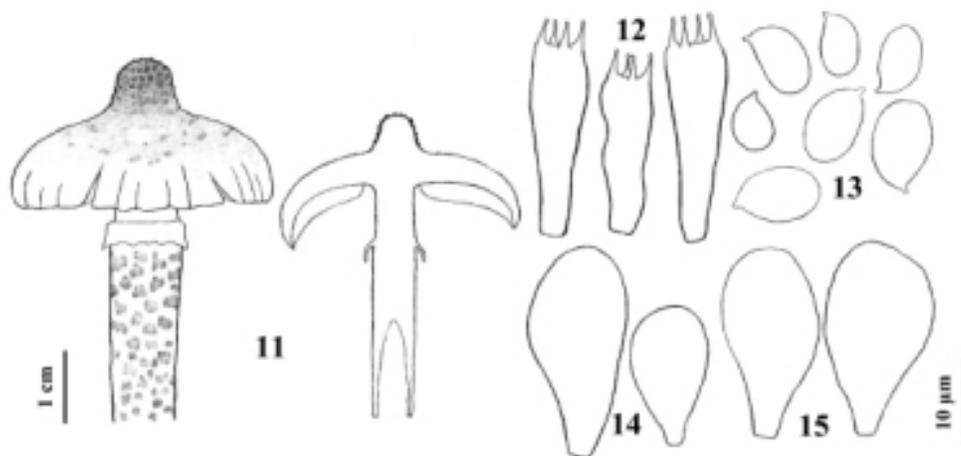
Similar to *S. carnosus*, the stipe of *S. cavus* was described up to 30 cm long in Zang (1981). The protuberances of cystidia emphasised in the original description (Zang, 1981) could not be confirmed from the collections listed above. According to the observation of the present authors, the cystidia of *Termitomyces* species are usually clavate to pyriform, occasionally with small protuberances on the apex. The interpretation of this character may have been different between the present observation and the original description of Zang (1981).

Sinotermitomyces griseus M. Zang in *Mycotaxon* 44: 22 (1992) (Figs. 11-15)

Synonym of *Termitomyces mammiformis* R. Heim in *Arch. Mus. Nat. Hist. sér.* 6, 18: 147 (1942).

Pileus 2-3.8 cm diam., convexo-applanate with a protruding mammiform and scrobiculate perforatorium; surface dark greyish brown at perforatorium and cream to pale greyish elsewhere, paling toward margin, rimose, with few velar remains; margin striate and radially fissile. *Lamellae* free, 4 mm wide; white to cream; crowded, with lamellulae. *Stipe* 5-8 × 0.6-1 cm, cylindrical or slightly thickened at annulus; surface white above the annulus and cream below, with pale brown velar squamules; solid and fibrous. *Pseudorhiza* up to 19 cm long, cylindrical; surface creamy, leathery; hollow. *Partial veil* membranous, present as velar squamules on surface of the pileus and the stipe and forming a persistent annulus. *Context* white, fleshy, soft; of inflated, hyaline, thin-walled hyphae, 3-7 µm diam., inflated to 18 µm. *Basidiospore deposit* pinkish cream. *Basidiospores* 6-10.5 × 4-6 µm, ovoid to ellipsoid. *Basidia* 17.5-24 × 6-8.5 µm, clavate. *Cheilocystidia* 19-30 × 10-13 µm, clavate to pyriform. *Pleurocystidia* 15-26 × 9-12 µm, similar to cheilocystidia, rare. *Hymenophoral trama* regular, 60-80 µm wide, of hyaline and thin-walled hyphae 5-18 µm diam. *Subhymenial layer* narrow, of narrow hyphae 2-6 µm diam. *Pileipellis* an epicutis of narrow, radial hyphae 3-4 µm diam.

Specimen examined: MYANMAR, Mandalay Division, Popa Mountain Park, in conifers and *Quercus* forests, on termite nest, alt. 1100 m, 23 Oct. 1991, K.Y. Guan 2 (HKAS 23648, **holotype**).



Figs. 11-15. *Sinotermitomyces griseus* (HKAS 23648, holotype). **11.** Habit. **12.** Basidia. **13.** Basidiospores. **14.** Pleurocystidia. **15.** Cheilocystidia.

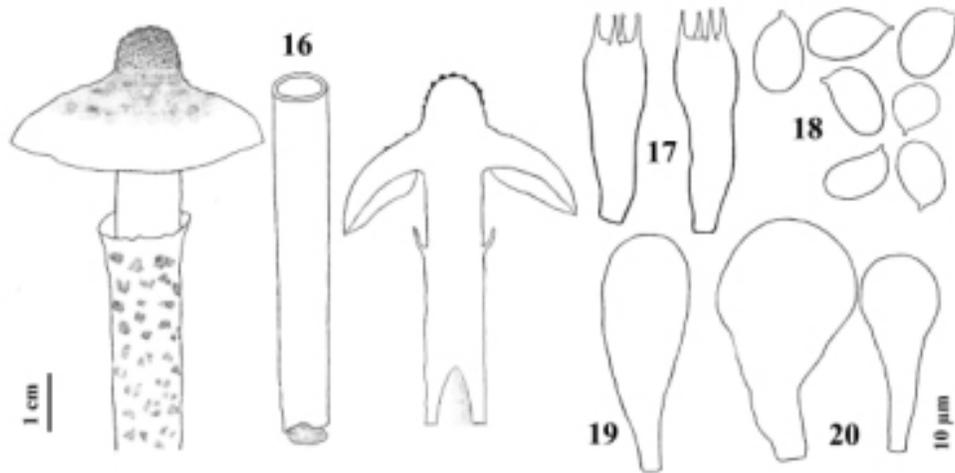
No further collection has been reported since *S. griseus* was described from a single collection from Burma (Zang, 1992). The holotype of *S. griseus* is very similar to the collections of *S. carnosus*, except for some minor variations, i.e. smaller basidiomata, slightly larger basidiospores and dark greyish brown perforatorium (rather than brown to dark brown in *S. carnosus*). All of these variations are here considered within the range of *T. mammiformis*. The mammiform and scrobiculate perforatorium is the key character demonstrating that *S. griseus*, *S. carnosus* and *T. mammiformis* are conspecific.

Sinotermitomyces rugosiceps M. Zang in *Mycotaxon* 44: 23 (1992)

(Figs. 16-20)

Synonym of *Termitomyces mammiformis* R. Heim in *Arch. Mus. Nat. Hist. sér. 6*, 18: 147 (1942).

Pileus 3.5-4.5 cm diam., convex to plano-convex, with an obtusely conic and scrobiculate perforatorium; surface brown to dark brown at centre, paling to almost white elsewhere, with small velar remains. *Lamellae* free, 3 mm wide; white, crowded, with lamellulae. *Stipe* 4-6 × 0.8-1.5 cm, cylindrical; surface white above annulus, cream and with pale brown squamules below; solid, soft, fibrous. *Pseudorhiza* up to 30 cm long, cylindrical; surface cream to pale brownish, leathery; hollow. *Partial veil* membranous, present as a firm annulus and persistent pale brown squamules on surfaces of the pileus and the stipe. *Context* white, fleshy, soft; of inflated, hyaline, thin-walled hyphae, 2-5 µm diam. and inflated to 15 µm. *Basidiospores* 6.5-9.5 × 4.5-6 µm, ovoid to ellipsoid. *Basidia* 17.5-26 × 6-8 µm, clavate. *Cheilocystidia* 22-27 × 9-18 µm, clavate to pyriform. *Pleurocystidia* 27 × 10 µm, similar to cheilocystidia, very



Figs. 16-20. *Sinotermitomyces rugosiceps* (HKAS 23647, holotype). **16.** Habit. **17.** Basidia. **18.** Basidiospores. **19.** Pleurocystidia. **20.** Cheilocystidia.

rare. *Hymenophoral trama* regular, 50-60 µm wide, of hyaline, thin-walled hyphae 5-20 µm diam. *Subhymenial layer* of narrow hyphae 2-5 µm diam. *Pileipellis* an epicutis of narrow, radial hyphae 2.5-3.5 µm diam.

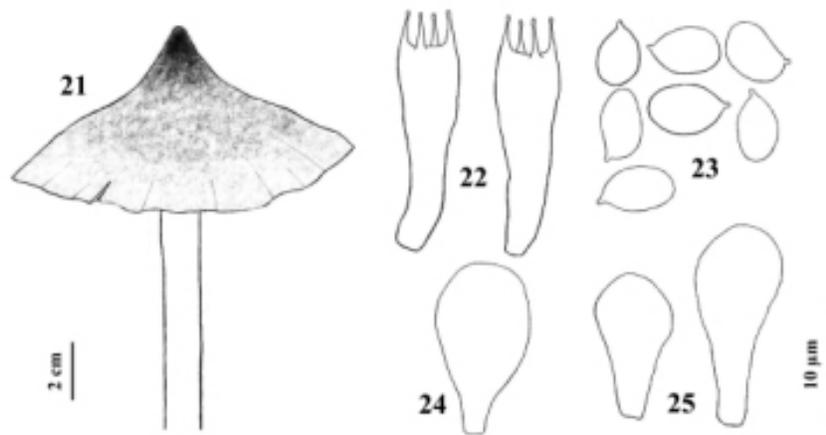
Specimen examined: MYANMAR, Mandalay Division, Pyin Oo Lwin, in monsoon forests, alt. 1000 m, 22 Oct. 1991, K.Y. Guan 1 (HKAS 23647, **holotype**).

The above specimen is the only collection on which *S. rugosiceps* was based (Zang, 1992). There is no further record reported. The obtusely conic and scrobiculate perforatorium and other characters observed from the type material coincide with that of *S. carnosus* and *T. mammiformis*. *Sinotermitomyces rugosiceps* is certainly conspecific with *S. carnosus*, and therefore is another synonym of *T. mammiformis*.

Sinotermitomyces taiwanensis M. Zang & C.M. Chen in *Fungal Science* 13: 25 (1998) (Figs. 21-25)

Synonym of *Termitomyces clypeatus* R. Heim in *Bull. Jard. Bot. État* 21: 207 (1951).

Pileus 6.5 cm radius, plano-umbonate, with a high spiniform perforatorium; surface dark brown at centre, brown elsewhere and paling toward margin, smooth and glabrous, striate and radially rimose; margin straight and splitting fissile. *Lamellae* free, up to 7 mm wide, white, crowded, with lamellulae. *Stipe* 7 cm long, 1.2 cm diam., central and cylindrical, slender; surface pale grey, smooth and glabrous, longitudinally striate, lacking both an annulus and other velar remnants, solid, fibrous. *Pseudorhiza* more than 13 cm long, cylindrical, slender; surface pale grey, smooth and glabrous; solid and fibrous. *Context* of pileus white, fleshy, of inflated, hyaline and thin-walled



Figs. 21-25. *Sinotermitomyces taiwanensis* (HKAS 30320, holotype). **21.** Habit. **22.** Basidia. **23.** Basidiospores. **24.** Pleurocystidia. **25.** Cheilocystidia.

hyphae; normal hyphae 2.5-7.5 μm diam., inflated to 30 μm . *Basidiospores* 6-8.5 \times 45 μm , ovoid to ellipsoid, subhyaline, thin-walled. *Basidia* 18.5-26 \times 5.5-9 μm , clavate, subhyaline and thin-walled, with four sterigmata. *Lamelle-edge* heterogeneous and fertile. *Cheilocystidia* 13-23 \times 7-12 μm , clavate to pyriform, hyaline, thin-walled. *Pleurocystidia* 16.5 \times 9.5 μm , pyriform, hyaline and thin-walled, rare. *Hymenophoral trama* regular, 60-70 μm wide, of hyaline and thin-walled hyphae 5-20 μm diam. *Subhymenial layer* narrow, consists of branched, repent hyphae 2-5 μm diam. *Pileipellis* an repent epicutis of narrow, radial hyphae 3-5 μm diam.

Specimen examined: CHINA, Taiwan, Taizhong, 9 Aug. 1995, C.M. Chen 840369 (HKAS 30320, holotype).

Sinotermitomyces taiwanensis has not been found in any other reports except the original description. It was described as having a persistent annulus, and hollow stipe and pseudorhiza (Zang and Chen, 1998). These characters cannot be confirmed in the present study. Examination of the type material of *S. taiwanensis*, which consists of only a half of a basidiome, showed no trace of a partial veil, but both the stipe and pseudorhiza are solid. The photograph of *S. taiwanensis* in Zang and Chen (1998) displayed the smooth and glabrous stipe surface, similar to the type. The slender and medium-sized basidiome, spiniform perforatorium, smooth and non-annulate stipe surface, and pale coloured stipe and pseudorhiza of the type indicate that it is a collection of *T. clypeatus*. Furthermore, the microscopic characters of the type, e.g. size and form of basidiospores, basidia and cystidia, are in agreement with that of *T. clypeatus*. *Termitomyces clypeatus*, widely distributed in Africa and south and southeast of Asia, is one of the most common species within the genus (Heim,

1951, 1977; Pegler, 1977; Pegler and Vanhaecke, 1994). The species is well known from the south of the Yangtze River in China (Wei and Yao, 2003). The type material of *S. taiwanensis* is the first record of the distribution of *T. clypeatus* in Taiwan Province.

Discussion

The main characters used by Zang (1981) to distinguish *Sinotermitomyces* from *Termitomyces* are velar remnants on the basidiome surface and the hollow stipe (in fact, pseudorhiza), but these characters are not present in all the *Sinotermitomyces* species and also are shared by some species of *Termitomyces*. Evidently, *S. taiwanensis* (= *T. clypeatus*) does not have all of these characters and should not belong to *Sinotermitomyces*, even if the genus is accepted. In addition to *T. heimii* and *T. mammiformis* discussed above, the pileus and the stipe of some other species of *Termitomyces*, such as *T. letestui* (Pat.) R. Heim (Heim, 1942, 1977; Pegler, 1977), *T. reticulatus* Van der Westhuizen and Eicker (Van der Westhuizen and Eicker, 1990), *T. schimperi* (Pat.) R. Heim (Heim, 1942, 1977; Pegler, 1977; Van der Westhuizen and Eicker, 1990, 1991), *T. singidensis* Saarim. & Härk. (Saarimäki *et al.*, 1994), *T. striatus* f. *anulatus* R. Heim (Heim, 1977), *T. titanicus* Pegler & Pearce (Pegler and Pearce, 1980), are covered with persistent membranous squamules formed by the remains of partial veil. The hollow pseudorhiza is also present in *T. citriophyllus* R. Heim (Heim, 1942, 1977). Although *T. heimii* and *T. mammiformis* may be considered as a recognisable group within the genus, they together with the *Sinotermitomyces* species are not sufficiently distinct to be separated from *Termitomyces*.

Termitomyces has been determined as a monophyletic group in recent molecular phylogenetic studies, i.e. Rouland-Lefevre *et al.* (2002), Aanen *et al.* (2002) and Frøslev *et al.* (2003), whilst the sequences of *T. heimii*, *T. mammiformis*, *T. clypeatus* and other *Termitomyces* species with persistent velar squamules on the basidiome surface (e.g. *T. letestui*, *T. schimperi*, *T. singidensis* and *T. titanicus*) were polyphyletic and clustered together with different *Termitomyces* species in the phylogenetic trees by Frøslev *et al.* (2003). Molecular study by the present authors (unpublished data) also supported the conclusion of Frøslev *et al.* (2003).

In summary, the evidences of both morphological and molecular studies do not support *Sinotermitomyces* as a separate genus and *Sinotermitomyces* should be regarded as a synonym of *Termitomyces*.

The examination of type material of all the five *Sinotermitomyces* species and other additional collections shows that they are representatives of three

known *Termitomyces* species. *Sinotermitomyces carnosus*, *S. griseus* and *S. rugosiceps*, are synonyms of *T. mammiformis* and the other two, *S. cavus* and *S. taiwanensis*, are respectively conspecific with *T. heimii* and *T. clypeatus*

According to Frøslev *et al.* (2003), the LSU-nrDNA sequence of *S. rugosiceps* is identical with that of *T. heimii*, but differs from that of *T. mammiformis*, and the LSU-nrDNA sequences of *S. cavus* is different from any other sequences of all the *Termitomyces* taxa examined in that paper. However, the present authors were unable to confirm this conclusion and obtained different results in the molecular work (to be published elsewhere). DNA samples from voucher specimens with careful morphological study, deposited in HMAS, showed identical LSU-nrDNA and slightly different ITS sequences between *T. heimii* and *T. mammiformis*. Unfortunately, the type material of *Sinotermitomyces* species was not well preserved for DNA work and the attempt to sequence DNA fragments from those materials has not been successful. The sequences of *Sinotermitomyces* species reported by Frøslev *et al.* (2003) were obtained from mycelium cultures without morphological information to confirm their origin. The identity of the cultures of *S. cavus* and *T. mammiformis* used in Frøslev *et al.* (2003) needs further investigation.

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References

- Aanen, D.K., Eggleton, P., Rouland-Lefèvre, C., Frøslev, T.G., Rosendahl, S. and Boomsma, J.J. (2002). The evolution of fungus-growing termites and their mutualistic fungal symbionts. *Proceedings of the National Academy of Sciences, USA* 99: 14887-14892.
- Frøslev, T.G., Aanen, D.K., Læssøe, T. and Rosendahl, S. (2003). Phylogenetic relationships of *Termitomyces* and related taxa. *Mycological Research* 107: 1277-1286.
- Heim, R. (1941). Études descriptives et expérimentales sur les agarics termitophiles d'Afrique tropicale. *Mémoires de l'Académie des Sciences de l'Institut de France* 64: 1-74, pls 1-10.
- Heim, R. (1942). Nouvelles études descriptives sur les agarics termitophiles d'Afrique tropicale. *Archives du Muséum National d'Histoire Naturelle, Séries. 6, 18*: 1-60, pls 9-12.

- Heim, R. (1951). Les *Termitomyces* du Congo Belge recueillis par Madame M. Goossens-Fontana. Bulletin du Jardin Botanique de l'État 21: 205-222.
- Heim, R. (1958). *Termitomyces*. Flore Iconographique des Champignons du Congo 7: 139-151, + pls 23-25.
- Heim, R. (1977). *Termites et Champignons*. Société Nouvelle Des Éditions Boubée, France.
- Kirk, P.M., Cannon, P.F., David, J.C. and Stalpers, J.A. (2001). *Dictionary of the Fungi*. 9th edn. CAB International, Wallingford, UK.
- Pegler, D.N. (1977). A Preliminary Agaric Flora of East Africa. Kew Bulletin, Additional Series 6: 1-615.
- Pegler, D.N. and Pearce, G.D. (1980). The edible mushrooms of Zambia. Kew Bulletin 35: 475-491.
- Pegler, D.N. and Vanhaecke, M. (1994). *Termitomyces* of Southeast Asia. Kew Bulletin 49: 717-736.
- Rouland-Lefevre, C., Diouf, M.N., Brauman, A. and Neyra, M. (2002). Phylogenetic relationships in *Termitomyces* of ITS: a first approach to elucidate the evolutionary history of the symbiosis between fungus-growing termite and their fungi. Molecular Phylogenetics & Evolution 22: 423-429.
- Saarimäki, T., Härkönen, M. and Mwasumbi, L. (1994). Tanzanian mushrooms and their uses 3. *Termitomyces singidensis*, sp. nov. Karstenia 34: 13-20.
- Van Der Westhuizen, G.C.A. and Eicker, A. (1990). Species of *Termitomyces* occurring in South Africa. Mycological Research 94: 923-937.
- Van Der Westhuizen, G.C.A. and Eicker, A. (1991). The 'Omajowa' or 'Termitenpilz', *Termitomyces* sp. (*Agaricales*) of Namibia. South Africa Journal of Botany 57: 67-70.
- Wei, T.Z. and Yao, Y.J. (2003). Literature review of *Termitomyces* species in China. Fungal Science 18: 39-54. (in Chinese).
- Ying, J.Z. and Zang, M. (1994). *Economic Macrofungi in the Southwest China*. Science Press, China. (in Chinese).
- Zang, M. (1981). *Sinotermitomyces*, a new genus of *Amanitaceae* from Yunnan, China. Mycotaxon 13: 171-174.
- Zang, M. (1992). Contribution to the study on the genus *Sinotermitomyces* from Asia. Mycotaxon 44: 21-26.
- Zang, M. and Chen, C.M. (1998). Four new taxa of *Basidiomycota* from Taiwan. Fungal Science 13: 23-28.

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