



## Coprophilous Agaricales (Agaricomycetes, Basidiomycota) from Brazil

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### Abstract

During a survey of coprophilous fungi along a gradient through different vegetational areas in Pernambuco, northeastern Brazil, twelve species of dung inhabiting mushrooms were reported. *Bolbitius demangei*, *Conocybe siliginea*, *Coprinellus angulatus*, *C. marculentus*, *Coprinopsis cothurnata*, *C. pseudoradiata*, *C. vermiculifer* and *Coprinus foetidellus* are new records for Brazil. Descriptions and drawings are provided, along with an identification key to all Agaricales species recorded on dung in Brazil.

**Key words:** Basidiomycetes, coprophilous fungi, taxonomy

### Introduction

Coprophilous fungi comprise a diverse ecological group composed of both specialized species, which display adaptations and convergent evolution to better exploit their substrate in multiple phases of their life cycle, and by facultative, opportunistic species, successfully establishing, growing and reproducing on dung (Webster 1970; Doveri 2004; Krug *et al.* 2004; Kirk *et al.* 2008).

Agaricales Underw. includes fungi whose fruit bodies are commonly known as mushrooms and other related basidiomycetes, occurring mainly as terrestrial saprobes, ectomycorrhizal mycobionts or, occasionally, as parasites on plants or fungi, being widely distributed and occurring on a great range of substrates (Singer 1986; Kirk *et al.* 2008; Hibbett *et al.* 2014). The group has undergone many changes in its classification. The work of Singer (1986) suggested three major groups within the order: the Agaricales, the Boletales and the Russulales, each one still accepted as natural groups in separate orders (Hibbett *et al.* 2007). The Agaricales *sensu* Singer (1986) corresponds to the Euagarics clade *sensu* Hibbett & Thorn (2001). Phylogenomic analyses have confirmed some aspects of Agaricomycetes phylogeny that had been resolved in earlier studies of rDNA and protein-coding genes, such as the monophyly of Agaricomycetidae (Hibbett *et al.* 2014). The group contains 33 families, with ca. 400 genera and 13.000 species (Kirk *et al.* 2008).

Some Agaricales are common on herbivore dung (Bell 1983; Richardson 2001; Doveri 2004; Prydiuk 2011) such as those species previously assigned to *Coprinus* Pers. (Krug *et al.* 2004). Since 2001, with the segregation of this genus, most species were reclassified into three genera: *Coprinus* Persoon (1797) (Agaricaceae), *Coprinellus* P. Karsten (1879) and *Coprinopsis* P. Karst. (Psathyrellaceae) (Redhead *et al.* 2001). Nevertheless, the denomination “coprinoid fungi” is commonly used when referring to these dark-spored genera with a *Coprinus*-like hymenophore (Singer 1986). Other genera, such as *Panaeolus* (Fr.) Quélet (1872), *Psathyrella* (Fr.) Quélet and *Psilocybe* (Fr.) P. Kummer (1871) can also be found on dung *in situ* or after some days in incubation. Members of Bolbitiaceae Singer also occur on herbivore dung, usually growing in substrates *in situ*, but occasionally found on incubation. *Conocybe* (Amandeep *et al.* 2015) and *Bolbitius* (Amandeep *et al.* 2013) are common examples.

Previous work on coprophilous Agaricales in Brazil include collections by Montagne (1856). For a brief historical treatment of this group in Brazil, see Wartchow *et al.* (2007). Although coprophilous fungi are very common on dung, known to professional and amateur mycologists alike and, thus, commonly collected during inventory studies, field trips and forays around the world, little is known about their diversity in Brazil, since focused studies have been

scarce. Wartchow *et al.* (2007) reported three species of *Psilocybe* recorded for the first time in northeastern Brazil. During a visit to Brazil in 1998, Richardson (2001) recorded and provided a brief description of *Coprinopsis stercorea* (Fr.) Redhead, Vilgalys & Moncalvo, *C. cordispora* (T. Gibbs) Krieglsteiner & Gminder (2010), *C. radiata* (Bolton) Redhead, Vilgalys & Moncalvo, *Coprinellus curtus* (Kalchbr.) Vilgalys, Hopple & Jacq. Johnson, *C. heptemerus* (M. Lange & A.H. Sm.) Vilgalys, Hopple & Jacq. Johnson, *C. pellucidus* (P. Karst.) Redhead, Vilgalys & Moncalvo, along with an unidentified species similar to *Coprinopsis stercorea*, from a small number of dung samples collected at Bonito and Pantanal do Rio Negro, Mato Grosso do Sul. Despite not being focused on coprophilous species, Guzmán (1978, 1984) provided significant additions to the knowledge of *Psilocybe* from Brazil.

In order to present new records and improve the knowledge of the distribution and diversity of coprophilous Agaricales, this study reports twelve species collected along a vegetational and substrate gradient in the state of Pernambuco, Brazil, and provides descriptions, illustrations and an identification key to all known agaricoid fungi found on dung in Brazil.

## Material and Methods

Two hundred and seventy samples of goat, cattle and horse dung in equal proportion were collected over three years (2011–2013) from animal precincts, such as pastures and small farms, in three different cities: Recife (8°00'54" S, 34°56'59" W), Caruaru (8°01'59" S, 36°06'59" W) and Serra Talhada (7°54'59" S, 38°17'0.14" W), located in Pernambuco, Northeastern Brazil. The samples were collected in clean plastic bags, taken to the laboratory and incubated in moist chambers at room temperature (28 °C ± 2 °C) for at least 60 days under alternating natural light and dark periods. Fruiting bodies found *in-situ* were photographed, placed (along with the dung sample) in paper bags or plastic containers. Specimens were observed under a stereomicroscope, and standard laboratory techniques were used for the identification of agarics (Singer 1986). Species were identified based on their morphology according to Singer (1986), Bell (1983), Uljé & Bas (1988, 1992), Uljé & Noordeloos (1993; 1997; 1999), Richardson & Watling (1997), Uljé (2003) and Doveri (2004). Polyvinyl-Lacto-Glycerol was used to make permanent slides for some structures. Permanent slides and dried specimens were deposited as vouchers in Padre Camille Torrend Herbarium (URM), Universidade Federal de Pernambuco.

## Results

Most samples studied in the surveys contained Agaricales, with high reoccurrence, producing basidiomata on different dung types from the first weeks until the end of the incubation period. Coprinoid fungi with black spores and deliquescent lamellae were dominant (9 of 12 species, with 102 occurrences), represented by species of *Coprinus*, *Coprinopsis* and *Coprinellus*. Some species, such as *Bolbitius demangei* (Qué.) Saccardo & Saccardo (1905). and *Panaeolus antillarum* (Fr.) Dennis (1961), were collected *in situ*. *Conocybe* and *Panaeolus* were also commonly reported on the substrates in the study areas. Twelve species growing directly on the dung were identified. An identification key to agaricoid fungi found on herbivore dung in Brazil is provided, including records from Silva *et al.* (2006, 2008), Trierweiler-Pereira & Baseia (2009) and Wartchow *et al.* (2007).

### Key to coprophilous Agaricales recorded in Brazil

1. Basidiomata angiocarpic, nidularioid, composed of peridioles inside a peridium..... *Cyathus stercoreus*
- Basidiomata gymnocarpic, agaricoid, with lammellate hymenophore.....2
2. Pileus deliquescent to some degree with maturation. Basidia of unequal length in different portions of the lamellae.....3
- Pileus non-deliquescent. Basidia uniform in length.....17
3. Velar remnants on pileus absent on mature basidiomata. Stipe and pileus with seta and/or setula .....4
- Velar remnants on pileus present on mature basidiomata. Stipe and pileus lacking seta and/or setula .....9
4. Stipe and pileus glabrous. Basidiospores triangular with rounded angles ..... *Parasola misera*
- Stipe and pileus with setulae and/or setae. Basidiospores otherwise .....5

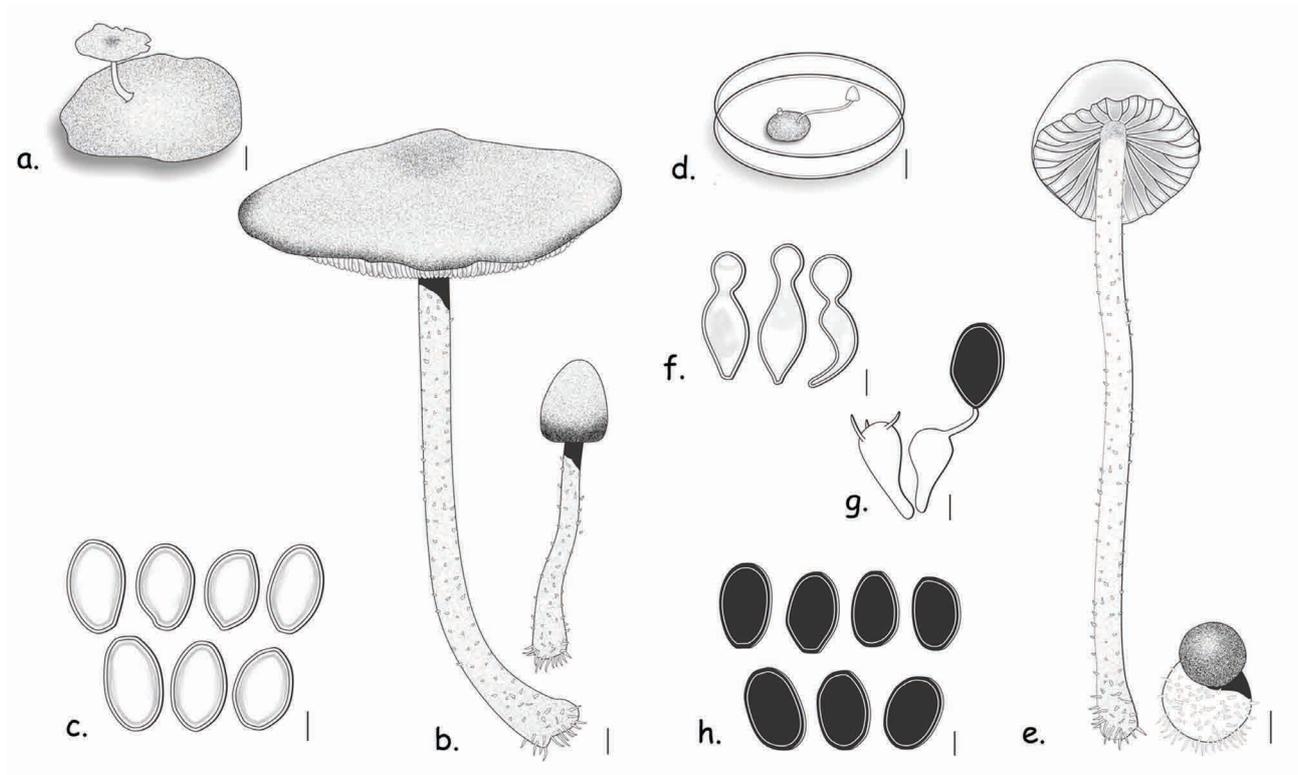
5.	Basidiospores angular.....	6
-	Basidiospores ellipsoid, ovoid or oblong .....	7
6.	Pileus setulose, with setula slightly capitate. Basidiospores hexagonal.....	<i>Coprinellus marculentus</i>
-	Pileus setose, with acute seta. Basidiospores mitriform in frontal view .....	<i>Coprinellus angulatus</i>
7.	Pileocystidia with rounded ends .....	<i>Coprinellus curtus</i>
-	Pileocystidia with abrupt ends .....	8
8.	Pilleipellis with velar sphaerocysts.....	<i>Coprinellus heptemerus</i>
-	Pilleipellis without velar sphaerocysts .....	<i>Coprinellus pellucidus</i>
9.	Velar remnants mainly composed of globose elements.....	10
-	Velar remnants mainly composed of filamentous elements .....	14
10.	Velar elements smooth, interspersed with small crystals .....	11
-	Velar elements ornamented with several crystalline projections.....	13
11.	Basidiospores limoniform in frontal view, with rounded angles.....	<i>Coprinopsis nivea</i>
-	Basidiospores angular in frontal view, with abrupt angles.....	12
12.	Basidiospores 6-sided, hexagonal in frontal view .....	<i>Coprinopsis cothurnata</i>
-	Basidiospores roughly 5-sided, cordiform in frontal view .....	<i>Coprinus patouillardii</i>
13.	Basidiomata with strong narcotic smell. Basidiospores ovoid to oblong, 7.5–10.5 × 5–7.5 µm.....	<i>Coprinus foetidellus</i>
-	Basidiomata without narcotic smell. Basidiospores cylindrical, 6.5–7.5 × 3–4 µm .....	<i>Coprinopsis stercorea</i>
14.	Terminal cells of velar filaments undifferentiated.....	15
-	Terminal cells of velar filaments with thickened wall.....	16
15.	Basidiospores 7.5–9.6 × 4.8–6 µm .....	<i>Coprinopsis pseudoradiata</i>
-	Basidiospores 14–16 × 7.5–8.5 µm.....	<i>Coprinopsis radiata</i>
16.	Velar filaments with constrictions at the septa, composed of sausage-shaped strings .....	<i>Coprinopsis cinerea</i>
-	Velar filaments without constrictions at the septa, composed of tubular strings.....	<i>Coprinopsis vermiculifer</i>
17.	Basidiomata growing on incubated dung or <i>in situ</i> .....	18
-	Basidiomata growing <i>in situ</i> on dung or in soil contaminated with dung, usually absent in incubation .....	22
18.	Pileus convex, hemispherical to conical-campanulate when expanded, pale cream, becoming ochraceous with age, bearing free to adnate lamellae, equally copper to rust coloured with basidiospores ripening. Spore print brown.....	19
-	Pileus hemispherical when expanded, whitish, usually remaining so with age, bearing adnexed lamellae, white, markedly punctate with black dots due the non-simultaneous basidia maturation. Spore print black.....	20
19.	Basidiomata growing <i>in situ</i> . Expanded pileus 36–40 mm diam .....	<i>Bolbitius demangei</i>
-	Basidiomata growing on incubated dung. Expanded pileus 9–14 mm diam .....	<i>Conocybe siliginea</i>
20.	Pileus umbonate, cinnamon colored to brown, with brownish context.....	<i>Panaeolus cinctulus</i>
-	Pileus hemispherical to campanulate, whitish to cream colored, with whitish context .....	21
21.	Expanded pileus convex to campanulate, brownish to pinkish brown, with involute margin .....	<i>Panaeolus papilionaceus</i>
-	Expanded pileus conical to hemispherical, whitish to pale cream, with lacerated margin .....	<i>Panaeolus antillarum</i>
22.	Spore print white to whitish. Lamellae whitish, with some shades of green. Expanded pileus with conspicuous yellowish scales.....	<i>Chlorophyllum hortense</i>
-	Spore print dark. Lamellae darkening with basidiospore maturation, never greenish. Expanded pileus without yellowish scales .....	23
23.	Chrysocystidia present.....	24
-	Chrysocystidia absent.....	25
24.	Partial veil fleshy. Basidiospores 7–9 × 5–5.5 µm .....	<i>Stropharia coronilla</i>
-	Partial veil glutinous. Basidiospores 13–14 × 7–9 µm.....	<i>Protostropharia alcis</i>
25.	Partial veil absent .....	<i>Psilocybe argentina</i>
-	Partial veil present .....	26

26.	Basidiomata turning blue when handled .....	27
-	Basidiomata not turning blue when handled .....	29
27.	Pleurocystidia absent. Basidiospores ovoid .....	<i>Psilocybe caeruleoannulata</i>
-	Pleurocystidia present. Basidiospores hexagonal .....	28
28.	Basidiospores 13–16 × 7–10 μm .....	<i>Psilocybe cubensis</i>
-	Basidiospores 11–13 × 7.5–8.8 μm .....	<i>Psilocybe subcubensis</i>
29.	Basidiospores up to 15 μm long .....	<i>Psilocybe coprophila</i>
-	Basidiospores shorter, not exceeding 12 μm long .....	30
30.	Annulus whitish. Basidiospores 8.5–12 × 6–8 μm .....	<i>Psilocybe pegleriana</i>
-	Annulus black. Basidiospores 10–11 × 6.5–7.5 μm .....	<i>Psilocybe merdaria</i>

## Taxonomy

### 1. *Bolbitius demangei* (Quéél.) Sacc. & D. Sacc., Sylloge Fungorum (Abellini) 17: 74 (1905)

(Figure 1, a–c)



**FIGURE 1.** *Bolbitius demangei* a. Habit of a basidioma on dung. b. Basidiomata. c. Basidiospores. *Conocybe siliginea* d. Habit of basidiomata on dung. e. Basidiomata. f. Capitulate cystidia. g. Basidia. h. Basidiospores. Scale bars: a=20 mm. b=2.5 mm. c, f, h= 5 μm. d= 200 μm. e=2 mm. g=7.5 μm. Figure: R.F.R. Melo.

*Expanded pileus* campanulate to umbonate, finally becoming applanate, 36–40 mm in diameter, brown to pale brown, darkening with age, with a central papilla slightly brownish, with a smooth to squamulose surface and a slightly wavy to crenulated edge. *Lamellae* non-deliquescent, adnexed or free, closely spaced, thin, fragile, initially pale cream, finally reddish brown to cupreous with the maturation of basidia and basidiospores. *Stipe* central, cylindrical, slightly swollen at the base, hollow, finely striate, fibrillose, white to pale cream, 47–50 mm long, 2–2.5 mm in diameter, 2.5–3 mm at the base. *Ring* absent. *Volva* absent. *Cheilocystidia* 17.5–45 × 7.5–37.5 μm, lageniform to clavate, rarely slightly capitate, hyaline, thin-walled. *Pleurocystidia* absent or indistinguishable. *Clamp connections* absent. *Basidia* 2- to 4-spored, clavate. *Basidiospores* ellipsoid, except for the truncated base, smooth, dark yellow to golden, 12.5–15 × 7.5–10 μm, thick-walled, with a single germ pore.

**Material examined:**—BRAZIL. Pernambuco, Universidade Federal Rural de Pernambuco (UFRPE), Recife, on cattle dung, 15 Mar 2013, R.F.R. Melo (URM86837a!, 86837b!).

**Distribution:**—Asia, Europe, North America and South America. This is the first record from Brazil.

**Notes:**—*Bolbitius demangei* resembles *B. coprophilus* (Peck) Hongo (1959) with a brown to reddish brown expanded pileus but differs by the smaller basidiomata (stipe up to 50 mm long) and darker lamellae at maturity (Amandeep *et al.*, 2013). A sequence of the partial LSU region obtained from this material (KX246930) had the best BLAST match with “*Bolbitius demangei* AF261520”.

**2. *Conocybe siliginea*** (Fr.) Kühner, *Encyclop. Mycol.* 7: 96 (1935)  
(Figure 1, d–h)

*Closed pileus* initially globose, finally conical with the stipe elongated, yellowish to ochraceous. *Expanded pileus* convex, hemispherical to conical-campanulate, 9–14 mm in diameter, white, pale cream, becoming more tapered and ochraceous with age, with a central papilla slightly darker, best observable in young basidiomata, with surface smooth to pruinose, not hygrophanous, and edge slightly wavy to crenulated, non striated. *Lamellae* adnate, thick, waxy, initially pale cream, finally rust red to coppery with the maturation of basidia and basidiospores. *Lamellulae* present, similar to the lamellae in morphology. *Stipe* central, cylindrical, slightly bulbous at the base, hollow, finely pilose, white to pale cream, 25–46 mm long, 1–1.5 mm in diameter, 2.5–3 mm at the base. *Ring* absent. *Volva* absent. *Cheilocystidia* slightly incrusted, 22.5–25 × 15–25 µm, lecythiform, capitate, capitula 3–4 µm in diameter, hyaline, thin-walled. *Pleurocystidia* absent. *Caulocystidia* lageniform to irregular in shape, 10–25.5 × 7.5–10, with tapering to 2–2.5 µm broad near the apex. *Clamp connections* present. *Basidia* 2-spored, clavate, 20–32.5 × 7.5–12.5 µm. *Basidiospores* oblong to ellipsoid, smooth, dark yellow to golden, 13.5–18 × 8.5–9.5 µm, thick-walled, with a central or slightly eccentric large germ pore, 1.8–2 µm.

**Material examined:**—BRAZIL. Pernambuco, Universidade Federal Rural de Pernambuco (UFRPE), Recife, on goat dung, 27 Oct 2011, R.F.R. Melo (URM86792!).

**Distribution:**—Europe (Austria, England, Germany, Iceland, Italy, Luxemburg, Sweden), Oceania (New Zealand). This is the first record from Brazil.

**Notes:**—*Conocybe siliginea* is recorded directly from incubated goat dung collected in Recife and forms pale colored basidiomata, usually with the stipe concolorous with the pileus. *Conocybe rickenii* (Jul. Schöff.) Kühner (1935) is similar to *C. siliginea*, differing by having slightly larger basidiospores as well as larger and darker pilea, usually with a distinct coloration from the stipe.

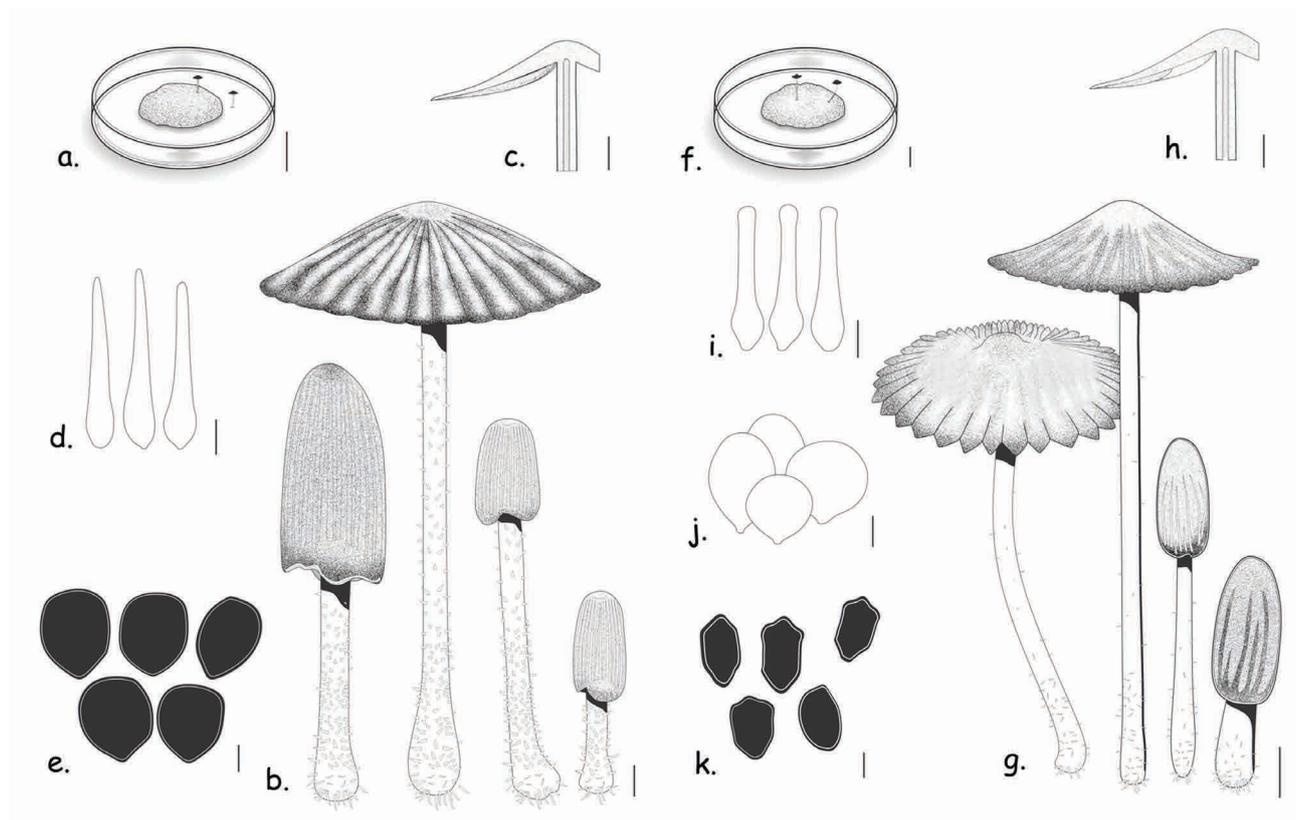
**3. *Coprinellus angulatus*** (Peck) Redhead, Vilgalys & Moncalvo, *Taxon* 50(1): 232 (2001)  
(Figure 2, a–e)

*Closed pileus* initially ellipsoid, 13–18 × 9–13 mm, ochraceous brown to gray-brown, becoming lighter towards the margin, naked, with several setose pileocystidia, hardly observable in stereomicroscopy. *Expanded pileus* campanulate, 25–27 mm in diameter, dark gray to whitish. *Veil* absent. *Lamellae* free, rarely adnexed, initially whitish, finally dark gray to black with the maturation of basidia and basidiospores. *Stipe* central, cylindrical, hollow, pubescent, straight or crooked, whitish, 25–50 mm long, 1.5–2 mm in diameter. *Ring* absent. *Volva* absent. *Pileocystidia* abundant, setose, 75–110 µm, lageniform, decreasing considerably in diameter towards the apex, about 10–15 µm in diameter at the proximal end, tapering to 1–2 µm near the distal end, hyaline, smooth, thin-walled. *Cheilocystidia* not observed. *Pleurocystidia* not observed. *Basidia* 4-spored, club-shaped, surrounded by hyphidial elements. *Basidiospores* mitriform in frontal view, cylindrical to ellipsoid in side view, flat, dark reddish brown, 7.2–8.5 × 6–7.5 µm, thick-walled, with a central germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Serra Talhada, on horse dung, 04. Jun 2012, R.F.R. Melo (URM86793!); Universidade Federal Rural de Pernambuco (UFRPE), Recife, on cattle dung, 19. Jun 2012, R.F.R. Melo (URM86794a!, 86794b!).

**Distribution:**—Europe (Netherlands, Switzerland). This is the first record from Brazil.

**Notes:**—*Coprinellus angulatus*, a rare species on herbivore dung, has small basidiomata forming directly on incubated dung, with a thinner stipe than the specimens described from soil or plant material. It can be easily distinguished by the combination of the following characters: naked pileus, with setose pileocystidia exceeding 100 µm in length and mitriform basidiospores in frontal view.



**FIGURE 2.** *Coprinellus angulatus* a. Habit of basidiomata on dung. b. Basidiomata. c. Lamellae and stipe insertion. d. Setae. e. Basidiospores. *Coprinellus marculentus* f. Habit of basidiomata on dung. g. Basidiomata. h. Lamellae and lamellulae. i. Setae. j. Cheilocystidia. k. Basidiospores. Scale bars: a, f=200 mm. b, c, e= 2.5  $\mu$ m. d, i=25  $\mu$ m. g=5 mm. h=2.5 mm. j=15  $\mu$ m. k=5  $\mu$ m. Figure: R.F.R. Melo.

**4. *Coprinellus marculentus*** (Britzelm.) Redhead, Vilgalys & Moncalvo, Taxon 50(1): 234 (2001)  
(Figure 2, f–k)

*Closed pileus* initially subglobose, becoming ellipsoid to cylindrical-ellipsoid, 13–14  $\times$  9–11 mm, ochraceous to rust brown in the center, becoming lighter towards the margin, light brown to amber and finally ochraceous yellow to luteous near the margin, extending radially to the edge. *Expanded pileus* convex-campanulate, 22–27 mm in diameter, bluish gray, slightly umbonate, reddish brown at the center, with smooth, setulose surface and wavy to crenulated edge. *Veil* absent. *Lamellae* free, initially whitish, finally dark gray to black with the maturation of basidia and basidiospores. *Stipe* central, cylindrical, hollow, pubescent, setulose, whitish to pinkish, 50–90 mm long, 1.5–2 mm in diameter. *Ring* absent. *Volva* absent. *Pileipellis* formed by globose sphaerocysts, 35–40  $\mu$ m in diameter. *Pileocystidia* up to 110 mm in length, setulose, located mainly in the center of the pileus, lageniform, slightly capitate, 10–15  $\mu$ m at the proximal end, tapering to 5–10  $\mu$ m near the distal end, hyaline, smooth, thin-walled. *Cheilocystidia* globose to ellipsoid, 45–50  $\times$  15–27.5  $\mu$ m, usually collapsing in mounting, hyaline, thin-walled. Pleurocystidia not observed. *Clamp connections* present. *Basidia* 4-spored, club-shaped, surrounded by hyphidial elements. *Basidiospores* hexagonal in frontal view, irregular in side view, smooth, reddish brown to dark brown, 10.8–15  $\times$  6.5–7.5  $\mu$ m, thick-walled, with an eccentric germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Caruaru, on cattle dung, 09 Apr 2012, R.F.R. Melo (URM86795); Instituto Agronômico de Pernambuco (IPA), Serra Talhada, on horse dung, 24 Oct 2011, R.F.R. Melo (URM86796); Universidade Federal Rural de Pernambuco (UFRPE), Recife, on cattle dung, 03 Feb 2013, R.F.R. Melo (URM86797!).

**Distribution:**—Europe (England, Italy, Netherlands, Serbia, Sweden). This is the first record from Brazil.

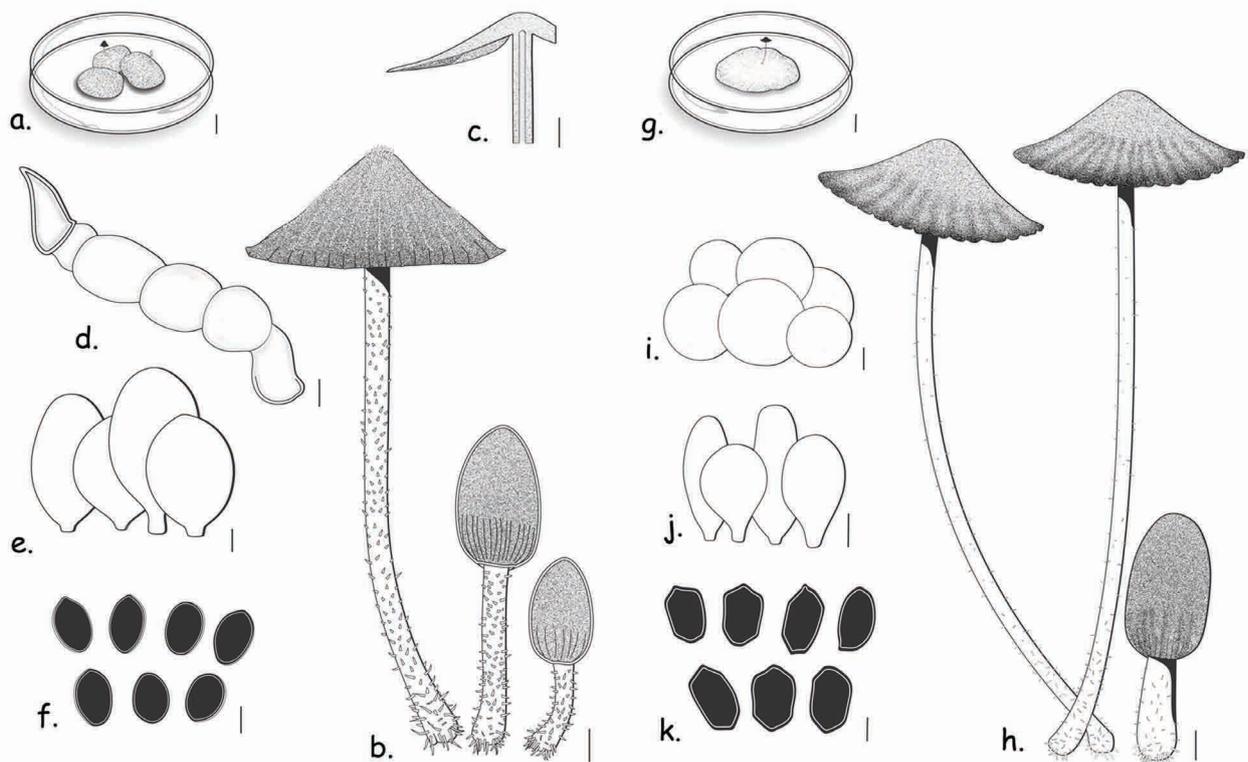
**Notes:**—*Coprinellus marculentus* has key morphological characteristics that aid in its identification such as the naked pileus (devoid of veil remnants), which is setulose since the beginning of stipe elongation, globose sphaerocysts, as well as hexagonal basidiospores in frontal view. *Coprinopsis cothurnata* also has hexagonal basidiospores,

differing by the non-setulose pileus, the presence of veil remnants composed of subglobose elements interspersed with conspicuous crystals and by the larger basidiomata.

**5. *Coprinopsis cinerea*** (Schaeff.) Redhead, Vilgalys & Moncalvo, *Taxon* 50(1): 227 (2001)

(Figure 3, a–f)

Closed pileus initially ellipsoid to subcylindrical, 15–17 × 12–14 mm, covered in all or part of its length by fibrillose velarremnants. Expanded pileus initially conical, becoming more convex and finally flattened, with revolute margin, 25–28 mm in diameter, brown-gray to dark gray. *Lamellae* initially white, becoming dark gray to black, up to 1.5 mm thick, deliquescent. *Lamellulae* present, similar in morphology. *Stipe* central, cylindrical to clavate, hollow, floccose-fibrillose, glabrous, whitish, 50–80 mm long, 2.5–5 mm in diameter. *Ring* absent. *Volva* absent. *Pileipellis* hyphal, composed of filamentous elements giving the pileus its fibrillose texture and gray to silver coloration in some parts, especially at the center. *Veil* composed of filamentous elements, forming chains of cells constricted at the each septum, up to 190 µm in diameter, usually with subglobose terminal cells. *Cheilocystidia* 37.5–52.5 × 17.5–25 µm, subglobose to ellipsoid, hyaline, thin-walled, smooth. *Pleurocystidia* utriform to obclavate, 45–100 × 17.5–22.5 µm, hyaline, thin-walled, smooth. *Clamp connections* present. *Basidia* 4-spored, club-shaped, surrounded by hyphidial elements. *Basidiospores* ovoid to ellipsoid in frontal view, somewhat cylindrical in side view, dark reddish-brown to black, 8.4–10.8 × 6–7.2 µm, with a central germ pore.



**FIGURE 3.** *Coprinopsis cinerea* a. Habit of basidiomata on dung. b. Basidiomata. c. Lamellae and lamellulae. d. Elongated velar element. e. Cheilocystidia. f. Basidiospores. *Coprinopsis cothurnata* g. Habit of a basidioma on dung. h. Basidiomata. i. Globular velar elements. j. Cheilocystidia. k. Basidiospores. Scale bars: a, g= 100 mm. b, c, h=5 mm. d= 75 µm. e= 7,5 µm. f, k= 5 µm. i= 30 µm. j=10 µm. Figure: R.F.R. Melo.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Serra Talhada, on horse dung, 04 Jul 2011, R.F.R. Melo (URM86798); Universidade Federal Rural de Pernambuco (UFRPE), Recife, on goat dung, 08 Feb 2013, R.F.R. Melo (URM86799a!, 86799b!).

**Distribution:**—Worldwide.

**Notes:**—Although underrepresented on herbivore dung in Recife, this is a common worldwide species being recorded not only on dung but on other substrates. *Coprinopsis cinerea* has velar remnants with filamentous elements,

smooth, septate, well differentiated terminal cells (Section *Lanatu* J. Lange *sensu* Uljé, 2003), and is distinguished by the basidiospore measurements ( $8.4\text{--}10.8 \times 6\text{--}7.2 \mu\text{m}$ ).

**6. *Coprinopsis cothurnata*** (Godey) Redhead, Vilgalys & Moncalvo, *Taxon* 50(1): 227 (2001)  
(Figure 3, g–k)

*Closed pileus* initially ellipsoid to subcylindrical, later ellipsoid to cylindrical-ellipsoid,  $17\text{--}22 \times 10\text{--}15$  mm, covered along its entire surface by powdery veil fragments. *Expanded pileus* conical to campanulate, 30–35 mm in diameter, becoming flattened, with revolute margin, dark gray to black, with a radial pattern of veil fragments from the center to the margin, composed of small flakes of globular elements, grouped mainly in the center, giving it the brown color where it is concentrated, strongly plicate-sulcate, with crenulated margin. *Veil* composed of globose to subglobose elements, up to 130  $\mu\text{m}$  in diameter, interspersed with conspicuous crystals. *Lamellae* adnexed or free, initially white, becoming dark gray to black, up to 1.5 mm thick, deliquescent. *Lamellulae* present, similar in morphology. *Stipe* central, cylindrical to clavate, hollow, finely fibrillose, with sparse velar flakes, especially near the pileus, white to pale gray, 80–95 mm long, 2–4.5 mm in diameter. *Ring* absent. *Volva* absent. *Cheilocystidia*  $27.5\text{--}40 \times 15\text{--}25 \mu\text{m}$ , globose, clavate to saccate, usually collapsing, hyaline, thin-walled, smooth. *Pleurocystidia* absent or not observed. *Clamp connections* rare. *Basidia* 4-spore, clavate. *Basidiospores* hexagonal in frontal view, ellipsoid in side view, brown to reddish brown,  $12.5\text{--}15 \times 7.5\text{--}9 \mu\text{m}$ , with a central germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Serra Talhada, on cattle dung, 24 Oct 2012, R.F.R. Melo (URM86800!).

**Distribution:**—Despite the worldwide distribution, this is the first record from Brazil.

**Notes:**—*Coprinopsis cothurnata* has relatively large basidiomata for species that grow on fresh herbivore dung in damp chambers. It resembles *C. nivea* (Pers.) Redhead, Vilgalys & Moncalvo, differing by the basidiospore shape and the absence of pleurocystidia. It differs from *Coprinellus marculentus*, which also has hexagonal spores, by the significantly larger basidiomata and basidiospores.

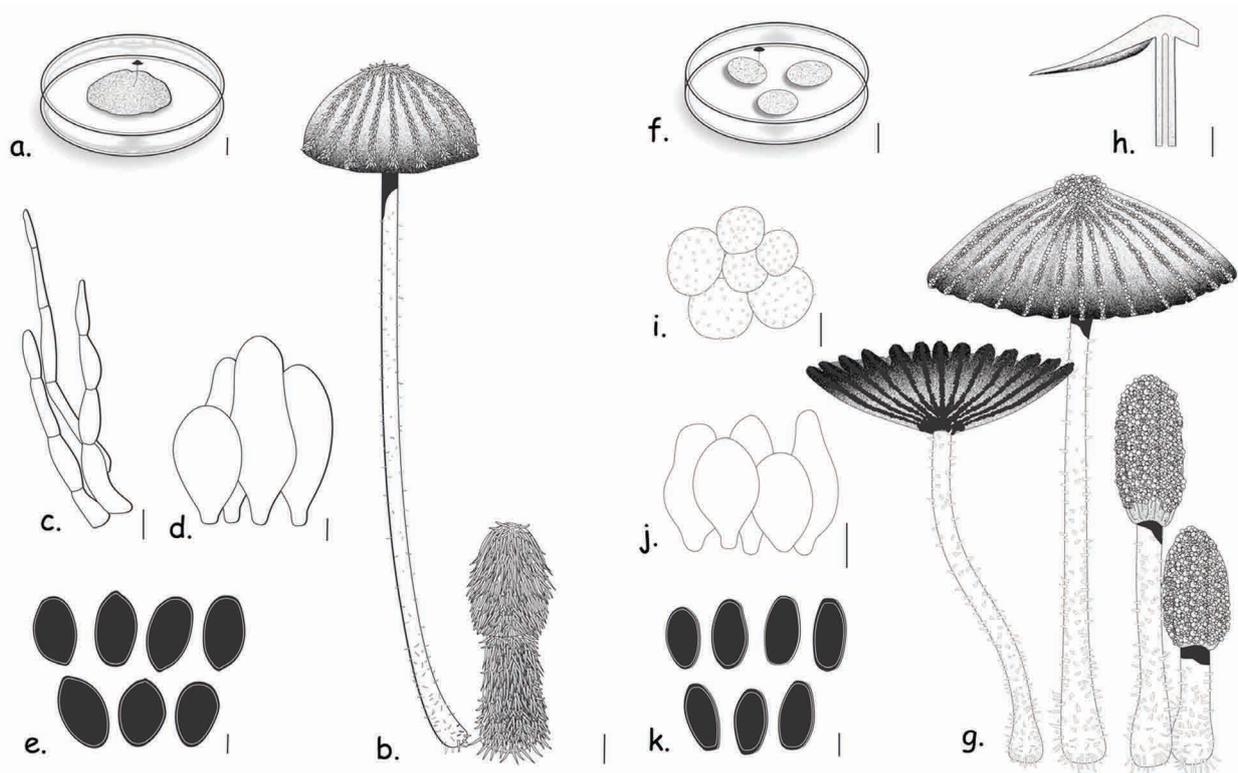
**7. *Coprinopsis pseudoradiata*** (Kühner & Joss. & Watling) Redhead, Vilgalys & Moncalvo, *Taxon* 50(1): 230 (2001)  
(Figure 4, a–e)

*Closed pileus* initially ellipsoid to cylindrical-ellipsoid, later semi-ovoid,  $4\text{--}6 \times 3.5\text{--}4$  mm, covered along its entire length by whitish veil fragments, pale gray, giving a tomentose texture. *Expanded pileus* conical to hemispherical, 10–12 mm in diameter, soon becoming flattened, convex-flattened or nearly plano-convex, with a margin slightly revolute, initially whitish, becoming pale gray to dark gray with maturation, with abundant cord-like woven white veil, forming radial filaments from the center to the edge, hyaline to pale luteous, lightly pigmented in maturity, plicate-sulcate, with wavy and finally grooved edge. *Lamellae* free, initially white, becoming dark gray, deliquescent. *Lamellulae* present, similar in morphology. *Stipe* central, cylindrical, hollow, finely fibrillose, especially near the base, whitish, 35–45 mm long, 1–2.5 mm in diameter. *Ring* absent. *Volva* absent. *Pileipellis* composed of filamentous hyphal elements. *Veil* composed of filamentous elements in chains, with subglobose to wide-ellipsoid cells, usually inflated when persistent, constricted at each septum, with terminal cells undifferentiated,  $60\text{--}150 \times 10\text{--}22.5 \mu\text{m}$ . *Cheilocystidia*  $30\text{--}50 \times 22.5\text{--}25 \mu\text{m}$ , globose to ellipsoid, thin-walled, smooth. *Clamp connections* present. *Basidia* 4-spored, interspersed with hyphidial elements. *Basidiospores* subglobose to ellipsoid, reddish-brown to black,  $7.5\text{--}9.6 \times 4.8\text{--}6 \mu\text{m}$ , smooth, with a central germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Serra Talhada, on goat dung, 21 Sep 2011, R.F.R. Melo (URM86801a, 86801b); on cattle dung, 25 Oct 2011, R.F.R. Melo (URM86802a!, 86802b!).

**Distribution:**—Europe (Finland, France, Netherlands, Norway, Ukraine) and North America (United States of America). This is the first record from Brazil.

**Notes:**—*Coprinopsis pseudoradiata* is a representative with typical morphology of the former subsection *Lanatu* J. Lange within sect. *Coprinus* Pers., possessing a pileus covered by veil formed by inflated, elongated elements in chains, with constrictions at the septa and without differentiation of terminal cells. It differs from *C. cinerea* by the terminal cells, which have cell walls thicker, as well as wider and slightly longer basidiospores ( $8.4\text{--}10.8 \times 6\text{--}7.2 \mu\text{m}$ ). Macroscopically, it is easily confused with *C. radiata*, which has significantly larger basidiospores. In our specimens the basidiospore shape is not cylindrical as described by Uljé & Nooderloos (1999), and basidiospores are slightly broader ( $4.8\text{--}6 \mu\text{m}$  wide).



**FIGURE 4.** *Coprinopsis pseudoradiata* a. Habit of a basidioma on dung. b. Basidiomata. c. Filamentous elements of veil remnants. d. Cheilocystidia. e. Basidiospores. *Coprinopsis stercorea* f. Habit of a basidioma on dung. g. Basidiomata. h. Lamellae and stipe insertion. i. Globular elements of veil remnants, ornamented with nipple-shaped crystal projections. j. Cheilocystidia. k. Basidiospores. Scale bars: a, f=100 mm. b=7.5 mm. c, i=30  $\mu$ m. d, k=5  $\mu$ m. e=3  $\mu$ m. g=2 mm. h=5 mm. j=10  $\mu$ m. Figure: R.F.R. Melo.

**8. *Coprinopsis stercorea*** (Fr.) Redhead, Vilgalys & Moncalvo, *Taxon* 50(1): 231 (2001)  
(Figure 4, f–k)

*Closed pileus* initially subglobose to oblong, becoming ellipsoid to cylindrical-ellipsoid, 5–6  $\times$  3–4 mm, covered along its entire length by velar fragments, giving it a floccose-granular texture, mainly in the center, extending radially towards the edge. *Expanded pileus* hemispherical to campanulate, 10–12 mm in diameter, soon becoming somewhat flattened, with revolute margin, initially white, becoming light gray to dark gray with age, plicate-sulcate. *Lamellae* free, initially white, finally becoming clear gray, poorly distinguishable, deliquescent. *Stipe* central, cylindrical to slightly clavate at the base, hollow, finely fibrillose, usually with abundant velar flakes throughout its length, white to pale gray, 25–50 mm long, 0.5–1 mm in diameter. *Ring* absent. *Volva* absent. *Pileipellis* composed of hyphal and globular hyaline elements. *Veil* composed of globular elements, 30–90  $\mu$ m in diameter, with nipple-shaped crystal projections. *Cheilocystidia* 17.5–35  $\times$  9.5–15  $\mu$ m, globose to ellipsoid or utriform, thin-walled, smooth. *Clamp connections* absent or not observed. *Basidia* 4-spored, 7–15  $\times$  3–4.5  $\mu$ m, clavate, interspersed with hyphidial elements. *Basidiospores* long-ellipsoid to cylindrical, brown to reddish-brown, 6.5–7.5  $\times$  3–4  $\mu$ m, smooth, with a central germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Caruaru, on cattle dung, 06 Feb 2012, R.F.R. Melo (URM86803a!, 86803b!).

**Distribution:**—Worldwide.

**Notes:**—*Coprinopsis stercorea* is one of the most common species of coprinoid fungi recorded on herbivore dung. Other key features, in addition to the habit, are the veil remnants formed by globular elements adorned by nipple-shaped crystal projections and cylindrical basidiospores less than 4.5  $\mu$ m wide. It resembles *Coprinus foetidellus* P.D. Orton, which has broader basidiospores (4.5–6.5  $\mu$ m wide).

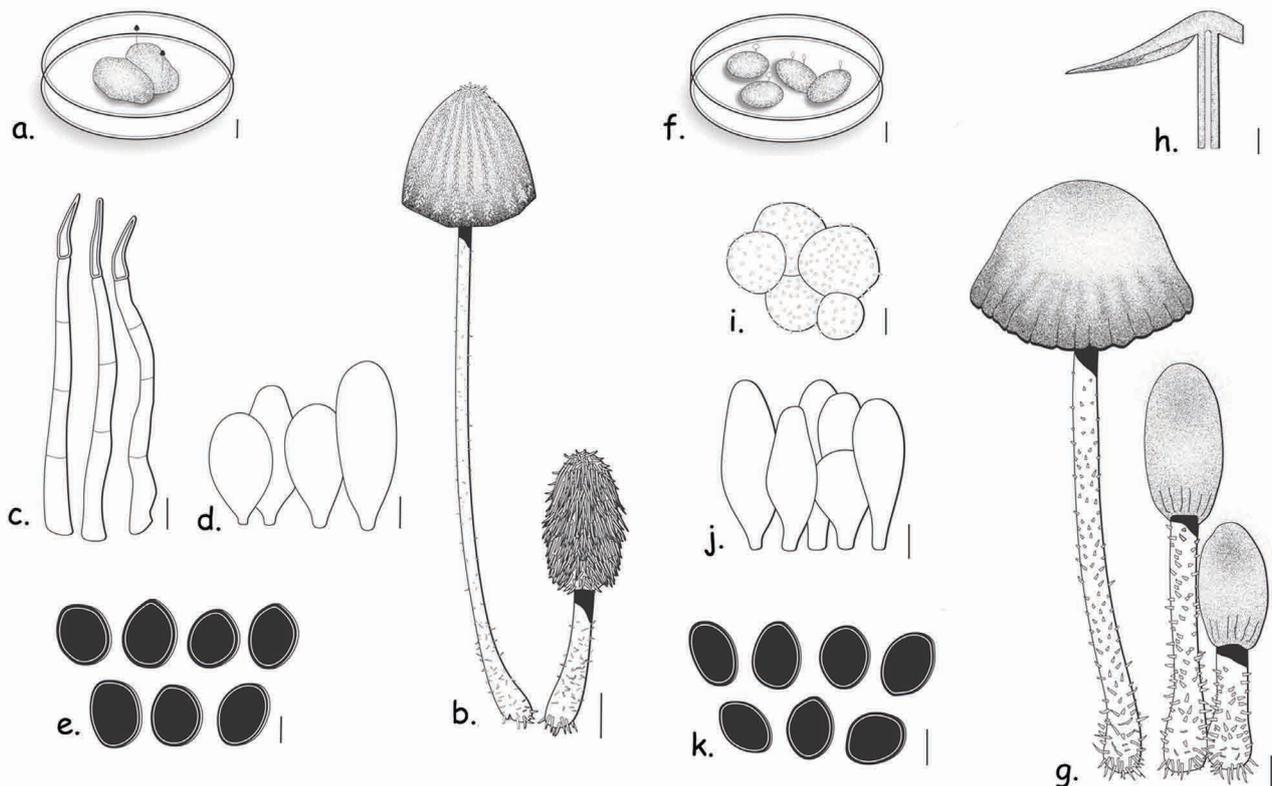
9. *Coprinopsis vermiculifer* (Joss. ex Dennis) Redhead, Vilgalys & Moncalvo, Taxon 50(1): 232 (2001)  
(Figure 5, a–e)

*Closed pileus* initially ellipsoid to subcylindrical, 5–6 × 3–4 mm, covered along its entire length by fibrillose velar fragments, giving it a cottony texture, whitish, greyish near the center. *Expanded pileus* conical to campanulate, 7–13 mm in diameter, becoming flattened, with revolute margin, initially whitish, becoming gray to dark gray with maturation. *Lamellae* free, initially white, becoming brownish to black, poorly distinguishable. *Stipe* central, cylindrical to slightly clavate at the base, hollow, finely fibrillose, whitish, 25–32 mm long, 0.5–1 mm in diameter. *Ring* absent. *Volva* absent. *Pileipellis* comprises hyphal elements, hyaline, from where emerges filaments of veil remnants, mainly on their center, spreading radially towards the edge, grouped into small scales in the center, giving a brownish appearance, plicate-sulcate, with sulcate margin. *Veil* composed of filamentous elements in chains, 5–7.5 mm in diameter, gradually decreasing towards the apex, with terminal elements with a thickened wall, hyaline, smooth. *Cheilocystidia* 30–40 × 20–25 μm, subglobose to ellipsoid, thin-walled, smooth. *Pleurocystidia* not observed. *Clamp connections* present. *Basidia* 4-spored, interspersed with hyphidial elements. *Basidiospores* broadly ellipsoid to ovoid in frontal view, reddish-brown to brown, 8.4–12 × 6–7.2 μm, flat, with a central germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Caruaru, on horse dung, 27 Sep 2011, R.F.R. Melo (URM86804!); Instituto Agronômico de Pernambuco (IPA), Serra Talhada, on horse dung, 14 Oct 2011, R.F.R. Melo (URM86805!), 24 Oct 2011, R.F.R. Melo (URM86806a!, 86806b!, 86806c!).

**Distribution:**—Africa (Namibia), Europe (England, Norway) and Oceania (Australia). This is the first record from Brazil.

**Notes:**—*Coprinopsis vermiculifer* is a relatively rare species with few records in the literature. It is distinguished by its veil remnants composed of filamentous elements, whose last cell has thick walls.



**FIGURE 5.** *Coprinopsis vermiculifer* a. Habit of basidiomata on dung. b. Basidiomata. c. Filamentous elements of veil remnants. d. Cheilocystidia. e. Basidiospores. *C. foetidellus* f. Habit of basidiomata on dung. g. Basidiomata. h. Lamellae and lamellulae, showing the stipe insertion. i. Globular elements of veil remnants, ornamented with nipple-shaped crystal projections. j. Cheilocystidia. k. Basidiospores. Scale bars: a, f=100 mm. b=2.5 mm. c=10 μm. d, j=7.5 μm. e, k=5 μm. g=2 mm. h=5 mm. i=25 μm. Figure: R.F.R. Melo.

10. *Coprinus foetidellus* P.D. Orton, Notes Royal Bot. Gdn Edinb. 32(1): 139 (1972)  
(Figure 5, f–k)

*Closed pileus* subglobose to ellipsoid, 4–5 × 3–4 μm, whitish to pale gray, abundantly covered along its entire length by farinaceous to fibrillose veil fragments, giving it a tomentose aspect. *Expanded pileus* initially ellipsoid to cylindrical-ellipsoid, later campanulate and finally flattened, 8–11 mm in diameter, whitish to light gray, with wavy to slightly sulcate margin. *Lamellae* free, initially white, becoming dark gray to black, ca. 1 mm thick, deliquescent. *Lamellulae* present, similar in morphology. *Stipe* central, cylindrical to slightly clavate near the base, hollow, finely fibrillose, whitish to pale gray, 30–40 mm long, 0.5 mm in diameter. *Ring* absent. *Volva* absent. *Pileipellis* hyphal. *Veil* composed of globular elements, hyaline, thin-walled, with up to 65 μm in diameter, adorned by nipple-shaped crystal projections. *Cheilocystidia* 22.5–37.5 × 15–22.5 μm, subglobose, saccate to clavate, usually collapsing, hyaline, thin-walled, smooth. *Pleurocystidia* large, up to 75 μm in length, subglobose, subellipsoid to obpyriform, hyaline, thin-walled, smooth. *Clamp connections* absent or not observed. *Basidia* 4-spored, usually interspersed with hyphidial elements. *Basidiospores* ovoid to oblong in frontal view, ellipsoid to cylindrical in side view, reddish-brown to dark brown, 7.5–10.5 × 5–7.5 μm, thick-walled, with rounded ends and a central germ pore.

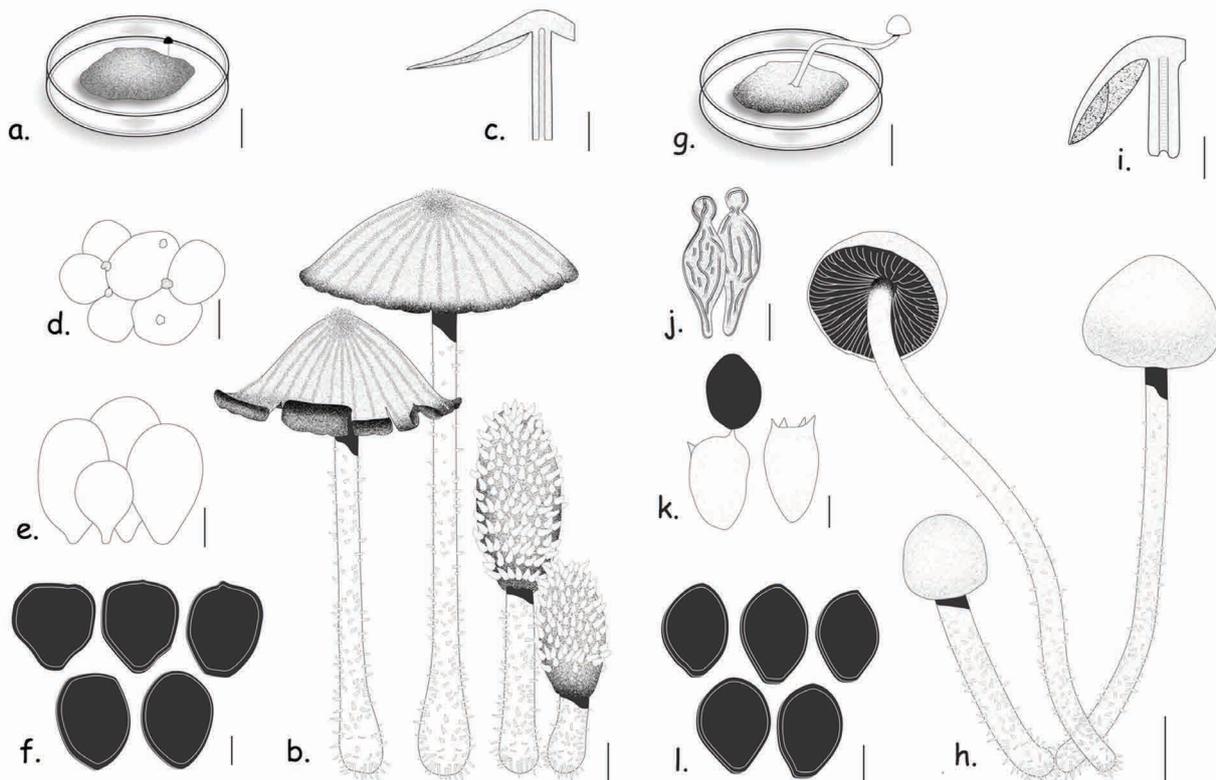
**Material examined:**—BRAZIL. Pernambuco, Instituto Agrônomo de Pernambuco (IPA), Serra Talhada, on cattle dung, 13 Sep 2011, R.F.R. Melo (URM86790!).

**Distribution:**—Europe (Netherlands, Ukraine). This is the first record from Brazil.

**Notes:**—This species was recorded on a few samples of herbivore dung in the semiarid region of Pernambuco, *Coprinus foetidellus* possesses a strong narcotic odor (which accounts for its specific epithet) and veil remnants formed by large globular cells adorned by nipple-shaped crystals. It resembles *Coprinopsis stercorea*, differing by the tomentose aspect of the pileus and by the wider basidiospores (7.5–10.5 × 5–7.5 μm).

#### 11. *Coprinus patouillardii* Quél., Tab. analyt. Fung. (Paris)(1): 107 (1884)

(Figure 6, a–f)



**FIGURE 6.** *Coprinus patouillardii* a. Habit of a basidioma on dung. b. Basidiomata. c. Lamellae and lamellulae, showing the stipe insertion. d. Globular elements of veil remnants. e. Cheilocystidia. f. Basidiospores. *Panaeolus antillarum* g. Habit of mature basidioma on incubated dung. h. Basidiomata. i. Lamellae and lamellulae, showing the conspicuous black punctation due to the maturation of basidia and basidiospores. j. Pleurocystidia. k. Basidia. l. Basidiospores. Scale bars: a, g= 200 mm. b= 2.5 mm. c= 2 mm. d= 25 μm. e, j, k= 10 μm. f= 2.5 μm. h= 25 mm. i= 20 mm. l= 7.5 μm. Figure: R.F.R. Melo.

*Closed pileus* initially globose to subglobose, becoming ellipsoid to cylindrical-ellipsoid, 6–8 × 3–5 mm, white, pale brown to pale luteous, covered along its entire surface by powdery veil fragments, mainly grouped in the center,

spreading towards the edge. *Expanded pileus* initially conical, becoming hemispherical to campanulate and finally flattened, about 15–20 mm in diameter, dark gray to light gray, with velar remnants forming radial groups of small pyramidal flakes composed of loosely aggregated globular elements, mainly grouped in the center, giving it a pinkish coloration, with margin strongly plicate-sulcate. *Lamellae* free, initially white, becoming dark gray to black, 15–22 mm long, ca.1 mm thick, deliquescent. *Lamellulae* present, 1–2 mm in length. *Stipe* central, cylindrical to slightly clavate near the base, hollow, finely fibrillose, with sparse velar flakes, especially near the pileus, white to pale gray, opaque to slightly shiny, 40–55 mm long, 1–1.5 mm in diameter. *Ring* absent. *Volva* absent. *Veil* composed of globose to subglobose elements, up to 50 µm in diameter, interspersed with conspicuous crystals. *Cheilocystidia* 22.5–40 × 15–27.5 µm, subglobose to ellipsoid, usually collapsing, hyaline, thin-walled, smooth. *Pleurocystidia* 27.5–50 × 25–32.5 µm, subglobose to subellipsoid, hyaline, thin-walled, smooth. *Clamp connections* absent. *Basidia* 4-spored, usually interspersed with numerous hyphidial elements. *Basidiospores* with considerable variation in morphology, heart-shaped, 5-angled in frontal view, cylindrical to ellipsoid in side view, reddish-brown to brown, 7.2–8.6 × 6–7.5 µm, with a central germ pore.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Caruaru, on cattle dung, 11 Jun 2012, R.F.R. Melo (URM86787!); Universidade Federal Rural de Pernambuco (UFRPE), Recife, on goat dung, 15 Jun 2012, R.F.R. Melo (URM86788!); on horse dung, 12 Mar 2012, R.F.R. Melo (URM86789a!, 86789b!).

**Distribution:**—Africa (Morocco), Europe (Finland, France, Germany, Ireland, Italy, Netherlands), Oceania (Australia, New Zealand), North America (United States of America) and South America (Brazil).

**Notes:**—*Coprinus patouillardii* is the most common basidiomycete species on herbivore dung in Pernambuco, and is a typical member of *Coprinopsis*. The presence of small basidiomata with plicated-sulcate pileus producing 5-angled, heart-shaped basidiospores in frontal view are the key diagnostic characters of this species. *Coprinopsis cordispora* (T. Gibbs) Gminder differs by the presence of lageniform cheilocystidia and larger basidiospores.

## 12. *Panaeolus antillarum* (Fr.) Dennis, Kew Bull. 15(1): 124 (1961) (Figure 6, g–l)

*Closed pileus* subglobose to ovoid, white, smooth. *Expanded pileus* hemispheric to campanulate, 6–9 × 4–6 mm, white, pale gray to pale luteous, smooth to slightly scaly. *Lamellae* adnexed, white, with a conspicuous black punctation in mature basidiomata due to the non-simultaneous basidial maturation giving it a grayish coloration and a powdery texture to the naked eye. *Lamellulae* 0.2–0.4 mm thick, similar in morphology. *Stipe* central, cylindrical, slightly bulbous near the base, flat, 70–140 mm in height, 2–3 mm at the base, 1.2–1.5 mm wide close to the pileus, white, solid to strongly contorted. *Ring* absent. *Volva* absent. *Pileipellis* formed by a few globose to saccate cells, hyaline, smooth. *Veil* not observed in mature basidiomata. *Cheilocystidia* lageniform to utriform, 17.5–25 × 7.5–12.5 µm. *Pleurocystidia* chrysocystidioid, clavate to fusoid, occasionally slightly capitate, 22.5–50 × 7.5–12.5 µm, with a short stipe, usually with a golden to luteous refractive body. *Clamp connections* not observed. *Basidia* 4-spored, clavate, 27–32.5 × 12–20 µm, with sterigmata 7.5–8.5 µm in length. *Basidiospores* limoniform to subellipsoid, 15–20 × 7.5–10 µm, smooth, dark brown. *Spore print* violet to black.

**Material examined:**—BRAZIL. Pernambuco, Instituto Agronômico de Pernambuco (IPA), Caruaru, on horse dung, 05 Dec 2011, R.F.R. Melo (URM86807!), 11 Apr 2012, R.F.R. Melo (URM86808!); on cattle dung, 06 Feb 2012, R.F.R. Melo (URM86809!); Universidade Federal Rural de Pernambuco (UFRPE), Recife, on goat dung, 28 Nov 2012, R.F.R. Melo (URM86810!); on horse dung, 14 Jun 2012, R.F.R. Melo (URM86811a!, 86811b!); on cattle dung, 03 Feb 2013, R.F.R. Melo (URM8612!).

**Distribution:**—Worldwide.

**Notes:**—*Panaeolus antillarum* is a common representative on herbivore dung, both collected *in situ* or on incubated dung, usually forming white or lightly colored mushrooms with campanulate pileus and dark basidiospores (Ola'h 1969). It differs from *P. semiovatus* (Sowerby) S. Lundell & Nannf. by the shape of the pileus, being more hemispherical, the absence of a ring and shape of pleurocystidia.

## Discussion

Agaricales, which has changed considerably in its circumscription due to advances in molecular biology and phylogeny, comprises even more coprophilous species than in previous classifications (Krug *et al.* 2004, Hibbett *et al.* 2007,

Kirk *et al.* 2008). Most species and records from Brazil belong to Psathyrellaceae, represented by *Coprinellus* and *Coprinopsis*. *Coprinellus marculentus* was recorded most often. *Coprinopsis stercorea*, a typical coprophilous species, was frequent as well. Agaricaceae, in which most members display the typical lamellar hymenophore on a mushroom form, was represented by *Coprinus*. *C. patouillardii* is the dominant species on herbivore dung in Pernambuco, forming fragile basidiomata throughout its development, on various dung types throughout the state. *Conocybe siliginia* and *Bolbitius demangei* were the representatives of Bolbitiaceae. Studies *in situ* would greatly enhance the extent of what is known about the diversity of coprophilous basidiomycetes, since most of them do not fruit with ease under laboratory conditions.

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