

## New and interesting *Cantharellus* from tropical Africa

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**Abstract** – This paper deals with some of the larger, more or less yellowish or orange *Cantharellus* species from the tropical African woodlands and rain forests. Four new species with clamp connections are described: *Cantharellus guineensis*, *C. mikemboensis*, *C. pseudomiomboensis* and *C. stramineus*. The new taxa show moderate to strong resemblance to either *Cantharellus rufopunctatus* or *C. miomboensis*. A two-locus phylogeny, based on part of the protein coding genes *rpb2* and *tef-1*, resolved them as a highly supported clade within *Cantharellus* subgenus *Rubrinus*, a subgenus still exclusively composed of tropical African species. This monophyletic clade is here described as a new section within subg. *Rubrinus*. As the subgenus was previously defined as being composed of chanterelles lacking clamp connections, the definition of the subgenus is here amended. Illustrations and new records are also presented for *Cantharellus afrociarius*, *C. defibulatus*, *C. miomboensis*, *C. rufopunctatus* and *C. sublaevis*. This paper provides first sequences for *C. defibulatus*, *C. rufopunctatus* and *C. sublaevis*, all of which are here epitypified, as well as new sequences for more than a dozen other *Cantharellus*. *Cantharellus cibarius* var. *latifolius* is considered a synonym of *C. afrociarius*. An identification key to all mainland African *Cantharellus* is proposed.

**Cantharellales / *Cantharellus rufopunctatus* / tef1-alpha / identification key / miombo / phylogeny / rain forest / RPB2 / taxonomy**

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## INTRODUCTION

Recent studies on *Cantharellus* Adans.:Fr. from tropical Africa (Zambia, Tanzania) and Madagascar describe a substantial number of new taxa from woodland vegetation (Ariyawansa *et al.* 2015; Buyck *et al.* 2000, 2012, 2013, 2014, 2015; Buyck 1994, 2014, Buyck & Randrianjohany, 2013; Eyssartier & Buyck 1999a,b; Eyssartier *et al.* 2002; Liu *et al.* 2015; Tibuhwa *et al.* 2008, 2012). A worldwide phylogeny was provided to accommodate most of these new African taxa (Buyck *et al.* 2014) and demonstrated that the bulk of the African chanterelles belong to two well-supported monophyletic clades that are entirely composed of species lacking clamp connections. One of the earliest described species among these clampless chanterelles, *Cantharellus rufopunctatus* (Beeli) Heinem., is probably one of the most cited but least understood taxa. Originally described from the Guineo-Congolian rainforest (Beeli 1928, Heinemann 1958), we will show here that this name has later been systematically misapplied to taxa from woodland vegetation in both the Zambezi and Sudanian ecozones of tropical Africa (Heinemann 1966, Buyck 1994, Buyck *et al.* 2000, Eyssartier 2001, De Kesel *et al.* 2002, De Kesel 2004, Eyi *et al.* 2011, Sharp 2011, Härkönen *et al.* 2015). Buyck *et al.* (2013) were the first to resolve part of the puzzle by describing *Cantharellus miomboensis* Buyck & V. Hofstetter, based on Tanzanian and Zambian material that had previously been identified as *C. rufopunctatus* (Buyck *et al.*, 2000). Nevertheless, even today the boundaries around *C. rufopunctatus* remain unclear and confusingly wide. The main reasons for this are (1) the fact that this species has never been recollected from its original habitat and (2) the impossibility to obtain sequences from the type collection.

During recent collecting trips to both the Guineo-Congolian rainforest and the miombo woodlands of the Democratic Republic of Congo (DR Congo), special emphasis was put on recollected *C. rufopunctatus*, *C. miomboensis* and morphologically similar species. The objective of this paper was to designate a suitable epitype for *C. rufopunctatus*, and to name and identify similar taxa using morphological and molecular data.

## MATERIAL AND METHODS

### Collecting and morphology

Specimens were collected in the field following the protocol outlined in De Kesel (2004) and Eyi Ndong *et al.* (2011). The macroscopic descriptions are based on notes and photographs taken from fresh basidiomata. Colour codes follow Kornerup & Wanscher (1978). Microscopic structures were revived in 5% potassium hydroxide (KOH) and examined in Congo-red ammonia solution using an Olympus BX-51 compound microscope. Basidiospores, basidia and pileal elements were randomly selected from the specimens and measured using a digital camera and AnalySIS Five imaging software (Soft Imaging System GmbH). Mean values (underlined)  $\pm 1.96 \times$  standard deviations, and extreme values (between brackets) are given for all microstructures and derived parameters (Q = length/width ratios).

All descriptions are based on the type material. Deviations observed in specimens other than the type are discussed in the comment sections.

All microscopic features were drawn by hand, using a drawing tube. Type specimens and other collections are deposited at BR (Herbarium Meise, Belgium).

### DNA extraction, amplification and sequencing

The genomic DNA of 53 *Cantharellus* species (Table 1) was isolated from CTAB-preserved tissues or dry specimens using a CTAB isolation procedure adapted from Doyle & Doyle (1990).

For transcription elongation factor 1-alpha (*tef-1*), a fragment located between exons 4 and 8 (Wendland & Kothe 1997) was amplified using the primer pair 983F and 2218R (Rehner & Buckley 2005) with the exception of a few specimens for which these primers did not work. For those specimens we used the primers pair *tef 1* F and *tef 1* R published by Morehouse *et al.* (2003) following the protocol described. For the primer pair 983F and 2218R a touchdown PCR was used with an initial annealing temperature of 60°C following Rehner & Buckley (2005). *tef-1* was amplified in 50- $\mu$ L reactions mix containing 1 $\times$  polymerase buffer, 200  $\mu$ M of each dNTP, 200  $\mu$ g  $\mu$ L<sup>-1</sup> bovine serum albumin, 0.3  $\mu$ M of forward and reverse primers, 1.25 U Taq polymerase (DreamTaq™, Thermo Fisher Scientific, St. Leon-Rot, Germany).

The region located between domains 6 and 7 of the second largest subunit of the RNA polymerase II (*rpb2*) (Frøslev *et al.* 2005, Matheny 2005) was amplified using the degenerate primers bRPB2-6F and bRPB2-7.1R using the PCR program detailed in Matheny (2005).

Partial *rpb2* gene was amplified in 40- $\mu$ L reactions containing 1 $\times$  polymerase buffer, 1  $\mu$ M MgCl<sub>2</sub> (2.5  $\mu$ M with the MgCl<sub>2</sub> contained in the polymerase buffer), 0.75 M betaine (Sigma B0300, Diegem, Belgium), 200  $\mu$ M of each dNTP, 200  $\mu$ g  $\mu$ L<sup>-1</sup> bovine serum albumin, 0.3  $\mu$ M of forward and reverse primers, 1.25 U Taq polymerase (DreamTaq™), using the PCR program detailed in Matheny (2005). Successful PCR reactions resulted in a single band observed on an 0.8% agarose gel, corresponding to approximately 1200 bp. PCR products were purified by adding 1 U of Exonuclease I and 0.5 U FastAP Alkaline Phosphatase (Thermo Scientific, St. Leon-Rot, Germany) and incubating at 37°C for 1 h, followed by inactivation at 80°C for 15 min.

Sequencing was performed by Macrogen InC. (Korea and The Netherlands) with PCR primers, for *tef-1* additional sequencing was performed with the two internal primers, 1953R and 2212R (Rehner & Buckley 2005). The sequences were assembled in Geneious Pro v. 6.0.6 (Biomatters).

### Phylogenetic analysis

One hundred and forty-six specimens representing 63 species or potential species/clades were included in the phylogenetic analysis. Nucleotide sequences were automatically aligned with Clustal X 2.0.11 (Thompson *et al.* 1997) with default settings. Materials and sequences used in this study are listed in Table 1.

The alignment was further optimized and manually adjusted as necessary by direct examination with the software Se-AL v. 2.0a11 (University of Oxford). The assignment of codon positions was confirmed by translating nucleotide sequences into predicted amino acid sequences using MacClade 4.0 (Maddison and Maddison 2000) and then compared with the annotated *C. cibarius* sequences AFTOL ID 607. Potential ambiguously aligned segments, especially in the four introns present in *tef-1*, were detected by Gblocks v0.91b (Castresana 2000; <http://molevol.cmima.csic.es/>

Table 1. List of species, specimens and GenBank accession numbers for sequences included in the phylogenetic analyses. Collectors abbreviated as BB Bart Buyck, AV Annemieke Verbeken, DS Dirk Stubbe, DT Donatha Tibuhwa, GE Guillaume Eyssartier, JV Jan Vesterholt, ADK André De Kesel, JD Jérôme Degreef, VDKO Omer Van de Kerckhove, KMP Kapepula Mutwale Paulin, MF Matthew Foltz, TIAN Tian Xiao-Fei & ZJP Zhang Jie Ping. The newly generated sequences are in **bold**

<i>Genus / species names</i> <i>Voucher extraction</i> <i>nr / collector nr.</i>	<i>Origin</i>	<i>Herb.Acc.Nr.</i>	<i>GenBank accession nr</i>	
			<i>tefl-a</i>	<i>rpb2</i>
<i>Cantharellus addaiensis</i> Henn. 1898				
<b>ADK 3983</b>	<b>Kenya</b>	<b>BR5020162751829</b>	<b>KX834362</b>	<b>KX834417</b>
<b>ADK 4371</b>	<b>Togo</b>	<b>BR5020163708693</b>	–	<b>KX834442</b>
<b>ADK 5377</b>	<b>RD Congo</b>	<b>BR5020184179731</b>	<b>KX834363</b>	<b>KX834418</b>
<b>JD 1093</b>	<b>RD Congo</b>	<b>BR5020172953022</b>	<b>KX834364</b>	<b>KX834419</b>
267 / BB 98.057	Tanzania	PC0084718	JX192976	KF294695
495 / BB 98.033 Neotype	Tanzania	PC0084717	JX192992	KF294745
<i>C. afrociarius</i> Buyck & V. Hofstetter 2012				
496 / BB 96.235 Holotype	Zambia	PC0084124	JX192993	KF294746
497 / BB 96.236	Zambia	PC0084125	JX192994	KF294747
<b>ADK 5389</b>	<b>RD Congo</b>	<b>BR5020184182533</b>	<b>KX834409</b>	<b>KX834420</b>
<b>ADK 5418</b>	<b>RD Congo</b>	<b>BR5020184185626</b>	<b>KX834365</b>	<b>KX834421</b>
<b>JD 937</b>	<b>RD Congo</b>	<b>BR5020169426645</b>	<b>KX834366</b>	<b>KX834422</b>
<i>C. albidolutescens</i> Buyck & V. Hofstetter 2014				
456 / BB 08.057	Madagascar	PC0084750	KF294752	KF294722
457 / BB 08.070 Holotype	Madagascar	PC0084751	JX192982	KF294723
<i>C. alborufescens</i> (Malençon) Papetti & S. Alberti 1998				
347 / BB 07.221	USA	PC0084085	GQ914939	KF294702
348 / BB 07.283	USA	PC0084090	GQ914945	KF294713
<i>C. altipes</i> Buyck & V. Hofstetter 2011				
318 / BB 07.019 Holotype	USA	PC0084085	GQ914939	KF294702
344 / BB 07.162 Paratype	USA	PC0084090	GQ914945	KF294713
<i>C. ambohitantelyensis</i> Buyck & V. Hofstetter 2014				
475 / BB 08.336 Holotype	Madagascar	PC0084754	JX192989	KF294733
<i>C. amethysteus</i> (Quél) Quél. 1888				
349 / BB 07.284	Slovakia	PC0084070	GQ914953	KF294716
352 / BB 07.309	Slovakia	PC0084071	GQ914954	KF294719
<i>C. appalachiensis</i> R.H. Petersen 1971				
342 / BB 07.123	USA	PC0084075	GQ914979	KF294711
<i>C. cerinoalbus</i> Eyssart. & Walley 2009				
487 / AV 06.051 Isotype	Malaysia	PC0084743	–	KF294741
<i>C. cibarius</i> Fr. :Fr. 1821				
AFTOL-ID 607		–	DQ059050	DQ366285
351 / BB 07.300	Slovakia	PC0084077	GQ914950	KF294718
479 / GE 07.025	France	PC0084088	GQ914949	KF294736
<b>VDKO 1135</b>	<b>Belgium</b>	<b>BR5020169491322</b>	<b>KX834367</b>	<b>KX834423</b>

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Genus / species names Voucher extraction nr / collector nr.	Origin	Herb.Acc.Nr.	GenBank accession nr	
			<i>tefl-α</i>	<i>rpb2</i>
<i>C. cibarius</i> var. <i>roseocanus</i> Redhead, Norvell & Danell, 1997 MF CC29	USA	–	JX030415	–
<i>C. cinnabarinus</i> (Schwein.) Schwein.1834 312 / BB 07.001 Neotype	USA	PC0084094	GQ914985	KF294698
326 / BB 07.053	USA	PC0084093	GQ914984	KF294705
<i>C. congolensis</i> Beeli 1928 <b>ADK 5214</b>	<b>RD Congo</b>	<b>BR5020184167660</b>	<b>KX834368</b>	<b>KX834424</b>
<b>ADK 5215</b>	<b>RD Congo</b>	<b>BR5020184166632</b>	<b>KX834369</b>	<b>KX834425</b>
<i>C. conspicuus</i> Eyssart., Buyck & Verbeken 2002 501 / GE 99.560 Isotype	Zimbabwe	PC0084809	–	KF294751
<i>C. decolorans</i> Eyssart. & Buyck 1999 469 / BB 08.278 Epitype	Madagascar	PC0084098	GQ914968	KF294731
<i>C. defibulatus</i> (Heinem.) Eyssart. & Buyck 2001 <b>ADK 5511 Epitype</b>	<b>RD Congo</b>	<b>BR5020184192549</b>	<b>KX834370</b>	<b>KX834426</b>
<b>ADK 6070</b>	<b>RD Congo</b>	<b>BR5020184215583</b>	<b>KX834371</b>	<b>KX834427</b>
<i>C. densifolius</i> Heinem. 1958 258 / BB 98.013	Tanzania	PC0084126	JX193014	KF294690
<i>C. diminutivus</i> Corner 1969 485 / DS 06.033	Malaysia	PC0084739	–	KF294740
<i>C. eucalyptorum</i> Buyck & V. Hofstetter 2015 59 / BB 06.148	Madagascar	PC0084127	JX192965	KF294678
60 / BB 06.149	Madagascar	PC0084128	JX192966	KF294679
<i>C. fistulosus</i> Tibuhwa & Buyck 2008 517 / DT 43 Isotype	Tanzania	PC0084738	JX192992	–
<i>C. flavus</i> Foltz & T.J. Volk 2013 MF C067	USA	–	JX030416	–
<i>C. friesii</i> Quél. 1872 481 / GE 07.077	France	PC0084719	–	KF294737
<b>VDKO 1165</b>	<b>Germany</b>	<b>BR5020173408699</b>	<b>KX834408</b>	<b>KX881922</b>
<i>C. gracilis</i> Buyck & V. Hofstetter 2012 251 / BB 98.234 Holotype	Tanzania	PC0084737	JX192970	KF294686
<i>C. guineensis</i> De Kesel & Yorou sp. nov. <b>ADK 3005 Holotype</b>	<b>Benin</b>	<b>BR5020129217139</b>	<b>KX834372</b>	<b>KX834428</b>
<b>ADK 3366</b>	<b>Benin</b>	<b>BR5020152165698</b>	<b>KX834373</b>	<b>KX834429</b>

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			<i>tefl-a</i>	<i>rpb2</i>
<b>ADK 3489</b>	<b>Benin</b>	<b>BR5020152044450</b>	<b>KX834374</b>	<b>KX834430</b>
<b>ADK 3525</b>	<b>Benin</b>	<b>BR5020152005062</b>	<b>KX834375</b>	<b>KX834431</b>
<i>C. heinemannianus</i> Eyssart. & Buyck 1998 491 / BB 96.307	Zambia	PC0084720	–	KF294743
<i>C. hygrophorus</i> S. C. Shao, Buyck & F. Q. Yu 2014 HKAS80614	China		–	KJ004003
<i>C. humidicolus</i> Buyck & V. Hofstetter 2013 493 / BB 98.036 Holotype	Tansania.	PC0084724	JX193005	KF294744
<i>C. ibityensis</i> Buyck & V. Hofstetter 2014 462 / BB 08.196 Holotype	Madagascar	PC0084109	GQ914980	KF294727
463 / BB 08.203 Paratype	Madagascar	PC0084722	JX192985	KF294728
<i>C. isabellinus</i> var. <i>parvisporus</i> Eyssart. & Buyck 2000 256 / BB 98.020 Holotype	Tanzania	PC0084753	JX192972	KF294688
249 / BB 98.037 Paratype	Tanzania	PC0084100	GQ914966	KF294685
<i>C. lateritius</i> (Berk.) Singer 1949 320 / BB 07.025 Epitype	USA	PC0084103	GQ914957	KF294703
330 / BB 07.058	USA	PC0084105	GQ914959	KF294708
<i>C. lewisii</i> Buyck & V. Hofstetter 2011 301 / BB 02.197 paratype	USA	PC0084073	GQ914961	KF294697
314 / BB 07.003 holotype	USA	PC0084074	GQ914962	KF294700
<i>C. luteostipitatus</i> Buyck & V. Hofstetter 2015 464 / BB 08.210	Madagascar	PC0085130	JX193008	–
<b><i>C. mikemboensis</i> De Kesel &amp; Degreef sp. nov.</b>				
<b>ADK 6039</b>	<b>RD Congo</b>	<b>BR5020184208660</b>	<b>KX834376</b>	<b>KX834432</b>
<b>ADK 6065</b>	<b>RD Congo</b>	<b>BR5020184214555</b>	<b>KX834377</b>	<b>KX834433</b>
<b>ADK 6073</b>	<b>RD Congo</b>	<b>BR5020184217648</b>	<b>KX834378</b>	<b>KX834434</b>
<b>JD 866</b>	<b>RD Congo</b>	<b>BR5020169371099</b>	<b>KX834379</b>	<b>KX834435</b>
<b>JD 918 Holotype</b>	<b>RD Congo</b>	<b>BR5020169410484</b>	<b>KX834380</b>	<b>KX834436</b>
<i>C. minor</i> Peck 1872 313 / BB 07.002	USA	PC0084747	JX192978	KF294699
329 / BB 07.057	USA	PC0084721	JX192979	KF294707
<i>C. miomboensis</i> Buyck & V. Hofstetter 2012 <b>ADK 3908</b>	<b>Kenya</b>	<b>BR5020162711427</b>	<b>KX834381</b>	<b>KX834437</b>
<b>ADK 5392</b>	<b>RD Congo</b>	<b>BR5020184183561</b>	<b>KX834382</b>	<b>KX834438</b>
<b>ADK 6006</b>	<b>RD Congo</b>	<b>BR5020184197698</b>	<b>KX834383</b>	<b>KX834439</b>

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Genus / species names Voucher extraction nr / collector nr.	Origin	Herb.Acc.Nr.	GenBank accession nr	
			<i>tefl-α</i>	<i>rpb2</i>
255 / BB 98.021 Holotype	Tanzania	PC0084748	JX192971	KF294687
<b>JD 877</b>	<b>RD Congo</b>	<b>BR5020169379170</b>	<b>KX834384</b>	<b>KX834440</b>
<b>JD 895</b>	<b>RD Congo</b>	<b>BR5020169390281</b>	<b>KX834385</b>	<b>KX834441</b>
<i>C. nigrescens</i> Buyck & V. Hofstetter 2015				
19 / BB 06.166	Madagascar	PC0084979	JX192998	–
66 / BB 06.176	Madagascar	PC0084078	JX192967	KF294680
69 / BB 06.197	Madagascar	PC0084076	GQ914982	KF294683
<i>C. nigrescens</i> aff.				
<b>ADK5441</b>	<b>RD Congo</b>	<b>BR5020184187682</b>	<b>KX834386</b>	–
<b>ADK5471</b>	<b>RD Congo</b>	<b>BR5020184190484</b>	<b>KX834387</b>	–
247 / BB 98.039	Tanzania	PC0084123	JX193015	–
512 / BB 98.058	Tanzania	PC0084776	JX192996	–
<i>C. pallens</i> Pilát 1959				
<b>998 / BB 09.430</b>	<b>Italy</b>	<b>PC0084769</b>	<b>KX834410</b>	<b>KX834463</b>
<b>999 / BB 09.441</b>	<b>Italy</b>	<b>PC0084788</b>	<b>KX834411</b>	<b>KX834464</b>
<i>C. paucifurcatus</i> . Buyck & V. Hofstetter 2014				
474 / BB 08.320 Holotype	Madagascar	PC0084729	JX192988	KF294732
<i>C. phasmatis</i> Foltz & T.J. Volk 2013				
MF C057	USA	–		JX030417
MF C074	USA	–		JX030418
<i>C. platyphyllus</i> Heinem. 1966				
<b>JD857</b>	<b>RD Congo</b>	<b>BR5020169362004</b>	<b>KX834388</b>	<b>KX834444</b>
<b>JD919</b>	<b>RD Congo</b>	<b>BR5020169411498</b>	<b>KX834389</b>	<b>KX834445</b>
<b>JD1107</b>	<b>RD Congo</b>	<b>BR5020172967166</b>	<b>KX834390</b>	–
259 / BB 98.012	Tanzania	PC0084108	GQ914969	KF294691
262 / BB 98.126 Epitype	Tanzania	PC0084723	JX192975	KF294694
<i>C. platyphyllus</i> subsp. <i>Bojeriensis</i> Eyssart. & Buyck 1999				
458 / BB 08.158	Madagascar	PC0084741	JX192983	KF294724
459 / BB 08.160	Madagascar	PC0084740	JX192984	KF294725
<i>C. pseudominimus</i> Eyssart. & Buyck 1999				
477 / JV 00.663	Portugal	PC0084725	JX192991	KF294735
<i>C. pseudomiomboensis</i> De Kesel & Kasongo sp. nov.				
<b>ADK 6029</b>	<b>RD Congo</b>	<b>BR5020184202484</b>	<b>KX834391</b>	<b>KX834446</b>
<b>JD 927 Holotype</b>	<b>RD Congo</b>	<b>BR5020169418565</b>	<b>KX834392</b>	<b>KX834447</b>
<i>C. quercophilus</i> Buyck, Lewis, Eyssart & V. Hofstetter 2010				
636/BB 07.097 Holotype	USA	PC0084726		JX192981

Table 1. List of species, specimens and GenBank accession numbers for sequences included in the phylogenetic analyses. Collectors abbreviated as BB Bart Buyck, AV Annemieke Verbeken, DS Dirk Stubbe, DT Donatha Tibuhwa, GE Guillaume Eyssartier, JV Jan Vesterholt, ADK André De Kesel, JD Jérôme Degreef, VDKO Omer Van de Kerckhove, KMP Kapepula Mutwale Paulin, MF Matthew Foltz, TIAN Tian Xiao-Fei & ZJP Zhang Jie Ping. The newly generated sequences are in **bold** (continued)

<i>Genus / species names</i> <i>Voucher extraction</i> <i>nr / collector nr.</i>	<i>Origin</i>	<i>Herb.Acc.Nr.</i>	<i>GenBank accession nr</i>	
			<i>tefl-a</i>	<i>rpb2</i>
<i>C. romagnesianus</i> Eyssart. & Buyck 1999				
482 / GE 07.031	France	PC0084735	–	KF294738
<i>C. rufopunctatus</i> (Beeli) Heinem. 1958				
<b>ADK 5892</b>	<b>RD Congo</b>	<b>BR5020184193577</b>	<b>KX834393</b>	<b>KX834448</b>
<b>ADK 5949 Epitype</b>	<b>RD Congo</b>	<b>BR5020184194604</b>	<b>KX834394</b>	<b>KX834449</b>
<i>C. sebosus</i> Buyck & V. Hofstetter 2014				
460 / BB 08.162 Paratype	Madagascar	PC0084079	GQ914981	KF294726
465 / BB 08.234 Holotype	Madagascar	PC0084736	JX192986	KF294729
<i>C. sp. ined. (aff. splendens)</i>				
499 / BB 96.199	Zambia	PC0084730	–	KF294749
498 / BB 96.306	Zambia	PC0084731	–	KF294748
<i>C. spectaculus</i> Foltz & T.J. Volk 2013				
C081	USA		JX030414	–
<i>C. splendens</i> Buyck 1994				
<b>ADK 6071</b>	<b>RD Congo</b>	<b>BR5020184216610</b>	<b>KX834395</b>	<b>KX834450</b>
<b>BB 5518 Holotype</b>	<b>Burundi</b>	<b>BR5020059800487</b>	–	<b>KX834443</b>
<b>JD 896</b>	<b>RD Congo</b>	<b>BR5020169391295</b>	<b>KX834396</b>	<b>KX834451</b>
<b>JD 968</b>	<b>RD Congo</b>	<b>BR5020169449873</b>	<b>KX834397</b>	<b>KX834452</b>
<i>C. stramineus</i> De Kesel sp. nov.				
<b>ADK 6051 Holotype</b>	<b>RD Congo</b>	<b>BR5020184210434</b>	<b>KX834398</b>	<b>KX834453</b>
<b>JD 1035</b>	<b>RD Congo</b>	<b>BR5020172909555</b>	<b>KX834399</b>	<b>KX834454</b>
<b>JD 1098</b>	<b>RD Congo</b>	<b>BR5020172958072</b>	<b>KX834400</b>	<b>KX834455</b>
<i>C. subamethysteus</i> Eyssart. & Stubbe 2009				
488 / DS 06.218 Isotype	Malaysia	PC0084744	–	KF294742
<i>C. subcyanoxanthus</i> Buyck, Randrianjohany & Eyssart. 2012				
476 / BB 00.1137 Holotype	Madagascar	PC0084746	JX192990	KF294734
<i>C. subcyanoxanthus</i> aff.				
257 / BB 98.014	Tanzania	PC0084745	JX192973	KF294689
<i>C. subincarnatus subsp. rubrosalmoneus</i> Buyck & V. Hofstetter 2014				
13 / BB 06.080 Holotype	Madagascar	PC0084727	JX192962	KF294675
55 / BB 06.096 Paratype	Madagascar	PC0084755	JX192963	KF294676
<i>C. sublaevis</i> Buyck & Eyssart. 2014				
<b>ADK 6057 Epitype</b>	<b>RD Congo</b>	<b>BR5020184211462</b>	<b>KX834401</b>	<b>KX834456</b>
<b>JD 942</b>	<b>RD Congo</b>	<b>BR5020169429677</b>	<b>KX834402</b>	<b>KX834457</b>
<b>JD 964</b>	<b>RD Congo</b>	<b>BR5020169445837</b>	<b>KX834403</b>	<b>KX834458</b>



Table 1. List of species, specimens and GenBank accession numbers for sequences included in the phylogenetic analyses. Collectors abbreviated as BB Bart Buyck, AV Annemieke Verbeken, DS Dirk Stubbe, DT Donatha Tibuhwa, GE Guillaume Eyssartier, JV Jan Vesterholt, ADK André De Kesel, JD Jérôme Degreef, VDKO Omer Van de Kerckhove, KMP Kapepula Mutwale Paulin, MF Matthew Foltz, TIAN Tian Xiao-Fei & ZJP Zhang Jie Ping. The newly generated sequences are in **bold** (continued)

Genus / species names Voucher extraction nr / collector nr.	Origin	Herb.Acc.Nr.	GenBank accession nr	
			<i>tefl-α</i>	<i>rpb2</i>
<i>C. symoensii</i> Heinem. 1966				
260 / BB 98.011	Tanzania	PC0084113	GQ914970	KF294692
261 / BB 98.113 Epitype	Tanzania	PC0084756	JX192974	KF294693
<b>KMP 2</b>	<b>RD Congo</b>	–	<b>KX834404</b>	<b>KX834459</b>
<b>JD 912</b>	<b>RD Congo</b>	<b>BR5020169405435</b>	<b>KX834405</b>	<b>KX834460</b>
<i>C. tabernensis</i> Feibelman & Cibula 1996				
328 / BB 07.056	USA	PC0084115	GQ914974	KF294706
340 / BB 07.119	USA	PC0084116	GQ914976	KF294709
333 / BB 07.064	USA	PC0084120	GQ914975	JN993600
<i>C. tanzanicus</i> Buyck & V. Hofstetter 2012				
268 / BB 98.040 Holotype	Tanzania	PC0084728	JX192977	KF294696
<b>JD 867</b>	<b>RD Congo</b>	<b>BR5020169372102</b>	<b>KX834406</b>	<b>KX834461</b>
<b>JD 878</b>	<b>RD Congo</b>	<b>BR5020169380183</b>	<b>KX834407</b>	<b>KX834462</b>
<i>C. tenuithrix</i> Buyck & V. Hofstetter 2011				
322 / BB 07.035 Paratype	USA	PC0084087	GQ914946	KF294704
343 / BB 07.125 Holotype	USA	PC0084084	GQ914947	KF294712
<i>C. texensis</i> Buyck & V. Hofstetter 2011				
317 / BB 07.018 Holotype	USA	PC0084097	GQ914988	KF294701
341 / BB 07.120 Paratype	USA	PC0084096	GQ914987	KF294710
<i>C. tomentosus</i> Eyssart. & Buyck 2000				
248 / BB 98.038 Paratype	Tanzania	PC0084121	GQ914965	KF294684
500 / BB 98.060 Holotype	Tanzania	PC0084732	JX192995	KF294750
<i>C. tricolor</i> Buyck & V. Hofstetter 2015				
67 / BB 06.179	Madagascar	PC0084129	JX192968	KF294681
68 / BB 06.180	Madagascar	PC0084130	JX192969	KF294682
<i>C. tuberculosporus</i> M. Zang 1980				
TIAN 351	China	HKAS 55782	KM893853	–
ZJP 17	China	HKAS 58215	KM893854	–
ZJP 117	China	HKAS 58225	KM893855	–
<i>C. variabilicolor</i> Buyck & V. Hofstetter 2015				
56 / BB 06.145	Madagascar	PC0084111	JX193003	–
57 / BB 06.146	Madagascar	PC0084757	JX192964	KF294677
20 / BB 06.168	Madagascar	PC0124633	JX192999	–
466 / BB 08.243	Madagascar	PC0084733	JX192987	KF294730
<i>Craterellus tubaeformis</i> (Fr.) Quéf.				
350 / BB 07.293	Slovakia	PC0084122	GQ914989	KF294717

castresana/Gblocks.html, settings “allow smaller final blocks”, “allow gaps within blocks”) and excluded from the analyses. The *rpb2* or *tef-1* sequences from some collections could neither be obtained nor gathered from GenBank and were considered as missing data in the combined dataset. To detect the possible bias from substitution saturation, we tested the first, second and the third codon position of the coding region analyzed (*rpb2* and *tef-1*) by using Xia’s test (Xia and Lemey 2009; Xia *et al.* 2003, as implemented in DAMBE (Xia and Xie 2001). Because the Iss.c is based on simulation results, there is a problem with more than 32 species. To circumvent this problem, DAMBE was used to randomly sample subsets of 4, 8, 16 and 32 OTUs multiple times and perform the test for each subset to see if substitution saturation exists for these subsets of sequences. In order to confirm the results of the Xia’s method we also plotted transitions and transversions at the first, second, and third codon positions against Tamura-Nei genetic distances with the aid of the DAMBE package, with an asymptotic relationship indicating the presence of saturation.

The dataset was subdivided into 7 data partitions: *tef-1*-1st, -2nd, -3rd codon positions, *tef-1* introns, and *rpb2* 1st, -2nd, -3rd codon positions. Phylogenetic analyses were performed separately for each individual and concatenated loci using Bayesian inference (BI) as implemented in MrBayes v3. 2 (Ronquist & Huelsenbeck 2003, Ronquist *et al.* 2011) and Maximum likelihood (ML) as implemented in RAxML 7.2.7 (Stamatakis *et al.* 2008). *Craterellus tubaeformis* was used as outgroup (Buyck *et al.* 2013, 2014).

Models of evolution for BI were estimated using the Akaike information criterion (AIC) as implemented in Modeltest 3.7 (Posada and Crandall 1998). In order to facilitate the data partitioning by codon position for the *tef-1*, the four introns present were excised and analyzed as a distinct partition. The best-fit models for each partition were implemented as partition specific models within partitioned mixed-model analyses of the combined dataset (Table 2). All parameters were unlinked across partitions. Bayesian analyses were implemented with two independent runs, each with four simultaneous independent chains for ten million generations, starting from random trees, and keeping one tree every 1000th generation. The tree with the best likelihood value (see below ML) was used as a starting tree for the Bayesian analyses. All trees sampled after convergence (average. standard deviation of split frequencies < 0.01 and confirmed using Tracer v1.4 [Rambaut and Drummond 2007]) were used to reconstruct a 50% majority-rule consensus tree (BC) and to calculate Bayesian posterior probabilities (BPP). BPP of each node was estimated based on the frequency at which the node was resolved among the sampled trees with the consensus option of 50% majority-rule (Simmons *et al.* 2004). A probability of 0.95 was considered significant. Maximum likelihood (ML) searches conducted with RAxML involved 1000 replicates under the GTRGAMMAI model, with all model parameters estimated by the program. In addition, 1000 bootstrap (ML BS) replicates were run with the same GTRGAMMAI model. We provided an additional alignment partition file to force RAxML software to search for a separate evolution model for each dataset. Clades with Maximum likelihood bootstrap values of 75% or greater were considered supported by the data.

To detect topological conflicts among data partitions, the nodes between the majority-rule consensus trees obtained in the ML analysis from the individual data sets were compared with the software *compat.py* (available at [www.lutzonilab.net/downloads](http://www.lutzonilab.net/downloads)). Paired trees were examined for conflicts only involving nodes with ML BS > 75% (Lutzoni *et al.* 2004, Mason-Gamer and Kellogg 1996, Reeb *et al.* 2004). A conflict was assumed to be significant if two different relationships for the same set of taxa (one being monophyletic and the other non-monophyletic) were observed in rival trees.

Table 2. Summary of *tef-1* and *rpb2* data sets

Properties	Datasets						
	<i>tef1</i> 1 <sup>st</sup>	<i>tef1</i> 2 <sup>nd</sup>	<i>tef1</i> 3 <sup>rd</sup>	<i>tef1</i> introns	<i>rpb2</i> 1 <sup>st</sup>	<i>rpb2</i> 2 <sup>nd</sup>	<i>rpb2</i> 3 <sup>rd</sup>
Alignment size	208	209	209	404	231	231	230
Excluded characters	–	–	–	20	–	–	–
Model selected	GTR+I+G	GTR+I+G	GTR+G	GTR+I+G	GTR+G	SYM+I	HKY+I+G
Likelihood score (neg.)	799.2458	625.9714	4119.1670	5196.3535	779.8090	546.2170	4380.7173
Base frequencies							
Freq. A =	0.3381	0.3065	0.1313	0.2418	0.2740	Equal	0.1910
Freq. C =	0.1924	0.2315	0.3131	0.2411	0.2203	Equal	0.2647
Freq. G =	0.3633	0.1914	0.2635	0.1886	0.3592	Equal	0.2274
Freq. T =	0.1061	0.2705	0.2921	0.3285	0.1465	Equal	0.3168
Proportion							
of invariable sites	0.6988	0.6827	–	0.1355	–	0.8199	0.0597
Gamma shape	1.2044	0.5479	2.2089	4.6272	0.2463	–	3.6622
Test of substitution saturation							
Iss	0.606	0.042	0.024	0.235	0.262	0.052	0.016
Iss.cSym	1.475	1.266	1.287	1.226	0.814	0.783	0.781
P (Sym)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Iss.cAsym	1.736	1.381	1.418	1.313	0.603	0.548	0.544
P (Asym)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: Iss: index of substitution saturation. Iss.cSym: critical value for symmetrical tree topology. Iss.cAsym: critical value for extremely asymmetrical tree topology. P: probability that Iss is significantly different from the critical value (Iss.cSym or Iss.cAsym).

## RESULTS

### Phylogenetic analysis

The final combined DNA sequence alignments of these two loci resulted in 1817 characters (*tef1*: 1030 characters, of which 626 in the exon partition and 404 in the combined introns partition, *rpb2*: 787 characters), including gaps. Summary statistics of sequence data and tests of substitution saturation for each dataset are provided in Table 2. No conflict involving significantly supported nodes was found between the tree topologies obtained for the individual datasets, using the 75% ML BP criterion; the datasets were therefore combined.

The test of substitution saturation (Table 2) showed that the observed index of substitution saturation (*Iss*) for the *tef-1* and *rpb2* alignments was significantly lower than the corresponding critical index substitution saturation (*Iss.c*), indicating that there was little saturation in our sequences ( $P < 0.001$ ).

Twenty characters in the *tef1* introns dataset were judged too ambiguous to be aligned and excluded from the analyses. The two Bayesian runs converged to stable likelihood values after 1261000 generations. 4739 stationary trees from each analysis were used to compute a 50% majority rule consensus tree and to calculate posterior probabilities (PP). In the ML searches with RAxML the combined dataset

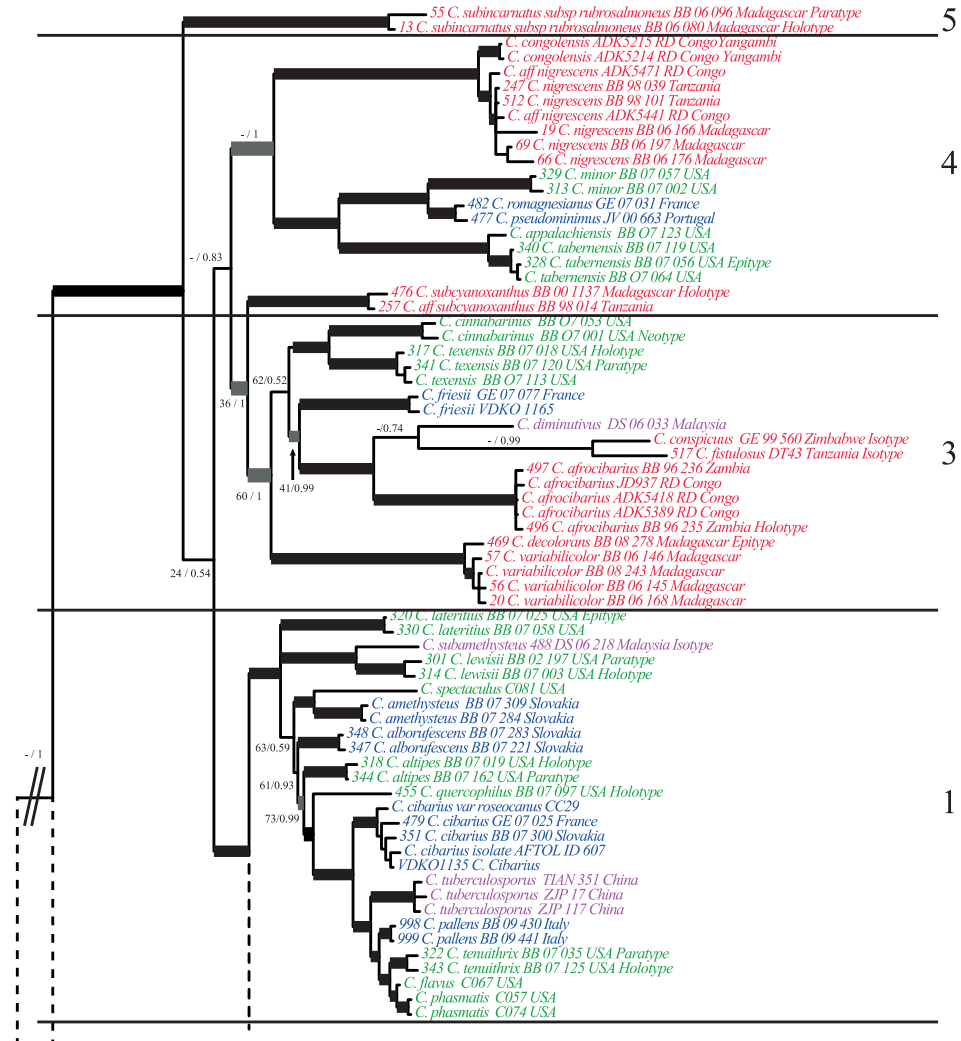


Fig. 1a

Fig. 1 (a = left page; b = right page). The 50% majority-rule consensus tree from Bayesian inference of the combined *tef1* and *rpb2* sequences. Thickened branches in bold represent ML BS support greater than 75% and BPP greater than 0.95; thickened branches in grey denote branches supported by either ML BS or BPP; For selected nodes ML BS support value and BPP are respectively indicated to the left and right of slashes; The new taxa are highlighted in the shaded box; Names of African-Malagasy chanterelles are in red font, Malaysian chanterelles are in lilac and North American and European chanterelles are in green and blue respectively. Outgroups are in black lettering. Numbers on the right refer to the recognized clades according to Buyck *et al.* (2014).

alignment had 1179 distinct patterns with a proportion of gaps and undetermined characters of 23.89%.

The topologies obtained analyzing the combined dataset are highly congruent with published trees (Buyck *et al.* 2013, 2014), at least for what concerns



Fig. 1b

significantly supported branches, and the Bayesian consensus tree (Fig. 1) was almost identical to the optimal tree inferred under the Maximum likelihood criterion (-lnL = -18214.812299). The two inferences mainly differ for what concerns the position of the “*Afrocantharellus*” subgenus, sister to *C. tabernensis*/*C. minor* subclade in the ML analyses, even if not supported, and basal to the main *Cantharellus* clade (also not significantly supported) in the Bayesian inference, and *C. afrociarius*, in a sister, well supported position to *C. fistulosus* in the ML analysis or sister (but not significantly supported) to a clade comprising *C. fistulosus*, *C. conspicuus* and *C. diminutivus* in the Bayesian inference. Our phylogenetic inferences resolved mainly the same, well-supported clades as previously reported (Buyck *et al.* 2013, 2014), although the relationships between these clades remain uncertain, the deeper internodes, in all topologies, being poorly supported whatever the analyses.

Several collections from tropical Africa cluster together in a well-supported clade (Fig. 1b, grey box). So far, this clade remains isolated but is notably distantly related to all other *Cantharellus* species as yet reported from Africa (Buyck *et al.* 2000, 2012, 2013, 2014, Buyck 1994, 2014, Tibuhwa *et al.* 2008, 2012.) or elsewhere, and for which sequences are known (Fig. 1b). Considered individually or concatenated, all phylogenetic inferences also revealed an internal structure within this clade, and concordantly and confidently resolved four well-supported, terminal sub-clades (i.e. phylogenetic species, Fig. 1b, grey box). Almost all collections pertaining to each of these four sub-clades were initially placed under existing names. Morphological re-examination showed combinations of morphological features unique to and characteristic of each, thereby defining four morphotypes. The critical morphological features that differentiate them are the presence of clamp connections, the spore shapes and size, the width of the terminal elements in the pileipellis and thickness of their walls, the spacing and interveination of the gill folds, the presence/absence of squamules on cap and/or stipe, and the colors of basidiomes and context. We therefore concluded that these four morphotypes/clades represent four distinct undescribed species belonging to an undescribed section in *Cantharellus* subg. *Rubrinus* Eyssart. & Buyck. Descriptions, comments and amendments are given in the taxonomical part.

## Taxonomy

*Cantharellus* Adans.:Fr., Systema Mycologicum 1:318 (1821)

= *Afrocantharellus* (Eyssart. & Buyck) Tibuhwa, *IMA Fungus* 3:33 (2012)

= *Goossensia* Heinem., *Bull. Jard. bot. État Brux.* 28: 424 (1958)

The various species are discussed in alphabetical order:

*Cantharellus afrociarius* Buyck & V. Hofstetter, in Buyck *et al.*, *Fungal Diversity* 58(1): 286 (2013) **Fig. 23**

= *Cantharellus cibarius* var. *latifolius* Heinem., *Bull. Jard. bot. État Brux.* 36: 340 (1966), **syn. nov.**

*Description:* For a full description of this recently described taxon we refer to Buyck *et al.* (2013). The material cited below entirely fits this description.

*Examined collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, from arable land regenerated miombo with *Julbernardia globiflora* (Benth.) Troupin, 1194 m, S11°28'56.7"-E27°39'27.7", 14 Jan. 2013, De Kesel leg., De Kesel 5389 (BR5020184182533); *ibidem*, miombo with *Julbernardia paniculata* (Benth.) Troupin, 1235 m, S11°28.974'-E27°40.445', 17 Jan. 2013, De Kesel leg., De Kesel 5418 (BR5020184185626); *ibidem*, miombo dominated by *Marquesia macroura* Gilg, 1216 m, S11°29'3.5"-E27°40'19.3", 23 Jan. 2013, De Kesel leg., De Kesel 5476 (BR5020184191511); *ibidem*, under *Julbernardia paniculata*, 1218 m, S11°28'57.8"-E27°40'23.5", 13 Jan. 2014, De Kesel leg., De Kesel 6000 (BR5020184195632) and De Kesel 6002 (BR5020184196660); *ibidem*, miombo dominated by *Julbernardia paniculata* and *Brachystegia wangermeeana* De Wild., 1184 m, S11°29'16.9"-E27°39'15.9", 15 Jan. 2014, De Kesel leg., De Kesel 6011 (BR5020184198725); *ibidem*, miombo woodland with *Julbernardia paniculata*, *J. globiflora*, *Uapaca pilosa* Hutch. and *Brachystegia wangermeeana*, 1195 m, S11°29'16.2"-E27°39'15.3", 15 Jan. 2014, De Kesel leg., De Kesel 6014 (BR5020184199753); *ibidem*, under

*Julbernardia globiflora*, 1222 m, S11°29'14.5"-E27°39'50.5", 15 Jan. 2014, De Kesel leg., De Kesel 6019 (BR5020184200428); ibidem, in miombo with only *Julbernardia globiflora*, 1188 m, S11°29'07.0"-E27°40'22.0", 17 Jan. 2014, De Kesel leg., De Kesel 6033 (BR5020184204549); ibidem, miombo with *Julbernardia paniculata*, 1229 m, S11°28'57.7"-E27°40'26.0", 18 Jan. 2014, De Kesel leg., De Kesel 6038 (BR5020184207632); ibidem, in mixed miombo with *Brachystegia wangermeeana*, *Marquesia macroura* and *Julbernardia paniculata*, 1221 m, S11°28'56.2"-E27°40'25.4", 23 Jan. 2014, De Kesel leg., De Kesel 6064 (BR5020184213527); ibidem, miombo with *J. globiflora*, along dirt road, 1079 m, S11°28'42.1"-E27°39'42.6", 21 Jan. 2015, De Kesel leg., De Kesel 6232 (BR5020184224561); ibidem, miombo woodland, 2 Feb. 2012, De Kesel & Degreef leg., Degreef 889 (BR5020169386246); ibidem, Lubemba (camp Hasson), miombo with *Julbernardia globiflora* and *Brachystegia spiciformis* Benth., 1040 m, S10°54.799'-E28°31.880', 10 Feb. 2012, De Kesel & Degreef leg., Degreef 937 (BR5020169426645); ibidem, Kipopo, miombo on clayey soil, January 1959, Schmitz-Levecq 25 (BR5020032479815, ex *Cantharellus cibarius* var. *latifolius* Heinem).

*Ecology and distribution:* This species was previously considered rare as it was only known from its type locality near Chibuli in the Copperbelt province of Zambia (Buyck *et al.* 2013). In Katanga, i.e. 200-300 km N-NW from the type locality, it is fairly common and occurring in several different types of woodland. It is mostly found in older woodland on deeper and finer soils, dominated by *Brachystegia wangermeeana*, *B. spiciformis*, *Julbernardia paniculata* or *J. globiflora*, or most often in mixed stands of the latter three tree species.

*Comments:* This clamped chanterelle is one of the larger species of subgenus *Cinnabarinus* Buyck & V. Hofstetter and is placed (Fig. 1a) as sister without support to a subclade comprising several much smaller species (the Malayan *C. diminutivus* Corner, and the African *C. conspicuus* and *C. fistulosus*). The caespitose habit of *C. afrociarius* is a very conspicuous, fairly constant feature of this species. Within the genus, this type of fruiting habit is a rare phenomenon, but in Africa a similar caespitose habit may often be observed in other species from different subgenera such as *Cantharellus stramineus*, *C. defibulatus*, *C. mikemboensis* or *C. sublaevis*. However, for identification purposes, the caespitose habit should always be used in combination with other characters. Caespitose *C. afrociarius* can be distinguished from caespitose specimens of the above-mentioned species by the complete lack of squamules on both stipe and cap, combined with a lamellar, orange hymenophore gradually becoming whitish orange to whitish towards the stipe.

A comparison of available macro- and microscopical data of the type specimen of *Cantharellus cibarius* var. *latifolius* shows that the latter taxon fully corresponds with typical *C. afrociarius*, except for the caespitose habit. Although we were unable to obtain sequences from this type specimen (BR, Schmitz-Levecq 25, DR Congo, Katanga, Kipopo, January 1959), we consider this taxon to represent an older synonym of *C. afrociarius*,

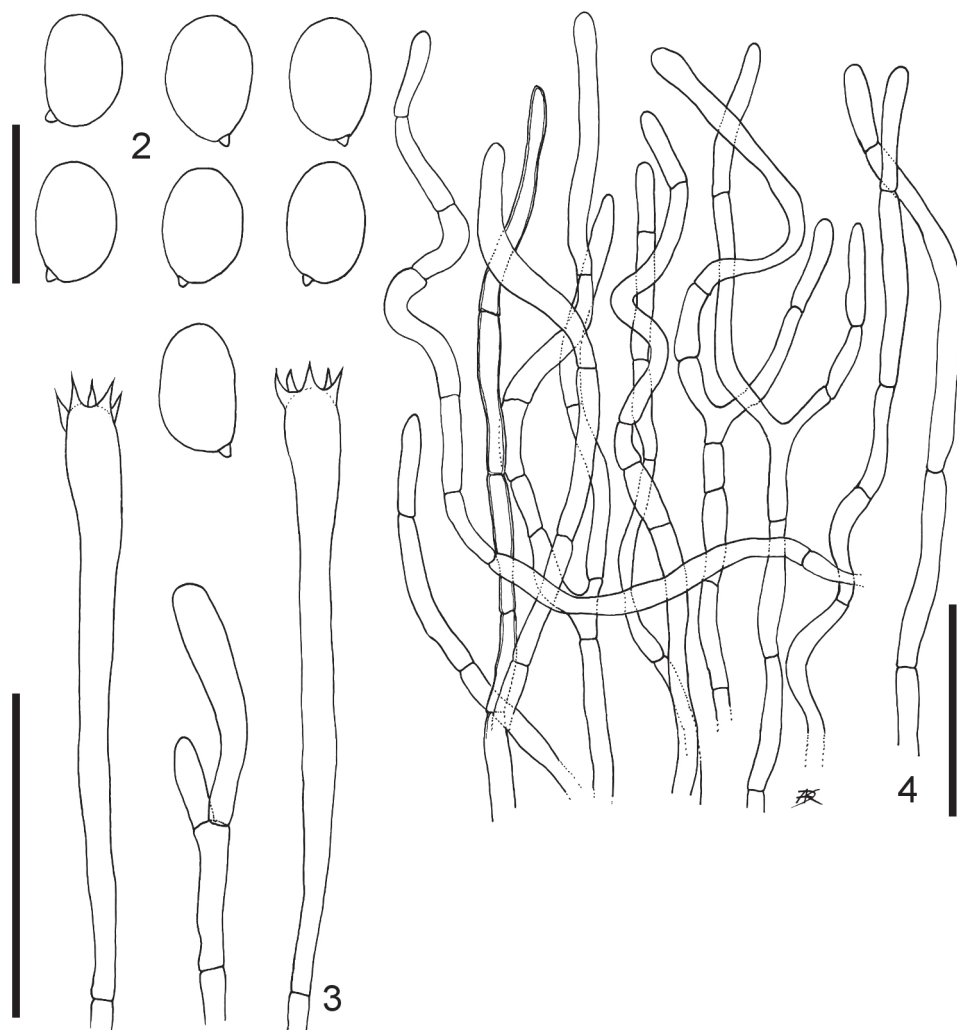
***Cantharellus defibulatus* (Heinem.) Eyssart. & Buyck, *Documents Mycol.* 31: 55 (2001)**

**Figs 2-4, 24**

*Mycobank:* Typification MBT372679.

= *Cantharellus cibarius* var. *defibulatus* Heinem., Bull. Jard. bot. État Brux. 36: 339 (1966)

A full description of this ill-known taxon is given by Heinemann (1966) and additional comments can be found in Buyck (2014, see the commentary relating



Figs 2-4. *Cantharellus defibulatus*. 2. Basidiospores (scale bar = 10  $\mu\text{m}$ ). 3. Basidia. 4. Hyphae from the pileipellis (all from De Kesel 5511, EPITYPE). Scale bar 3-4 = 50  $\mu\text{m}$ .

to *C. sublaevis*). The material cited below entirely fits the original description and we have chosen one sequenced collection to represent the epitype, which is described in more detail below.

**Epitype:** DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, nearly monospecific *Brachystegia longifolia* Benth. miombo woodland mixed with few *Monotes katangensis* (De Wild.) De Wild., 1187 m, S11°28'41.63"-E 27°39'40.26", 27 Jan. 2013, De Kesel leg., De Kesel 5511 (**EPITYPUS hic designatus:** De Kesel 5511, BR5020184192549).

**Fruit bodies** very fleshy and firm, up to 120 mm diam. and more than 80 mm high, often buried for another 30-50 mm in the soil, multipileate. **Pileus**



smooth, convex to plane, becoming only slightly depressed, pastel yellow (3A5-6), then pale yellow to light yellow (4A3-5) or towards amber yellow (4B5-6), slightly zonate towards the margin, sometimes with whitish areas when old and humid; margin smooth, first inrolled, remaining more or less inflexed, always irregularly undulating and strongly lobed. **Hymenophore** decurrent, gill-folds normally spaced (10-12/cm), anastomosing and forking, transversally connected by conspicuous veins, uniformly colored, slightly paler and more yellow than the pileus (3A2-5), becoming light yellow (4A2-4). **Stipe** thick and rooting, most often splitting upwards and/or giving rise to several fruit bodies from belowground, smooth, mat, whitish at first becoming yellowish white. **Context** whitish, yellow underneath the pileipellis and stipitipellis. **Taste** mildly peppery. **Smell** fruity. **Spore print** not obtained.

**Spores** ellipsoid to subglobose, (6.8-)6.9-7.7-8.4(-8.8) × (4.5-)4.6-5.2-5.8 (-5.9) μm {N = 67}, Q = (1.26-)1.3-1.47-1.64(-1.67), smooth. **Basidia** 58.7-72.3-85.9(-97.8) × (6-)6.1-7.5-8.9(-9.1) μm {N = 30}, narrowly clavulate to subcylindrical, mostly (4)5-spored. **Subhymenium** composed of narrow cells, 3-5 μm diameter. **Cystidia** not differentiated. **Pileipellis** composed of slender, straight to curvy, mostly thin-walled elements; terminal elements very narrow 32.3-54.8-77.3 × 2.9-4.8-6.7 (-7.1) μm {N = 29}. **Clamp connections** absent.

*Additional collections examined:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, woodland with only *Brachystegia longifolia*, 1183 m, S11°28'33.8"-E27°39'42.0", 25 Jan. 2014, De Kesel leg., De Kesel 6070 (BR5020184215583); ibidem, miombo dominated by *Marquesia macrourea*, growing on the ground around a young *M. macrourea*, 23 Jan. 2015, De Kesel leg., De Kesel 6234 (BR5020184225599); ibidem, Lubumbashi, Jan. 1933, de Loose B13 (Holotype, BR5020032475770). TOGO: **Central Prov.**, Fazao, National Parc Fazao-Malfakassa, woodland dominated by *Uapaca togoensis* Pax, on gravelly soil, 556 m, N08°43.145'-E0°46.332', 20 Jul 2007, De Kesel leg., De Kesel 4467 (BR5020163802667).

*Ecology and distribution:* So far considered rare but apparently widely distributed and now known from Katanga province (DR Congo) and Togo (West-Africa). This chanterelle occurs in the DR Congo in woodlands dominated by *Brachystegia longifolia*, sometimes mixed with the dipterocarps *Marquesia macrourea* and *Monotes katangensis* (Dipterocarpaceae). In West Africa (Togo) known only from woodlands dominated by *Uapaca togoensis* and equally presence of some dipterocarps, in this case *Monotes kerstingii* Gilg.

*Comments:* Buyck *et al.* (2013) did not provide sequenced collections of *C. defibulatus*. This taxon was previously known only from the type and one additional specimen (Heinemann 1966). We checked the latter collection (Schmitz-Levecq 14) and found significant differences with the type. Based on the clearly squamulose caps, with 9-12 μm wide pileal elements and excessively rare clamps, this second collection does not belong to *Cantharellus defibulatus*, but to *C. pseudomiomboensis*.

The epitype, and all other new collections presented here, fully correspond with the holotype, although the holotype (de Loose B13) has slightly narrower spores (6.7-)6.8-7.6-8.5(-8.4) × 4.1-4.6-5(-5.1) μm {N = 49}, hence a higher Q value of 1.48-1.67-1.84. This confirms the spore measurements provided by Eyssartier (2001) for the holotype with a Q value of 1.4-1.73-2.0.

*Cantharellus defibulatus* is a large, multipileate and entirely smooth-capped species. In the field it can only be confused with *C. afrociarius*. However, the latter has gills that are whitish near the stipe and yellow-orange near the margin. Under

the microscope, the difference is very easily made as the latter species has clamps in all tissues.

Our phylogeny confirms the placement of *C. defibulatus* in subg. *Rubrinus* sect. *Heinemannianus* Eyssart. & Buyck. It is placed sister with maximum support (100 ML BS, 1 BPP, fig. 1b) to the Malagasy *C. sebosus* Buyck & V. Hofstetter as already suggested by Buyck *et al.* (2015).

***Cantharellus guineensis* De Kesel & Yorou sp. nov.**

**Figs 5-7, 25**

*Mycobank*: MB 818087.

*Diagnosis*: Differs from *Cantharellus rufopunctatus* by the presence of clamp connections, a yellowish-orange context, hymenophore without much interveination, much less elongate spores and slightly narrower elements in the pileipellis.

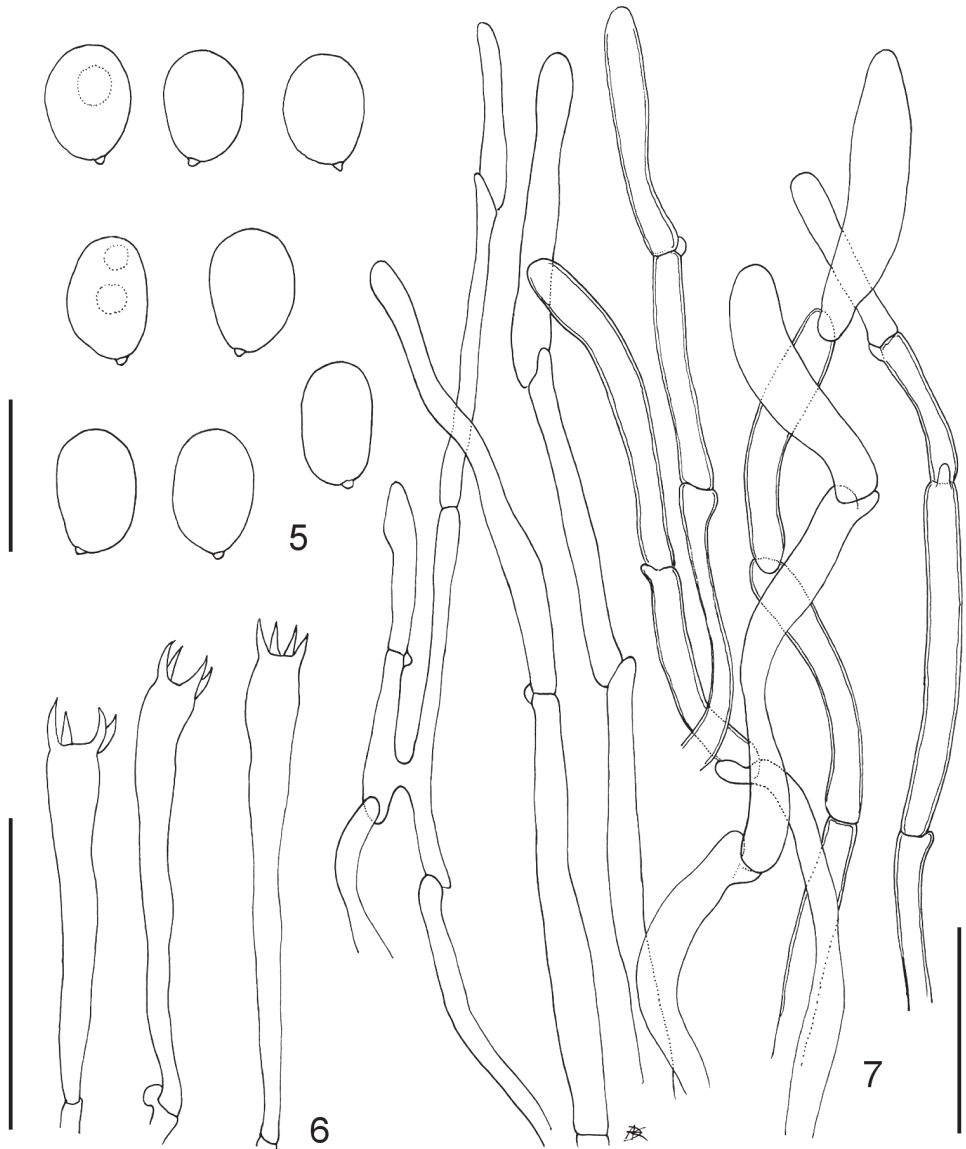
*Holotype*: BENIN: **Donga prov.**, Bassila, Forêt Classée de Bassila, in old forest gallery dominated by *Berlinia grandiflora*, alt 370 m, N8°59.805'-E1°38.689', 5 Oct. 2000, De Kesel 3005 (ADK3005, BR5020129217139).

*Etymology*: refers to its occurrence in Benin's Guineo-Sudanian transition zone.

**Fruit bodies** solitary or gregarious, not fasciculate, fleshy, compact, 6-8 (9) cm diameter and up to 10 cm high. **Pileus** thick-fleshed, convex with central depression at first, becoming infundibuliform at maturity; surface deep yellowish orange (4A5) with a faint greenish hue (4B4-B5), soon paler yellowish (3A2) with darker squamules, the latter fine, appressed, relatively dense in the centre and gradually sparser to absent near the margin; margin first inrolled and slightly lobed, soon inflexed, finally smooth, straight and upright, sharp and undulate. **Hymenophore** deeply decurrent, gill folds widely spaced (4-6/cm margin), furcate, not or very moderately interveined, mostly anastomosing near the stipe, easily removed from the underlying context, yellowish-orange (4A8-4A5), becoming concolorous with the pileus or more vivid. **Stipe** (3)4-5(6) × 1.0-1.8 cm, more or less cylindrical or slightly tapering downwards, concolorous with the pileus, almost entirely beset with darker (orange) punctiform squamules; basal mycelium whitish yellow to white. **Context** fleshy-fibrous, uniformly yellowish-orange (3A3-5), slightly paler in the stipe (age), deeper colored under the pileipellis, turning very slowly (hours) orange or orange-brown when bruised. **Taste** mild, not peppery. **Odour** very strong, fruity. **Spore print** not obtained.

**Spores** broadly ellipsoid, 7.1-8-8.8(-9.1) × 5.1-5.7-6.3(-6.4) µm {N = 55}, Q = 1.25-1.4-1.55(-1.58), hyaline, thin-walled, smooth. **Basidia** 53.5-66.9-80.3 × (7.1-)-7.4-8.7-9.9 µm {N = 25}, narrowly clavate to subcylindrical, mostly 4 sterigmate, some 1-3 sterigmate with conspicuously enlarged sterigmata. **Subhymenium** indistinct, composed of interwoven elements of 2-5 µm diam. **Cystidia** not differentiated. **Pileipellis** composed of wider elements than the ones from the subtending context, often with oblique septa and slightly thickened walls; terminal cells 34.8-74.4-114 × 8.8-11.6-17.2(-20.1) µm {N = 18}, subcylindrical, constricted at the septum. **Clamp connections** large, present in all tissues.

*Other collections*: BENIN: **Donga prov.**, Bassila, Forêt Classée de Bassila, riparian woodland with *Berlinia grandiflora*, alt 370 m, N8°59.883'-E1°38.748', 03 Oct. 2000, A. De Kesel 2981 (BR5020129193860); ibidem, N8°59.874'-E1°38.728', 11 Jun. 2002, A. De Kesel 3366 (BR5020152165698); ibidem, N8°59.685'-E1°38.606', 27 Jun. 2002, A. De Kesel 3475 (BR5020152173778); ibidem, N8°59.874'-E1°38.728', 28 Jun. 2002, A. De Kesel 3489 (BR5020152044450); ibidem, N8°59.001'-E1°38.631', 7 Oct. 2002, A. De Kesel 3525 (BR5020152005062).



Figs 5-7. *Cantharellus guineensis*. 5. Basidiospores (scale bar = 10  $\mu$ m). 6. Basidia with mostly four sterigmata. 7. Hyphae from the pileipellis with clamps (all from De Kesel 3005, HOLOTYPE). Scale bar 6-7 = 50  $\mu$ m.

*Ecology*: So far only known from its type locality, i.e. a relatively intact riparian woodland dominated by *Berlinia grandiflora* (Caesalpiniaceae), with *Uapaca togoensis* (Phyllanthaceae), *Lonchocarpus sericeus* (Poir.) Kunth, *Pterocarpus santalinoides* L'Herit. ex DC. (Fabaceae), *Elaeis guineensis* Jacq. and *Napoleonaea vogelii* Hook. & Planch. (Lecythidaceae) along the rivulet Akoka. The

herbaceous cover is poor or lacking. The species grows in the same habitat as *Cantharellus solidus* De Kesel, Yorou & Buyck (De Kesel *et al.* 2011).

*Comments:* Our diagnosis of *C. guineensis* compares this species against *C. rufopunctatus* because it is the most striking look-alike. The type was previously identified as *C. rufopunctatus* in Eyi *et al.* (2011), a logical consequence of the fact that Heinemann (1959, 1966) placed woodland specimens with much shorter spores ( $Q < 1.6$ ) and clamp connections under *C. rufopunctatus*. The presence of clamp connections in *C. guineensis* can be used to separate it from *C. rufopunctatus*, which is the sister-species of *C. miomboensis* and belongs to a different clade (Fig. 1b). Macroscopically, *C. guineensis* can be distinguished from both latter species by its striking yellowish-orange context. From *C. rufopunctatus* it differs also in its gill-folds lacking the typically strong interveination.

Together with the three other here newly described species (*C. mikemboensis*, *C. stramineus*, *C. pseudomiomboensis*), it composed a highly supported monophyletic clade that is here described as a new section (see below).

***Cantharellus mikemboensis* De Kesel & Degreef *sp. nov.***

**Figs 8-10, 26**

*Mycobank:* MB 818088.

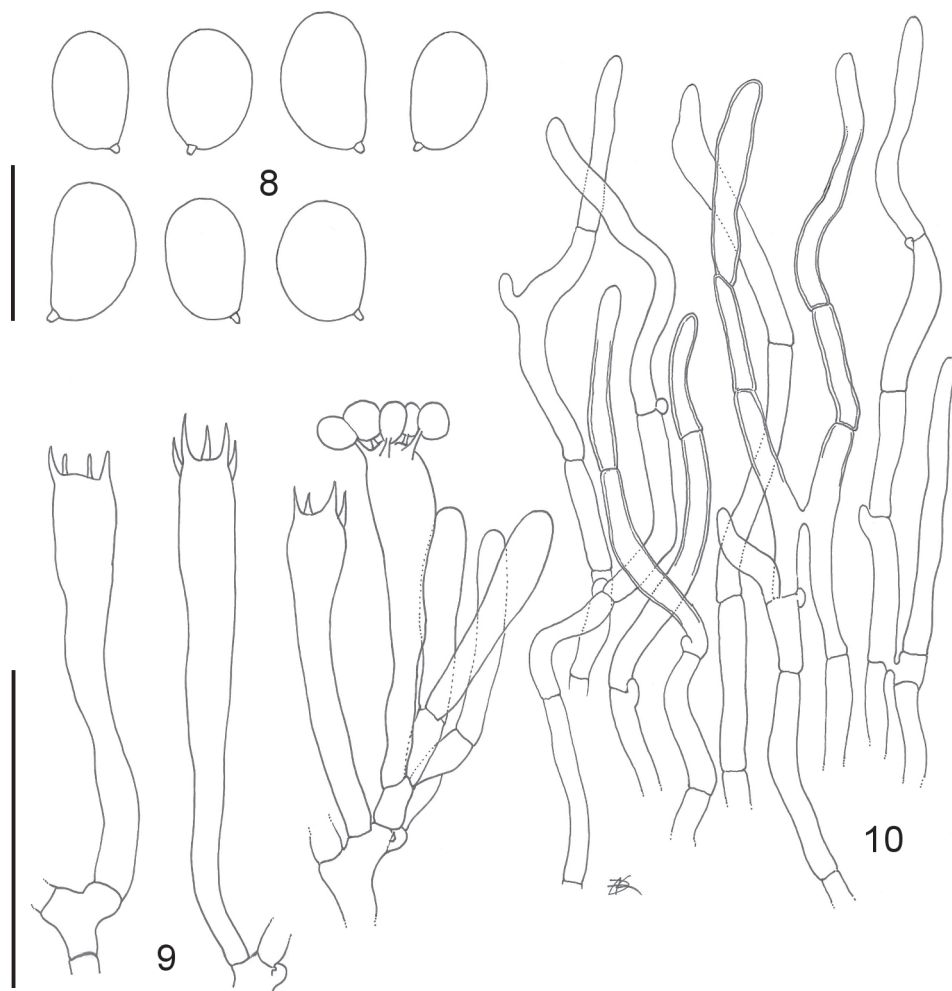
*Diagnosis:* Differs from *Cantharellus miomboensis* by the presence of clamp connections, a whitish smooth to minutely squamulose stipe, more spaced and little interveined gill folds, much less elongate basidiospores ( $Q_{\text{mean}} = 1.54$ ) and much wider terminal cells in the pileipellis ( $> 8 \mu\text{m}$ ).

*Holotype:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, miombo woodland, under *Uapaca pilosa* Hutch., S11°28.874' - E27°40.105', 06 Feb. 2012, De Kesel & Degreef leg., Degreef 918 (JD918, BR5020169410484).

*Etymology:* Refers to the name of the type locality, Mikembo.

**Fruit bodies** solitary or gregarious, fleshy, compact, up to 12 cm diameter and 10 cm high, sometimes caespitose with 2(3) pilei. **Pileus** thick-fleshed, convex to plano-convex then depressed to funnel-shaped on expansion; surface glabrous-tomentose, light yellow to dull yellow (3A5-3, 3B4-5) when young, then entirely squamose, wax yellow (3AB5) to yellowish orange (4A5) and paler (3A2-3) towards the edge; margin lobed, briefly inrolled, soon inflexed to straight, sharp and undulate. **Hymenophore** deeply decurrent, pseudolamellate, not anastomosing, furcate and moderately interveined, sometimes leaving smooth patches deeper on the stipe, concolorous with the cap (3A5-3), then becoming deeper yellow, butter yellow (4A4-6) to amber yellow (4B6), strongly demarcated from the stipe. **Stipe** (2)3-5 × 0.8-1.5 cm, cylindrical, wider and more massive in multipileate specimens, non-rooting, entirely smooth or only minutely squamulose, whitish or very pale yellow (3A2). **Context** fleshy-fibrous, whitish in the stipe, yellow marbled in the cap, yellow (3-4A6) under the pileipellis. **Taste** mild. **Odour** fruity. **Spore print** not obtained.

**Spores** broadly ellipsoid to ellipsoid, rarely slightly constricted, 7.3-8.2-9.1(-9.6) × (4.5-)4.6-5.3-6.1(-6.9)  $\mu\text{m}$  {N = 56},  $Q = 1.37-1.54-1.71(-1.72)$ , hyaline, thin-walled, smooth. **Basidia** slender, 52.8-63.9-75.1(-75.6) × 6.6-8.5-10.3(-10.6)  $\mu\text{m}$  {N = 20}, narrowly clavate to subcylindrical, with (3)4(5) sterigmata. **Subhymenium** indistinct, composed of loosely interwoven cells of 3-5  $\mu\text{m}$  diam. **Cystidia** not differentiated. **Pileipellis** composed of regular and slender, only slightly thick-walled elements with occasional clamps; terminal elements 33.1-57.2-93.1(-110.6) × 5.1-8.1-11.1  $\mu\text{m}$  {N = 20}, subcylindrical often slightly constricted at the septum. **Clamp connections** present in all tissues.



Figs 8-10. *Cantharellus mikemboensis*. **8.** Basidiospores (scale bar = 10  $\mu$ m). **9.** Basidia with 4-5 sterigmata. **10.** Narrow hyphae from the pileipellis with clamps (all from Degreeef 918, HOLOTYPE). Scale bar 9-10 = 50  $\mu$ m.

*Other collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, miombo woodland dominated with *Julbernardia paniculata*, S11°28'57.7"-E27°40'26.0", 1229m alt.s.m., 18 Jan. 2014, leg. A. De Kesel, De Kesel 6039 (BR5020184208660); ibidem, miombo woodland dominated with *Brachystegia spiciformis* (old), *Uapaca nitida* Müll. Arg. and *U. kirkiana* Müll. Arg., S11°28'57.5"-E27°40'22.2", 1220m alt.s.m., 23 Jan. 2014, leg. A. De Kesel, De Kesel 6065 (BR5020184214555); ibidem, miombo woodland, 1200 m, 25 Jan. 2014, leg. M. Hasson, De Kesel 6073 (BR5020184217648); ibidem, miombo woodland, S11°29.088'-E27°40.571', 1180 m, 31 Jan. 2012, leg. A. De Kesel & J. Degreeef, Degreeef 866 (BR5020169371099); Luiswishi, miombo woodland, close to *Marquesia macrourea*, 1150 m, 15 Feb. 1990, leg. J. Degreeef, Degreeef 90-34 (BR5020005058146).

*Ecology:* *Cantharellus mikemboensis* is much less common than *C. miomboensis*. It occurs in a number of different types of woodland with deeper soils. Usually found under older growth of *Marquesia macroua*, *Julbernardia paniculata* or *Brachystegia spiciformis*, most often mixed with *Uapaca* spp. It is impossible to indicate a specific host.

*Comments:* Although the diagnosis of *Cantharellus mikemboensis* compares it against features of *C. miomboensis*, it also strongly resembles *C. pseudomiomboensis*.

Based on its white and smooth to almost smooth stipe, *C. mikemboensis* is easily separated from *C. miomboensis*. Based on its pale yellow to dull yellow cap and almost concolorous yellowish scales it clearly differs from *C. pseudomiomboensis*. In fact, the cap of the latter species is brownish to cinnamon brown at first, becoming yellowish and densely beset with light brown to cinnamon brown scales, especially in the center.

Based on its relatively large size, squamulose cap, yellow color and smaller basidia, *C. mikemboensis* resembles species in subg. *Rubrinus* sect. *Isabellinus* (clade 2a, Buyck *et al.* 2013), particularly *C. miomboensis*. However, it differs from all species in this subgenus by the presence of abundant clamp connections.

Young and massive fruitbodies of *C. mikemboensis* could be confused with the smooth capped *C. afrociarius*. Both taxa are indeed large and fleshy, with one or several yellow caps, showing clamp connections in most tissues and slightly thick-walled elements in the pileipellis. The new species, however, becomes squamulose at maturity, has a deeper yellow and uniformly colored hymenophore and shows wider terminal cells in the pileipellis.

Together with the three other here newly described species (*C. guineensis*, *C. stramineus*, *C. pseudomiomboensis*), it composed a highly supported monophyletic clade that is here described as a new section (see below).

***Cantharellus miomboensis*** Buyck & V. Hofstetter, in Buyck *et al.*, *Fungal Diversity* 58(1): 291 (2013) **Fig. 27**

A description of this recently described taxon is given in Buyck *et al.* (2013). The material cited hereunder entirely fits the description; the sequenced collections cluster with the type.

*Other collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, regenerated miombo with *Julbernardia globiflora*, 1194 m, S11°28'56.7"-E27°39'27.7", 14 Jan. 2013, De Kesel leg., De Kesel 5392 (BR5020184183561); *ibidem*, miombo dominated by *Julbernardia globiflora* (young and old), 1202 m, S11°29'02.9"-E27°39'20.2", 14 Jan. 2014, De Kesel leg., De Kesel 6006 (BR5020184197698); *ibidem*, miombo woodland dominated by *Brachystegia spiciformis* (old) and *Julbernardia paniculata* (very young), 1218 m, S11°28'57.4"-E27°40'24.7", 19 Jan. 2014, De Kesel leg., De Kesel 6044 (BR5020184209698); *ibidem*, miombo dominated by *Julbernardia paniculata*, 1223 m, S11°28'59.4"-E27°40'26.3", 23 Jan. 2014, De Kesel leg., De Kesel 6059 (BR5020184212490); *ibidem*, miombo with *Brachystegia spiciformis* and *Julbernardia globiflora*, 1160 m, S11°29'02.1"-E27°40'28.9", 16 Jan. 2015, De Kesel leg., De Kesel 6203 (BR5020184222505); *ibidem*, miombo dominated by *Julbernardia globiflora* and *J. paniculata*, 19 Jan. 2015, De Kesel leg., De Kesel 6219 (BR5020184223533); *ibidem*, miombo dominated by *Julbernardia globiflora* and *Brachystegia* spp., 1176 m, S11°29.042'-E27°40.043', 1 Feb. 2012, De Kesel & Degreef leg., Degreef 877 (BR5020169379170); *ibidem*, miombo dominated by *Brachystegia boehmii* Taub., *B. longifolia* & *Uapaca pilosa*, 3 Feb. 2012, De Kesel & Degreef leg., Degreef 895 (BR5020169390281); *ibidem*, Kipopo, miombo

woodland, 1250 m, S11°33'-E27°21', 1 Jan. 1959, Schmitz-Levecq 39 (BR5020032810243, ex. *Cantharellus rufopunctatus* var. *ochraceus*).

**KENYA: Coast Prov.**, Malindi district, Arabuko - Sokoke, coastal miombo with *Brachystegia spiciformis* and *Julbernardia magnistipulata* (Harms) Troupin, S3°17.1'-E39°56.5', 27 Nov. 2004, De Kesel leg., De Kesel 3908 (BR5020162711427) and De Kesel 3909 (BR5020162721525); ibidem, near Shimba Hills, coastal miombo, under *Paramacrolobia* sp. and *Brachystegia* sp., S4°07'-E39°30', 30 Nov. 2004, De Kesel leg., De Kesel 3936 (BR5020162814487); ibidem, Kwalé, Lunguma area, Kayateleza, coastal miombo with *Brachystegia* sp., S4°07.966'-E39°30.655', 04 Dec. 2004, De Kesel leg., De Kesel 3995 (BR5020162782168).

**ZIMBABWE: Harare Prov.**, Kutsaga (Tobacco Research Center), miombo woodland with *Brachystegia spiciformis*, S17°50'-E31°08', 31 Jan. 1999, De Kesel leg., De Kesel 2368 (BR5020112538180).

*Ecology & distribution:* Buyck *et al.* (2013) indicated that *C. miomboensis* is one of the most common chanterelles of the African miombo. The species is known from Tanzania and Zambia (Buyck *et al.* 2013), reported under *Brachystegia*. Our records extend its distribution to Kenya, Zimbabwe and the Democratic Republic of the Congo. We confirm its occurrence in miombo woodland dominated by *Brachystegia spiciformis*. However, it is also frequently found under *Julbernardia globiflora* and *J. paniculata*. In spite of intensive surveying in Togo, Bénin and Burkina Faso, it is so far unrecorded from the Soudano-Guinean woodlands of West Africa. This may possibly be explained by the absence of suitable host genera, i.e. *Julbernardia* and *Brachystegia* (Caesalpiniaceae).

Notwithstanding the high similarity between *C. miomboensis* and some of the here newly described species, it is genetically not close and belongs in subg. *Rubrinus*, sect. *Isabellinus* Eyssart. & Buyck together with *C. rufopunctatus* and several other yellowish-brown African chanterelles lacking clamp connections (Fig. 1).

***Cantharellus pseudomiomboensis* De Kesel & Kasongo sp. nov. Figs 11-13, 28**

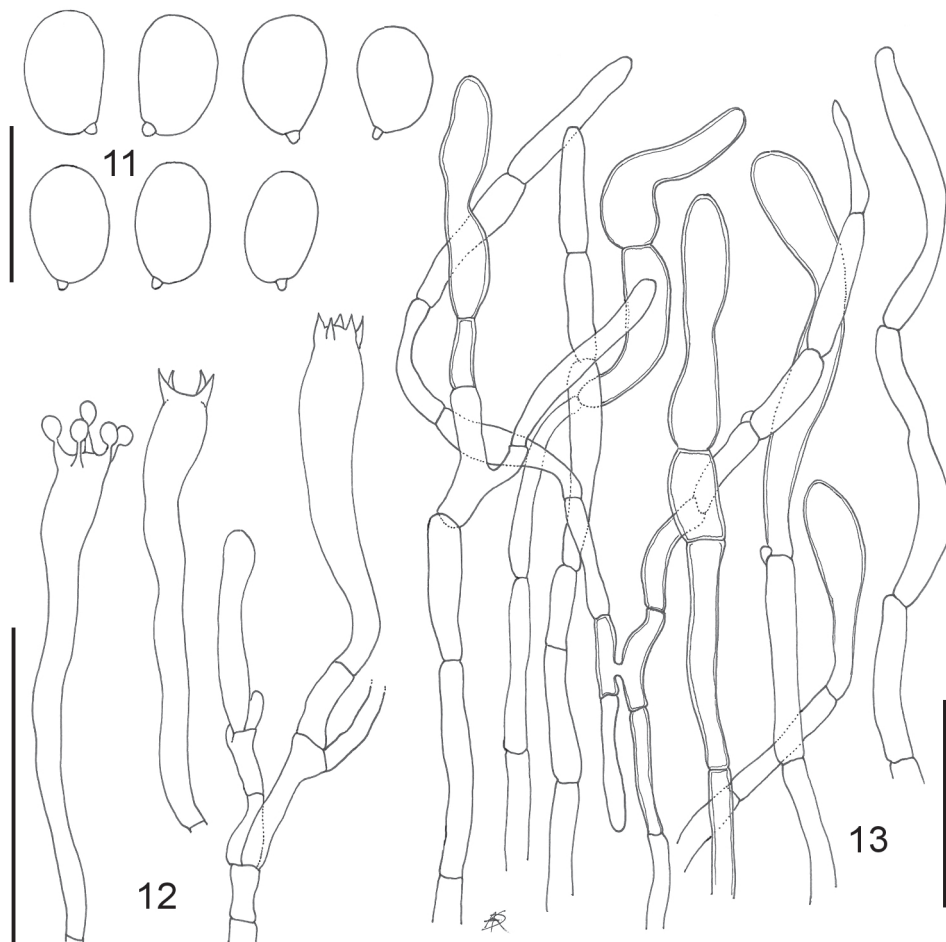
*Mycobank:* MB 818089.

*Diagnosis:* Differs from *Cantharellus miomboensis* by the light cinnamon brown color of the young cap, much larger and light brown scales on the cap, the whitish squamulose stipe, slightly more spaced gill folds, and much less elongate basidiospores ( $Q = 1.5$ ), much wider ( $> 8 \mu\text{m}$ ) terminal cells in the pileipellis and the rare presence of large clamp connections.

*Holotype:* DEMOCRATIC REPUBLIC OF THE CONGO: Katanga province, near Kisangwe, Mikembo sanctuary, miombo woodland with *Julbernardia globiflora*, *Brachystegia microphylla* Harms and *Uapaca kirkiana*, S11°29,074'-E27°40,180', 1210m alt.s.m., 8 Feb. 2012, leg. A. De Kesel, Degreef 927 (BR5020169418565).

*Etymology:* The name epithet refers to the resemblance with *Cantharellus miomboensis*.

**Fruit bodies** solitary or fasciculate, only rarely gregarious. **Pileus** up to 120 mm diam., fleshy and compact, first convex to plano-convex, very soon with a central depression and somewhat lobed towards the edge; margin lobed, wavy, thick, for a long time enrolled, eventually becoming straight and sharp; surface at first entirely light cinnamon brown (6C6-6D5) and felty-tomentose, very soon disrupting and showing a whitish to yellowish context (3A5) in between fine and flattened to semi-erect squamulae, the centre often remaining felty-tomentose and light brown.



Figs 11-13. *Cantharellus pseudomiomboensis*. **11.** Basidiospores (scale bar = 10  $\mu$ m). **12.** Basidia with 4-5 sterigmata. **13.** Hyphae from the pileipellis with rare clamps (all from Degreef 927, HOLOTYPE). Scale bar 12-13 = 50  $\mu$ m.

**Hymenophore** consists of deeply decurrent gill folds of different lengths, well-spaced (3-5/cm margin), very rarely anastomosing, most often forked, usually interveined, often bright yellow (3A4-5) and strongly demarcated from the whitish stipe. **Stipe** (2)3-5.5  $\times$  1.0-2.5 cm, cylindrical or tapering towards the base, non-rooting, almost white or with a faint hue of yellow, entirely beset with very fine to inconspicuous squamulae, the latter pale brown, pale orange or whitish, the basal part of the stipe often slowly bruising yellowish or orange. **Context** fleshy-fibrous, whitish in the stipe and most of the pileus, orange under the pileipellis, unchanging. **Taste** mild. **Odour** fruity. **Spore print** not obtained.

**Spores** broadly ellipsoid to ellipsoid, (6.3-)6.4-7.2-7.9(-8.3)  $\times$  4.4-4.9-5.5 (-5.6)  $\mu$ m {N = 48}, Q = 1.29-1.46-1.63(-1.67), hyaline, thin-walled, smooth. **Basidia** slender, 41.8-56.5-71.2  $\times$  6.3-8.2-10.1  $\mu$ m {N = 18}, narrowly clavate to subcylindrical, mostly (4)5 sterigmata. **Subhymenium** poorly defined, composed of



loosely interwoven cells of 3-5  $\mu\text{m}$  diam. **Cystidia** not differentiated. **Pileipellis** composed of regular and slender, only slightly thick-walled elements, occasionally with clamps; terminal cells 31.7-43.9-56  $\times$  5.4-8.4-11.4(-11.6)  $\mu\text{m}$  {N = 14}, subcylindrical often slightly constricted at the septum. **Clamp connections** large, not common, but most frequent on pileipellis elements (see ADK6198, very rare in ADK6190).

*Other examined collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, miombo woodland with *Julbernardia paniculata*, *J. globiflora* and *Uapaca kirkiana*, S11°28'52.5"-E27°39'32.1", 1088m alt.s.m., 13 Jan. 2015, leg. A. De Kesel, De Kesel 6190 (BR5020184219703); ibidem, on the ground, 16 Jan. 2014, leg. M. Hasson, De Kesel 6029 (BR5020184202484); ibidem, old *Marquesia macroura* stand, S11°29'14.0"-E27°39'52.1", alt.s.m. 1097 m, leg. A. De Kesel, De Kesel 6198 (BR5020184220440); ibidem, Kipopo, miombo forest, Jan. 1959, Schmitz-Levecq 14 (BR5020032474766).

*Ecology:* Miombo woodland with *Marquesia macroura*, but also regenerated and denser miombo woodlands with *Julbernardia paniculata*, *J. globiflora*, *Brachystegia microphylla* and *Uapaca kirkiana*, all of which represent possible host trees.

*Comments:* Although the diagnosis of *C. pseudomiomboensis* compares the new species against features of *C. miomboensis*, it also resembles *C. mikemboensis*, a much less common species. The young pileus of *C. pseudomiomboensis* is brownish to cinnamon brown or yellowish and then densely beset with light brown to cinnamon brown scales, especially in the center. This feature separates it from *C. mikemboensis* who has a pale yellow to dull yellow cap and almost concolorous yellowish scales. Under the microscope very little differences can be observed, although *C. mikemboensis* tends to have slightly narrower terminal pileal elements and much more frequent clamp connections. Based on molecular data all three taxa are well separated from each other.

Clamp connections can be excessively rare in *C. pseudomiomboensis*. The collection Schmitz-Levecq 14, formerly placed by Heinemann (1966, pg. 340) under what is now called *Cantharellus defibulatus*, is such an example. Because of its very squamulose pileus and terminal pileal elements measuring 9-12  $\mu\text{m}$  in diameter, this collection actually belongs in *C. pseudomiomboensis*. The specimen depicted in Sharp (2011, page 27, as *C. rufopunctatus*) probably belongs to *C. pseudomiomboensis*.

In the event clamp connections are not detected in *C. pseudomiomboensis* it may also be confused with *C. tanzanicus* Buyck & V. Hofstetter and *C. miomboensis*. However, spores of the latter two taxa are on average more elongate (Q > 1.6 and up to 2.0) while those from *C. pseudomiomboensis* range from Q = 1.46 (JD927) to Q = 1.55 (ADK6029).

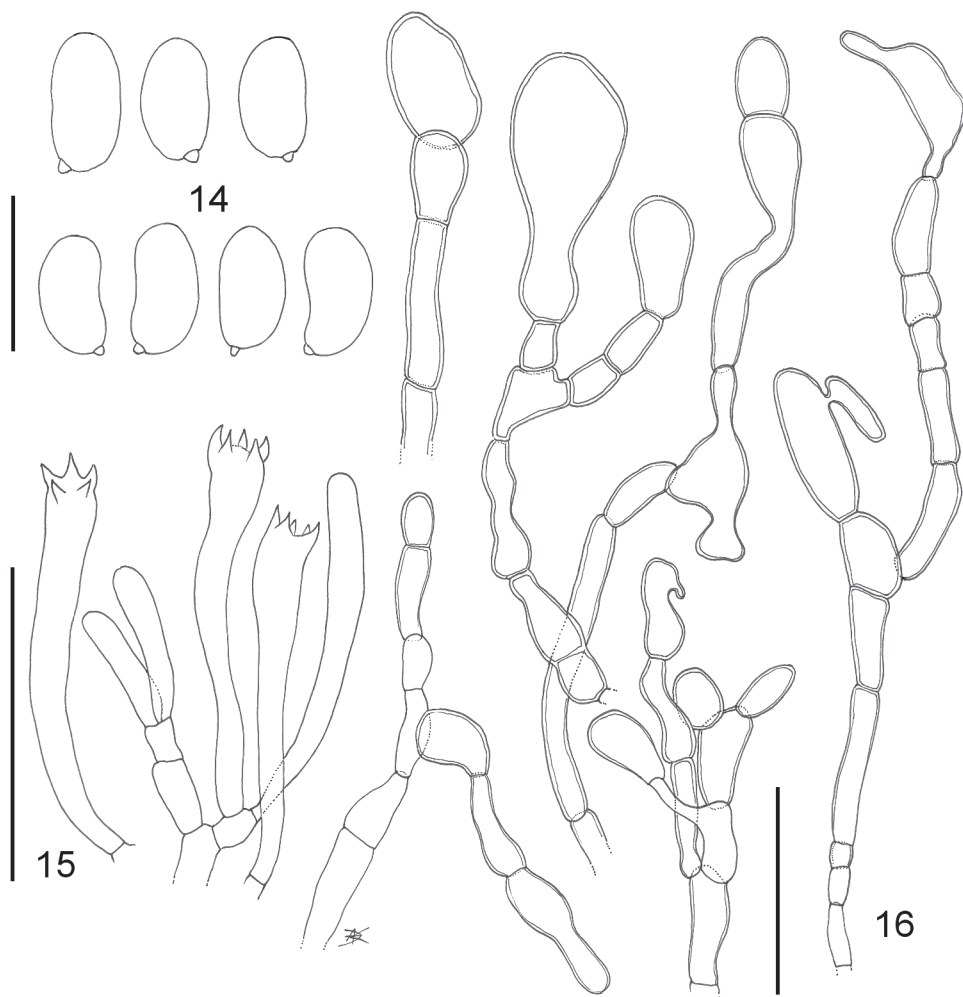
Together with the three other here newly described species (*C. mikemboensis*, *C. stramineus*, *C. guineensis*), it composed a highly supported monophyletic clade that is here described as a new section (see below).

***Cantharellus rufopunctatus*** (Beeli) Heinem., *Bull. Jard. bot. État Brux.* 28: 396 (1958) **Figs 14-16, 30**

*Mycobank:* Typification: MBT372680.

= *Lentinus rufopunctatus* Beeli, *Bull. SoC. R. Bot. Belg.* 60: 160 (1928).

= *Cantharellus rufopunctatus* var. *ochraceus* Heinem., *Bull. Jard. bot. État Brux.* 28: 398 (1958).



Figs 14-16. *Cantharellus rufopunctatus*. **14.** Basidiospores (scale bar = 10  $\mu$ m). **15.** Basidia with 4-5 sterigmata. **16.** Hyphae from the pileipellis (all from De Kesel 5949, EPITYPE). Scale bar 15-16 = 50  $\mu$ m.

*Epitype*: DEMOCRATIC REPUBLIC OF THE CONGO: **Oriental Prov.**, Tshopo distr, Yangambi, Man-and-Biosphere reserve, rainforest dominated by *Brachystegia laurentii* (De Wild.) Louis ex Hoyle and a few *Gilbertiodendron dewevrei* (De Wild.) J.Leonard, alt 420 m, N00°49'11,5"-E24°31'20,3", 18 Nov. 2013, leg. A. De Kesel, De Kesel 5949 (**EPITYPUS hic designatus**: ADK5949, BR5020184194604).

**Fruit bodies** solitary or gregarious, not connected from a common base, fleshy, compact, 6-9 cm diameter and up to 10 cm high. **Pileus** thick-fleshed, at first convex, quickly with central depression, finally infundibuliform; surface vivid yellow (3A5-6) to vivid yellowish orange (4A5-6), sometimes zonate, the margin at first orange yellow (4B6-7), becoming paler yellowish; entirely beset with fine,

mostly punctate squamules, denser and darker in the center (4B6), becoming finer, more spaced and paler towards the margin; margin first inrolled and slightly lobed, soon inflexed, finally straight, upright, sharp, somewhat wavy and subcrenulate. **Hymenophore** deeply decurrent, composed of gill folds normally spaced (8-12/cm margin), furcate, strongly interveined, sometimes anastomosing near the stipe, pale yellowish (3A2-3A3) with a significantly brighter margin when young (3A4-3A6), becoming pale yellow (3-4A2), unchanging when bruised. **Stipe** (4)5-7(8) × 1.0-1.8 cm, frequently tapering downwards, upper part up to 2.5cm wide, often slightly compressed, vivid yellow (3A5-6) to vivid yellowish orange (4A5-6), yellowish white towards the base, almost entirely beset with concolorous or darker (orange) punctiform squamules; basal mycelium yellowish. **Context** fleshy-fibrous, whitish, 3A2-4A2 underneath the pileipellis and stipitipellis, unchanging when cut or injured. **Taste** mild then becoming peppery. **Odour** strong, similar to *C. cibarius*. **Spore print** not obtained.

**Spores** ellipsoid, (6.8-)7.0-8.0-8.9(-9.1) × (3.6-)3.7-4.2-4.7(-5.1) μm {N = 52}, Q = 1.7-1.91-2.15(-2.2), hyaline, thin-walled, smooth. **Basidia** (40.5-)40.8-51.6-62.3 × 5.7-7.5-9.3 μm {N = 24}, narrowly clavate to subcylindrical, mostly having 5 sterigmata. **Subhymenium** indistinct, composed of interwoven elements of 2-4 μm diam. **Cystidia** not differentiated. **Pileipellis** composed of elements wider than those from the subtending context, frequently with thickened walls; terminal cells 19.6-32.7-53.2(-64.5) × 9.7-12.8-16.9(-17.6) μm {N = 21}, subcylindrical, moderately to distinctly constricted at the septum. **Clamp** connections absent.

*Other examined collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Oriental Prov.**, Tshopo distr., Yangambi, Man-and-Biosphere reserve, mixed rainforest with *Gilbertiodendron dewevrei* and *Brachystegia laurentii*, alt 429 m, N0°52'5,6"-E24°27'23,5", 13 Nov. 2013, leg. A. De Kesel, De Kesel 5892 (ADK5892, BR5020184193577); **Equator Prov.**, Binga, dry dense forest, Oct. 1934, Goossens-Fontana 992 (BR5020032807212); ibidem, Aug. 1929, Goossens-Fontana 878 (holotype of *Cantharellus rufopunctatus* var. *ochraceus* Heinem., GF878, BR5020032811257); ibidem, Djongo, rainforest with *Gilbertiodendron dewevrei*, December 1925, Goossens-Fontana 500 (holotype GF500, BR5020032805195); **Maniema Prov.**, Parc National de la Lomami, ca. 3km E-NE of Katopa, pristine dense rainforest, sandy soil, alt 450 m, S002°43.5'-E25°06.4', 06 Apr. 2015, leg. Marc Sosef, Sosef 2804 (BR5020184226626).

*Ecology:* Only known from dense rainforests in Central Africa where it is found almost exclusively under *Gilbertiodendron dewevrei*, to a lesser extent also under *Brachystegia laurentii*. Both tree species are often co-occurring and *C. rufopunctatus* tends to appear only in climax situations.

*Comments:* *Cantharellus rufopunctatus* is sufficiently well described (Beeli 1928, Heinemann 1958) and its morphological characteristics are well documented, including drawings and a water color painting. The holotype is in good condition but its DNA is apparently too deteriorated for sequencing. *C. rufopunctatus* was first described from the *Gilbertiodendron dewevrei* forests of central Africa (Heinemann 1958), together with a paler-colored var. *ochraceus*. However, in 1966 Heinemann reports both *C. rufopunctatus* and its variety *ochraceus* also from the miombo woodlands of Katanga (DR Congo), but mentions that the species is rather polymorphic as the specimens from Katanga differ from the type in having abundant clamps and a different morphology of spores and pileal elements. This weak importance attributed by Heinemann to the presence/absence of clamps (evidenced also, for ex., by his recognition of *C. cibarius* var. *defibulatus* Heinem.) led many later researchers into confusion, not only increasing the number of citations in the

Zambezi and Guineo-sudanian ecozone (De Kesel *et al.* 2002, Buyck 1994, among many others) but also broadening the species boundaries set around the type.

So far none of the *C. rufopunctatus* collections previously reported from the miombo ecozone correspond to *C. rufopunctatus* and most probably the species doesn't occur there as already suggested by Buyck *et al.* (2013). The miombo woodlands, however, harbour a number of siblings, all of which are used for food and local populations make no distinction between them.

We have equally studied the holotype of *C. rufopunctatus* var. *ochraceus* Heinem. (Goossens-Fontana 878, DR Congo, Binga, 29 August 1929; Bull. Jard. bot. État Brux. 28: 398, 1958) and, apart from a color difference, we could not detect any significant microscopic differences with the type variety. We therefore share the opinion of Eyssartier (2001), and consider it a mere synonym of *C. rufopunctatus*. Former records of *C. rufopunctatus* and *C. rufopunctatus* var. *ochraceus* from the miombo woodlands of Katanga (Heinemann 1966, pg. 344), i.e. collections Schmitz-Levecq 25bis and Schmitz-Levecq 39, were re-examined and belong to the here newly described *C. stramineus* (see below) and to *C. miomboensis* (see above), respectively.

***Cantharellus stramineus* De Kesel *sp. nov.***

**Figs 17-19, 31**

*Mycobank*: MB 818090.

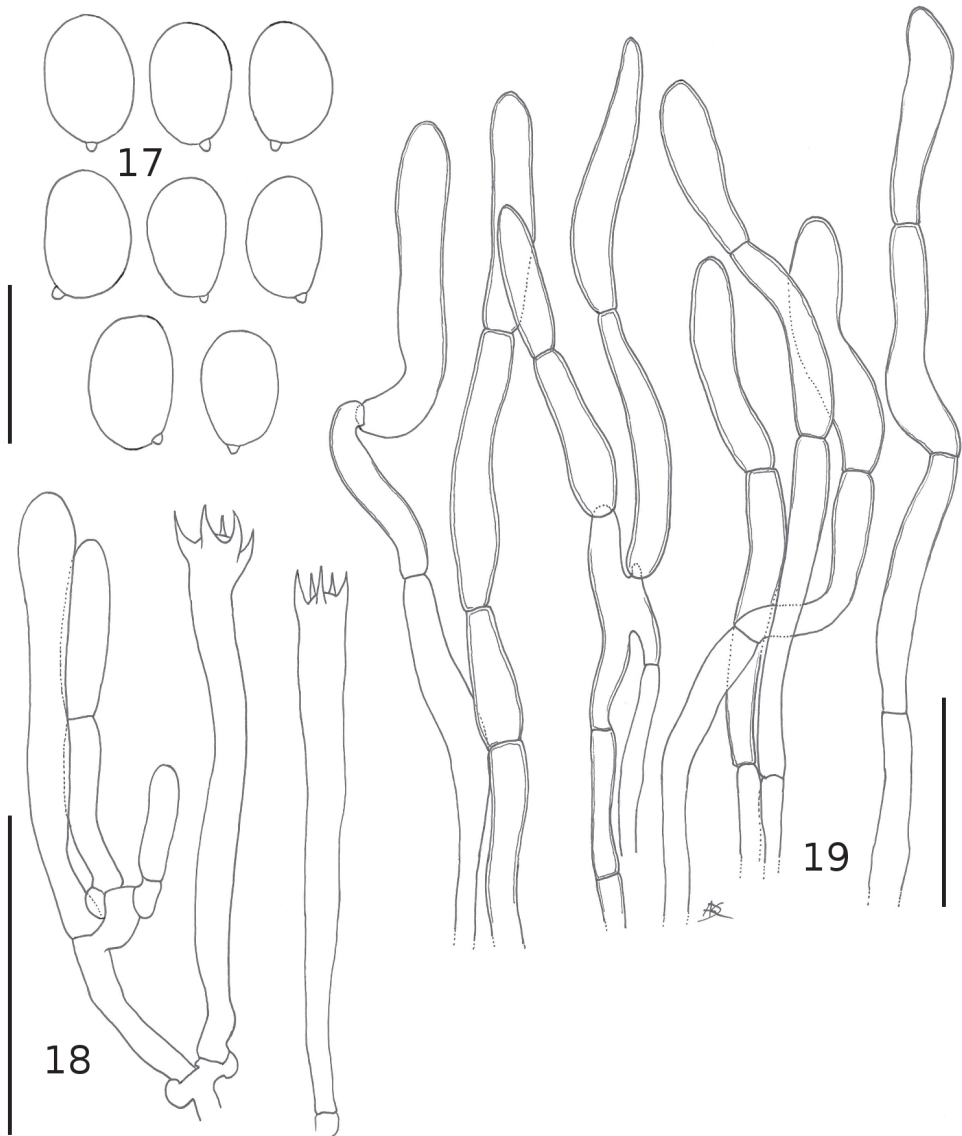
**Diagnosis**: Differs from *Cantharellus miomboensis* by its overall straw yellowish color, a paler whitish yellow hymenophore with widely spaced gill folds, the presence of clamps connections, less elongate spores and much wider terminal cells in the pileipellis.

**Holotype**: DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, monodominant miombo woodland with *Brachystegia wangermeeana*, S11°29'10.2" - E27°39'11.7", alt 1170 m, 21 Jan. 2014, De Kesel 6051 (ADK6051, BR5020184210434).

**Etymology**: *stramineus* refers to the straw-coloured fruitbodies

**Fruit bodies** solitary or fasciculate, fleshy, compact, up to 12 cm diameter and 10 cm high. **Pileus** thick-fleshed, convex to plano-convex then moderately to strongly depressed on expansion; surface greyish and powdery when young, very soon uniformly dull yellow, straw yellow to greyish yellow (3B2-3, 4B2-3), with brownish orange (5C4-6) squamules, the latter relatively dense and gradually smaller towards the margin; margin first somewhat lobed, inrolled, soon inflexed to straight, sharp and undulate, striate in older specimens. **Hymenophore** moderately to deeply decurrent, pseudolamella furcate, moderately to strongly interveined, anastomosing near the stipe, almost white at first, soon becoming yellowish white (4A2) to orange white (5A2), remaining relatively pale and never becoming deep orange. **Stipe** (4)5-8(9) × 1.5-2.4 cm, more or less cylindrical, concolorous with the pileus and entirely beset with minute pale brownish squamules, basal part often widened and forming lateral fruit bodies, vigorous specimens rooting several centimeters below the soil surface, basal mycelium white. **Context** fleshy-fibrous, white in the stipe, pale yellow (3A2-3) under the pileipellis, slowly bruising orange. **Taste** mild. **Odour** strong, fruity. **Spore print** not obtained.

**Spores** broadly ellipsoid to ellipsoid, (6.9-)7-7.9-8.9(-9.1) × (4.7-)4.8-5.4-6(-6.3) μm {N = 78}, Q = (1.26-)1.3-1.47-1.64(-1.68), hyaline, thin-walled, smooth. **Basidia** 47.1-60.3-73.5 × 5.8-7.6-9.5 μm {N = 20}, narrowly clavate to subcylindrical, mostly 4(5) sterigmata. **Subhymenium** indistinct, composed of interwoven elements of 2-5 μm diam. **Cystidia** not differentiated. **Pileipellis** composed of much wider



Figs 17-19. *Cantharellus stramineus*. 17. Basidiospores (scale bar = 10  $\mu\text{m}$ ). 18. Basidia clamped, with mostly 5 sterigmata. 19. Hyphae from the pileipellis with rare clamps (all from De Kesel 6051, HOLOTYPE). Scale bar 18-19 = 50  $\mu\text{m}$ .

elements than the subtending context, with slightly thickened walls and occasional clamp connections; terminal cells  $30.9\text{-}53.4\text{-}75.8\text{-}(85) \times 7.7\text{-}11.6\text{-}15.5\text{-}(22) \mu\text{m}$  {N = 14}, subcylindrical, constricted at the septum. **Clamp connections** present in all tissues.

*Other examined collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, miombo woodland

with *Brachystegia boehmii*, S11°28,558' - E27°39,716', alt. 1200 m, 01 DeC. 2012, De Kesel leg., Degreef 1035 (BR5020172909555); *ibidem*, miombo woodland with *B. boehmii* and *B. longifolia*, S11°28,712' - E27°39,808', alt. 1188 m, 11 DeC. 2012, Degreef 1098 (BR5020172958072); *ibidem*, Kipopo, miombo forest on brown clayey soil, Jan. 1959, Schmitz-Levecq 25bis (BR5020032809230).

*Ecology*: This species seems to be associated with *Brachystegia wangermeeana* on gravelly soils with lateritic crusts, either in monodominant stands or mixed with *B. boehmii* and *B. longifolia*.

*Comments*: *Cantharellus stramineus* shares its robust and caespitose habit with *C. afrociarius*, *C. defibulatus* and *C. mikemboensis*. Although the latter three do not occur in exactly the same type of miombo habitat, they can be found not far from each other. In the field they can be easily separated from *C. stramineus* by their striking yellow colors and completely smooth stipe.

The oldest record of *C. stramineus* consists of a specimen (January 1959, M.C. Schmitz-Levecq 25bis) identified by Heinemann (1966, pg. 344) as *C. rufopunctatus*, a taxon that does not occur in the Zambezian ecozone.

In the field *C. stramineus* can easily be confused with *C. miomboensis*, especially when dealing with the off-white to yellow forms mentioned by Buyck *et al.* (2013, pg292). Separating *C. stramineus* unambiguously from other large and pale yellowish squamulose chanterelles requires microscopic observation of spore shape, presence/absence of clamps and the width of the terminal elements of the pileipellis.

Together with the three other here newly described species (*C. mikemboensis*, *C. guineensis*, *C. pseudomiomboensis*), it composed a highly supported monophyletic clade that is here described as a new section (see below).

***Cantharellus sublaevis*** Buyck & Eyssart., in Buyck, *Cryptog. Mycol.* 35(1): 26 (2014)

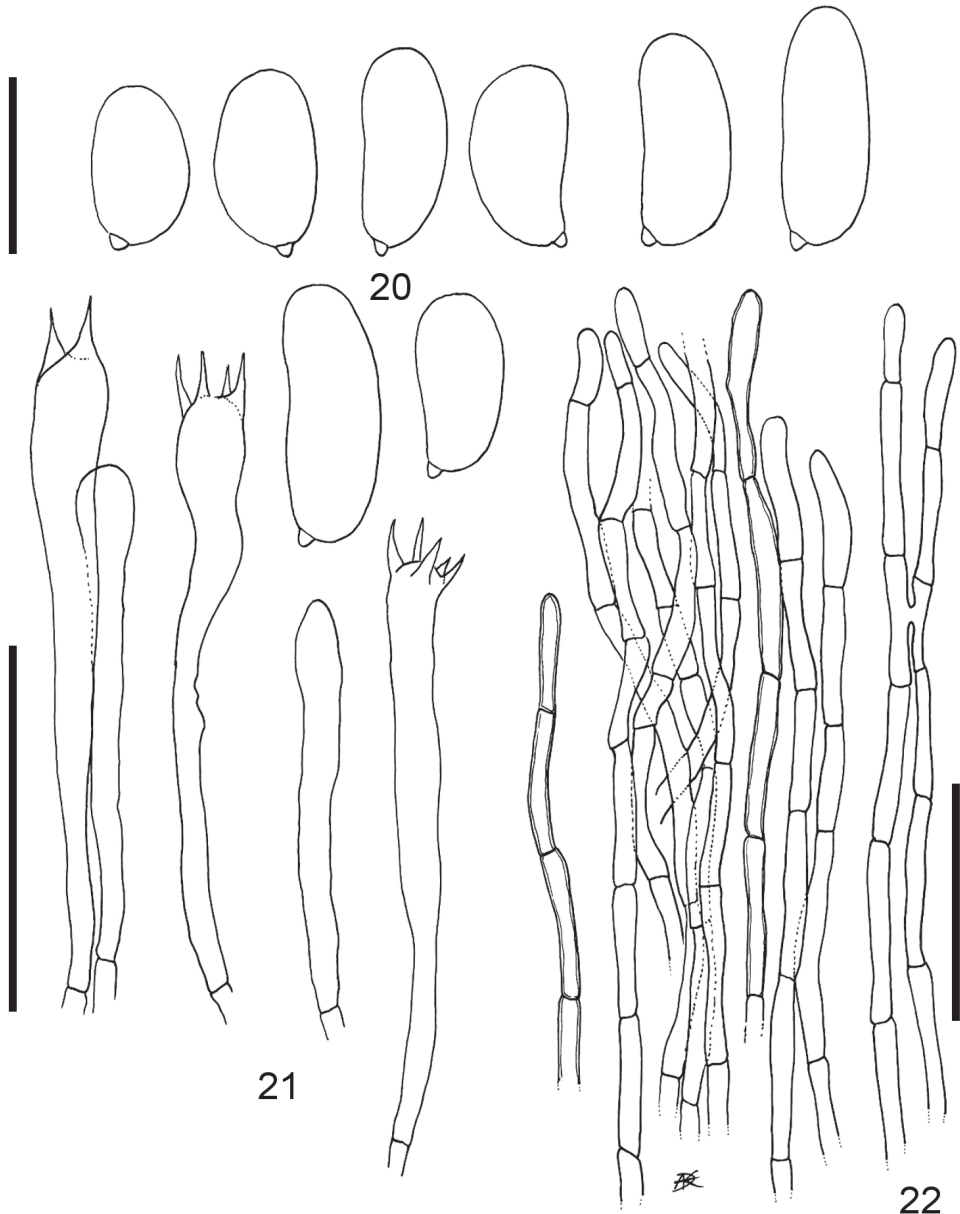
**Figs 20-22, 32**

*Mycobank*: Typification MBT372681.

A description of this recently described taxon is given in Buyck (2014). The material cited hereunder entirely fits the description of the type.

*Epitype*: DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, under *Brachystegia spiciformis* (old) and several very young *Julbernardia globiflora*, 1222 m, S11°28'50.2"-E27°40'49.7", 22 Jan. 2014, De Kesel leg., De Kesel 6057 (**EPITYPUS hic designatus**: ADK6057, BR5020184211462).

**Fruit bodies** mostly gregarious, fleshy, compact, 6-12 cm diameter, up to 10 cm high, most often caespitose with 2(3) pilei emerging from a common stipe. **Pileus** convex to plano-convex soon becoming depressed to funnel-shaped; surface nearly smooth, sometimes minutely fissurate towards the margin, light yellow, dull yellow to bright egg-yolk (3A7-6, 4AB7-6); margin lobed becoming irregularly and strongly undulate, briefly inrolled, later inflexed to straight and sharp. **Hymenophore** almost entirely smooth, becoming faintly to moderately ridged towards the margin, deeply decurrent and often leaving isolated patches on the stipe, pale yellow (4A3-4) near the margin, with a pinkish white (7A2) hue elsewhere, strongly demarcated from the stipe. **Stipe** (2)3-6 × 0.9-1.5 cm, cylindrical or slightly compressed, more massive in multipileate specimens, entirely smooth, pale yellow (3A3-4, 4A3-4), often with a rooting part that generates new basidiomes below the surface. **Context** fleshy-fibrous, whitish in the stipe, yellowish (3-4A3) under the pileipellis and stipitipellis. **Taste** mild. **Odour** fruity. **Spore print** not obtained.



Figs 20-22. *Cantharellus sublaevis* **20**. Basidiospores (scale bar = 10  $\mu\text{m}$ ). **21**. Basidia. **22**. Hyphae from the pileipellis (all from De Kesel 6057, EPITYPE). Scale bar 21-22 = 50  $\mu\text{m}$ .

**Spores** very variable, ranging from broadly ellipsoid to elongate, often subreniform,  $8.7\text{-}10.9\text{-}13.1\text{-}(14.1) \times 4.6\text{-}5.4\text{-}6.1\text{-}(6.2) \mu\text{m}$  {N = 46}, Q = 1.57-2.04-2.51(-2.68), hyaline, thin-walled, smooth. **Basidia** slender,  $53.9\text{-}65\text{-}80.8\text{-}(81.8) \times 4.2\text{-}5.5\text{-}6.8\text{-}(7.2) \mu\text{m}$  {N = 32}, narrowly clavate to subcylindrical, with (2)3-4(5)

sterigmata in fairly equal frequencies. **Subhymenium** composed of slender cells of 3-5  $\mu\text{m}$  diam. **Cystidia** not differentiated. **Pileipellis** composed of regular and slender, sometimes slightly thick-walled elements; terminal elements  $30.9\text{-}52.2\text{-}70.8(-82) \times 3.7\text{-}5.3\text{-}7(-7.2) \mu\text{m}$  {N = 33}. **Clamp connections** absent.

*Other collections:* DEMOCRATIC REPUBLIC OF THE CONGO: **Katanga Prov.**, near Kisangwe, Mikembo sanctuary, miombo with old *Brachystegia spiciformis* and young undergrowth of *Julbernardia globiflora*, 1205 m, S11°29'08.8"-E27°40'35.0", 27 Jan. 2014, De Kesel leg., De Kesel 6077 (BR5020184218676); ibidem, Lubemba (camp Hasson), miombo woodland, under *Julbernardia globiflora* & *Brachystegia spiciformis*, 1040 m, S10°54,799'-E28°31,880', 10 Feb. 2012, De Kesel leg., De Kesel 5082 (BR5020184178703); ibidem, savannah woodland on Kalahari sands, under *Uapaca pilosa*, *U. nitida* and few *Isoblerlinia angolensis* (Benth.) Hoyle & Brenan, 11 Feb. 2012, De Kesel & Degreef leg., Degreef 942 (BR5020169429677); ibidem, miombo woodland, 12 Feb. 2012, De Kesel & Degreef leg., Degreef 964 (BR5020169445837); ibidem, Fungurume; East from Koperberg, miombo woodland, 26 Feb. 1986, Schreurs1216 (BR5020008019656); ibidem, Kanonga, Upemba National Park, savannah woodland, 15 Feb. 1949, leg. Van Meel, De Witte 5542 (BR-5020032473752, ut *Cantharellus cibarius* Fr. var. *cantharellus* (Schwein.) Heim).

*Ecology and distribution:* This species is considered very rare and was only known from its type locality near Chibuli in the Copperbelt province of Zambia and also from one collection in the Upemba National park in Katanga, DR Congo (Buyck 2014). We can confirm that it is indeed a rare species. We found it exclusively in older woodland, mostly under old *Brachystegia spiciformis*, often mixed with younger *Julbernardia globiflora*.

*Comments:* The systematic position of this species was never molecularly established although Buyck (l.c.) suggested that it was probably close to the Malagasy *C. sebosus* and therefore belonged in subg. *Rubrinus*. Our phylogeny now confirms this placement and places this chanterelle together with other clampless, medium-sized, yellow chanterelles, such as *C. defibulatus* and *C. sebosus*, in sect. *Heinemannianus*.

The morphology of the epitype entirely fits the description given in Buyck (2014), although the holotype of *C. sublaevis* misses the base of the stipe (Buyck 2014, fig. 19) and hence the protologue (Buyck l.c., pg. 26) doesn't present information on its nature. The second collection (De Witte 5542) and all of the above mentioned collections show basidiomata being aggregated at the stipe base. Although we think the multipileate nature is a constant feature of *C. sublaevis*, it cannot be used as sole identification criterium since another smooth chanterelle from tropical Africa, i.e. *C. solidus*, is also multipileate (De Kesel *et al.* 2011).

Our collections also add to the variation of spore dimensions because of the more variable number of sterigmata that we observed per basidium. Indeed, Buyck (2014) indicates predominantly 5-spored basidia [i.e. (2-4)5] in *C. sublaevis*. Our observations indicate that the frequency of 3-, 4- and 5-spored basidia is more or less equal, and that 2-spored basidia are actually not so rare. This certainly explains the very irregular size and shape of the spores of *C. sublaevis*. Buyck (2014) gives spore measurements for the type as  $(8.7)8.9\text{-}9.77\text{-}10.6(11) \times (4.0)4.7\text{-}5.21\text{-}5.7(6.0) \mu\text{m}$ , while the range in spore size – particularly the spore length – in both the epitype and De Witte 5542 are more important, i.e.  $8.7\text{-}10.9\text{-}13.1(-14.1) \times 4.6\text{-}5.4\text{-}6.1(-6.2) \mu\text{m}$  and  $7.8\text{-}9.7\text{-}11.5(-14.2) \times (4.3\text{-})4.6\text{-}5.3\text{-}5.9(-6) \mu\text{m}$  {N = 49} respectively.





Fig. 23. *Cantharellus afroibarius* (ADK6038, photograph A. De Kesel).



Fig. 24. *Cantharellus defibulatus* (ADK5511, photograph A. De Kesel).



Fig. 25. *Cantharellus guineensis*. Fruitbodies at different stages of development (De Kesel 3005, photograph A. De Kesel, HOLOTYPE).



Fig. 26. *Cantharellus mikemboensis*. Fruitbodies at different stages of development (Degreef 918, photograph A. De Kesel, HOLOTYPE).



Fig. 27. *Cantharellus miomboensis* (ADK6059, photograph A. De Kesel).



Fig. 28. *Cantharellus pseudomiomboensis*. Fruitbodies at different stages of development (Degreef 927, photograph A. De Kesel, HOLOTYPE).

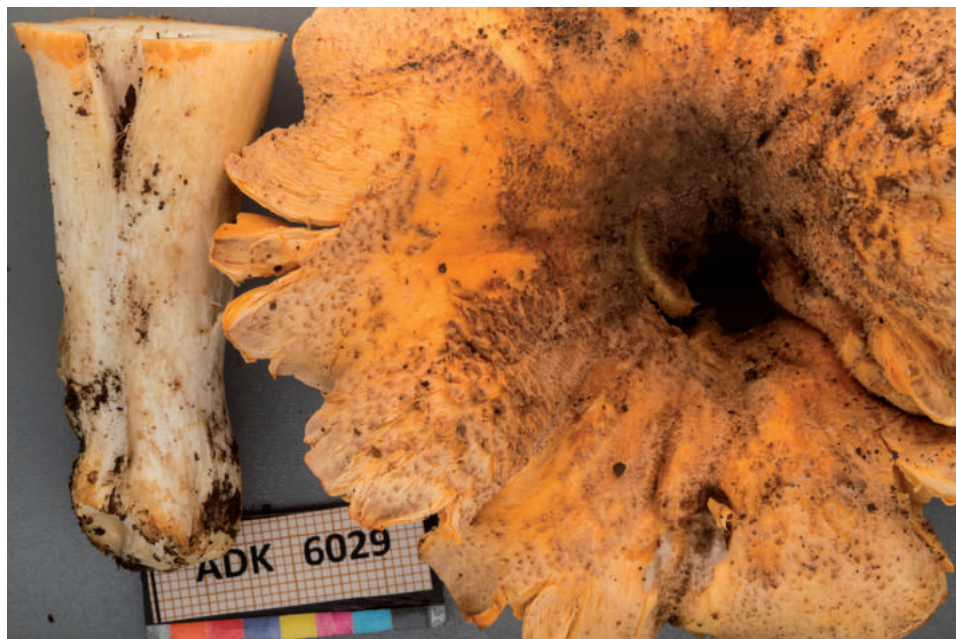


Fig. 29. *Cantharellus pseudomiomboensis*. Upper surface of a mature fruit body showing semi-erect squamulae (De Kesel 6029, photograph A. De Kesel).



Fig. 30. *Cantharellus rufopunctatus*. Fruitbodies at different stages of development (De Kesel 5949, photograph A. De Kesel, EPITYPE).



Fig. 31. *Cantharellus stramineus*. Fruitbodies at different stages of development (De Kesel 6051, photograph A. De Kesel, HOLOTYPE).



Fig. 32. *Cantharellus sublaevis* (ADK6057, photograph A. De Kesel).

***Cantharellus* sect. *Stramineus* De Kesel, sect. nov.**

*Mycobank*: MB 818091.

*Diagnosis*: Differs from subg. *Rubrinus* sect. *Isabellinus* by the presence of clamp connections, although these are in some taxa of variable frequency and therefore not always easy to observe.

*Type species*: *Cantharellus stramineus* De Kesel, in De Kesel *et al.* *Cryptogamie, Mycologie* 37(3), this issue, 2016, **sp. nov.**

*Etymology*: The name refers to the straw-colour of the type species.

*Comments*: The four newly described taxa (*C. guineensis*, *C. mikemboensis*, *C. pseudomiomboensis*, *C. stramineus*) form a significantly supported ML BS 88%, BPP 1 fig. 1b) and so far unknown monophyletic clade within subg. *Rubrinus*. Our phylogeny places this new clade as sister with very high support (95% ML BS, fig. 1) to a still highly supported (ML BS 98%, BPP 1) sect. *Isabellinus*, and both these sections compose the sister clade to sect. *Heinemannianus* with significant support (ML BS 75%, BPP 1). Our new section is very similar to sect. *Isabellinus* in being composed of medium-sized to rather large, yellowish-brown species possessing a squamulose cap (and stipe) surface, in contrast to species composing sect. *Heinemannianus*, which have a smooth cap surface and are mostly much smaller and also more frequently orange-red.

In contrast to both other sections of this subgenus, our new clade is composed of species that always possess clamp connections, although of variable frequency and therefore not always easy to observe, e.g. in *C. pseudomiomboensis*. The position of this clade within subgenus *Rubrinus* challenges the definition of being a subgenus entirely composed of species lacking clamp connections (Buyck *et al.* 2014). As a result, the definition of the subgenus is amended below:

***Cantharellus* subg. *Rubrinus* Eyssart. & Buyck, *emend.* De Kesel & Buyck**

Fruit bodies variably fleshy, large to very small; hymenophore very variable, from nearly smooth to producing well-developed gill-folds, forking – anastomosing or not; cap and stipe smooth to strongly squamulose; hyphal endings thick- to thin-walled; clamp connections absent or present. Type: *C. floridulus* Heinem.

### IDENTIFICATION KEY FOR *CANTHARELLUS* FROM MAINLAND TROPICAL AFRICA

Buyck *et al.* (2013) proposed an identification key for all tropical African *Cantharellus*. Due to the addition of 4 new taxa with clamps, clearer boundaries around *C. rufopunctatus* and an increasing separation between rainforest and woodland species, we here propose an updated/adjusted identification key for tropical African *Cantharellus*.

Taxa are first keyed out based on their occurrence in either woodland or rainforest. Species reported from both vegetation types have multiple entries and are followed by an asterisk (\*) when the habitat is not the original one and their presence therefore still needs molecular confirmation. Endemic Malagasy species are not included in the key.

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|---|----|
| 1a. Species growing in the rainforest.....      | 30 |
| 1b. Species growing in woodland vegetation..... | 2  |

- 2a. Hymenophore mouse gray and densely veined, becoming black with ageing or when handled or injured. Common.....*C. congolensis* (\*)
- 2b. Hymenophore neither gray nor black and fruit body not blackening with age or when bruised .....3
- 3a. Fruit bodies medium-sized to large, with very well developed unequal gills that hardly fork but may have a much lower anastomosing network in between, the whole mushroom reminding strongly of the genus *Cuphophyllus* (Hygrophoraceae). Clamp connections entirely absent .....4
- 3b. Fruit bodies not reminiscent of Hygrophoraceae, medium-sized to (very) small; hymenophore reticulately veined or forming well-developed, unequal, rarely forking gill-folds .....6
- 4a. Fruit bodies large (up to 18 cm diam.) with cap and stipe thick, firm and fleshy, of an intense, bright orange to reddish orange or blood red that sticks to the fingers upon handling; gills yellowish orange. Rare .....  
.....*C. splendens*
- 4b. Fruit bodies usually distinctly smaller and with different colors. Very common and widespread.....5
- 5a. Spores ellipsoid,  $Q_{\text{mean}} = 1.6-2.0$ . Cap distinctly smaller and less fleshy than in *C. splendens*, typically blood red and contrasting with the much more intense yellowish gills and stipe .....*C. symoensii*
- 5b. Spores shortly ellipsoid to nearly subglobose,  $Q_{\text{mean}} = 1.2-1.4$ . Cap versicolorous, usually a mixture of gray, vinaceous, grayish red or even yellow or greenish, sometimes with clear bluish tints in the context. Gills cream-colored to pale yellow..... *C. platyphyllus*
- 6a. Cap and sometimes also stipe surface exhibiting, at least partly, distinct lilac-bluish-violaceous tints; fruitbodies generally distinctly yellowing with age .....7
- 6b. Cap and stipe without such distinct lilac-bluish-violaceous tints.....8
- 7a. Fruit body reminiscent of *Craterellus*, very thin-fleshed and fragile; cap strongly squamulose; hymenophore densely veined and anastomosing, whitish. Growing in gallery forest. Rare.....*C. conspicuus*
- 7b. Fruit body firm and fleshy, at least in the cap center and stipe; cap often with some appressed squamulae; hymenophore usually not strongly anastomosing and with well-developed, unequal gill-folds, young very pale with yellowish or pinkish tints, then gradually yellowing. Rare .....*C. cf. subcyanoxanthus*
- 8a. Fruit bodies pink to red.....9
- 8b. Fruit bodies without pink or red.....11
- 9a. Clamp connections present; spores ellipsoid ( $Q_{\text{mean}} = 1.2-1.4$ ).....*C. ruber*
- 9b. Clamp connections absent; spores more variable in form, ranging from subglobose to elongate.....10
- 10a. Cap up to 6 cm diam.; spores elongate,  $Q > 2$ . Rare.. *C. heinemannianus*
- 10b. Cap < 3 cm diam.; spores broadly ellipsoid,  $Q < 1.6$ . Very common and widespread .....*C. addaiensis*
- 11a. Hymenophore smooth or nearly so .....12
- 11b. Hymenophore with well-developed anastomosing veins or gill-folds.....13
- 12a. Clamp connections present. Basidia two-spored producing very large, ellipsoid to subglobose spores ( $Q = 1.1-1.4$ ). Only known from forest galleries in Guineo-Sudanian woodland. Rare ..... *C. solidus*

- 12b. Clamp connections absent. Basidia (2), 3-5 spored, spores not remarkably voluminous, ellipsoid ( $Q = 1.5-2.5$ ). Rather uncommon ..... *C. sublaevis*
- 13a. Cap smooth or matted, usually not disrupted, never squamose nor areolate .14
- 13b. Cap disrupted, with cracks, scales, squamules or areolate.....22
- 14a. Spores distinctly elongate,  $Q_{\text{mean}} = 2.3$ , fresh fruitbodies entirely bright mandarin orange, cap 30-65 mm ..... *C. humidicolus*
- 14b. Spores ellipsoid,  $Q_{\text{mean}} < 1.8$ , not with this color .....15
- 15a. Small species, with fine stipe ( $< 4$  mm) and cap less than 40 mm diameter ....17
- 15b. Large species with fleshy fruitbodies, context compact and firm, with massive stipe ( $> 10$  mm diam), cap diameter 40-100 mm or more, usually forming caespitose clusters .....16
- 16a. Cap yellow with paler, off-white areas, up to 18 cm diam. Gills whitish near the stipe, yellow-orange near the margin. With abundant clamps .....  
..... *C. afrociarius*
- 16b. Cap bright yellow orange, sometimes with off-white areas. Gills uniformly colored, never whitish near the stipe. Without clamps ..... *C. defibulatus*
- 17a. Clamps present.....18
- 17b. No clamps .....20
- 18a. Stipe hollow, cap 15-25 mm, yellow with brown matted centre; hymenophore with pinkish hue, terminal elements of pileipellis 3-5  $\mu\text{m}$  diameter, spore  $Q = 1.7$ . Rare..... *C. fistulosus*
- 18b. Stipe full, cap less than 20 mm, hymenophore without pinkish hue, terminal elements of pileipellis  $> 6$   $\mu\text{m}$  diameter, spore  $Q = 1.2-1.5$ .....19
- 19a. Cap brown, 10-20 mm, gills yellow orange, terminal elements of pileipellis (8) 10-15 (20)  $\mu\text{m}$  diam, spore  $Q = 1.3-1.5$ . Rare..... *C. schmitzii*
- 19b. Cap yellow-orange, 8-15 mm; gills yellowish; terminal elements of pileipellis 6-12  $\mu\text{m}$  diameter, spore  $Q = 1.26$ . Rare..... *C. microciarius*
- 20a. Cap vivid yellow, strongly infundibuliform, gills pale cream to vivid yellow,  $Q = 1.4$ . Rare..... *C. gracilis*
- 20b. Cap and gills not (vivid) yellow, brownish, olive brown to greyish yellow, pileipellis tomentose;  $Q > 1.5$ .....21
- 21a. Gill folds dense,  $> 20/\text{cm}$  near cap margin, flesh greyish turning orange yellow when bruised, pileipellis sometimes fibrillose-squamose; spores: 6-6.98-8  $\times$  3.5-3.92-4.5  $\mu\text{m}$ ,  $Q = 1.5-1.79-2.1$  ..... *C. tomentosus*
- 21b. Gill folds not so dense,  $< 10/\text{cm}$  at cap margin, flesh whitish, pileipellis regularly tomentose; spores larger: (7)7.5-8.1-8.5(9)  $\times$  (4)4.4-4.75-5  $\mu\text{m}$ ,  $Q = (1.5)1.6-1.7-1.8(1.9)$ . Rare ..... *C. isabellinus* var. *parvisporus*
- 22a. Hymenophore composed of densely crowded gill folds ( $> 20/\text{cm}$  near cap margin).....23
- 22b. Hymenophore with more spaced gill folds ( $< 10/\text{cm}$  near cap margin) .24
- 23a. Cap brown tomentose, sometimes fibrillose-squamose; gill folds beige brown to olive brown at maturity; spores narrowly ellipsoid to elongate,  $Q = 1.5-1.79-2.1$ . Rare ..... *C. tomentosus*
- 23b. Cap distinctly squamulose-scaly, pale lemon yellow, cream to grayish or brown. Gill folds very pale, brownish to yellowish gray, remaining so at maturity, staining yellow when bruised; spores broadly ellipsoid,  $Q = (1.17-1.2-1.37-1.54(-1.63))$ . Common..... *C. densifolius* (\*)



- 24a. Clamps absent; spores elongate,  $Q_{\text{mean}} = 1.6-2.0$  .....25
- 24b. Clamps present; spores broadly ellipsoid,  $Q_{\text{mean}} = 1.4-1.6$  .....  
 ..... (section *Stramineus*) 27
- 25a. Fruit bodies smaller, 27-40 mm diam., thin-fleshed, fragile context; terminal elements of pileipellis thick-walled, 5-8(10)  $\mu\text{m}$  diam. Possibly also associated with introduced eucalypts. Rare ..... *C. tanzanicus*
- 25b. Fruit bodies firm and fleshy, up to 12 cm diam or more .....26
- 26a. Stipe orange yellow and squamulose; spores elongate  $Q = 1.7-2.1$ , terminal elements of pileipellis thin-walled and 4-7  $\mu\text{m}$  diam. Very common and widespread ..... *C. miomboensis*
- 26b. Stipe almost white or with a faint hue of yellow, entirely beset with fine pale brown, pale orange or whitish squamules; less elongate spores  $Q = 1.46-1.55$  and wider (8-12  $\mu\text{m}$ ) terminal cells in the pileipellis .....  
 ..... *C. pseudomiomboensis*
- 27a. Fruitbodies straw yellowish, hymenophore pale whitish yellow. Rare .....  
 ..... *C. stramineus*
- 27b. Fruitbodies more vivid orange, hymenophore intense yellow-orange (egg yolk color) .....28
- 28a. Context in cap and stipe entirely yellowish orange; cap and stipe surface deep orange, densely beset with darker orange punctiform squamules; terminal elements of pileipellis (8.8-)-6.1-11.6-17.2(-20.1)  $\mu\text{m}$  diam. Rare, under *Berlinia grandiflora* ..... *C. guineensis*
- 28b. Context white, except for a narrow yellowish orange zone beneath the pileipellis; stipe generally whitish or pale yellow, with or without squamules; terminal elements of pileipellis slightly narrower: (5.1)5.6-8.3-11.2(11.3)  $\mu\text{m}$  diam. A complex of two morphologically similar species...29
- 29a. Young cap yellow, never reddish brown. Stipe whitish or very pale yellow (3a2), almost entirely smooth, sometimes with few squamules in the upper third ..... *C. mikemboensis*
- 29b. Young cap reddish brown, later showing yellow context between brownish squamules. Stipe almost white or with a faint hue of yellow, entirely beset with fine pale brown, pale orange or whitish squamules ..... *C. pseudomiomboensis*
- 30a. Hymenophore mouse gray and densely veined, becoming instantly black when handled/injured or with ageing ..... *C. congolensis*
- 30b. Hymenophore neither gray nor black and fruit body not blackening with age or when handled .....31
- 31a. Cap and sometimes also stipe surface exhibiting, at least partly, distinct lilac-bluish-violaceous tints; fruitbodies generally distinctly yellowing with age..32
- 31b. Cap and stipe without such distinct lilac-bluish-violaceous tints .....34
- 32a. Spores narrowly ellipsoid, 5.5-6.72-8  $\times$  3-3.97-5  $\mu\text{m}$ ,  $Q = 1.37-1.71-2.0$ . Cap very dark violaceous when young; context with faint pinkish hue ....  
 ..... *C. goossensiae*
- 32b. Spores distinctly elongate,  $Q_{\text{mean}} > 2$  .....33
- 33a. Cap completely smooth or only wrinkled-striate or crenulate near the extreme margin, lacking vividly yellow colors and more pinkish, lilac to cream. Spores narrow (ca 4  $\mu\text{m}$  wide) ..... *C. longisporus*
- 33b. Cap radially wrinkled or striate outside the center, partly with vividly yellow colors; spores larger ca 5  $\mu\text{m}$  wide ..... *C. cyanoxanthus*

- 34a. Cap and/or stipe at least partly with distinct red or pink colors .....35
- 34b. Cap and stipe lacking such colors entirely, either yellow, bright orange, brown or gray or a mixture of these colors .....40
- 35a. Clamp connections present, medium-sized species .....36
- 35b. Clamp connections absent, small to very small species.....38
- 36a. Fruit bodies fleshy and firm. Cap and stipe squamulose – hirsute.....  
.....*C. rhodophyllus*
- 36b. Cap and stipe smooth, tomentose, or minutely squamulose.....37
- 37a. Fruit bodies fleshy and firm; gill folds pink, becoming orange, not anastomosing, and sometimes forked, not intervenose. Possibly conspecific with *C. rhodophyllus*.....*C. subincarnatus*
- 37b. Fruit bodies thin-fleshed; gill folds whitish, with yellow or pinkish hues, strongly veined-anastomosing in between .....*C. miniatescens*
- 38a. Cap not exceeding 10 mm in diameter; stipe proportionally long, at least twice as long as cap diameter at maturity.....*C. minutissimus*
- 38b. Cap wider, 10-30(40) mm diameter; stipe proportionally shorter than cap diameter at maturity .....39
- 39a. Basidia shorter than 40  $\mu\text{m}$ ; cap up to 40 mm diam.; spores (5.7)5.6-6.5-7.3(8.1)  $\times$  (3.4)3.5-4.0-4.5(4.7)  $\mu\text{m}$ ..... *C. floridulus*
- 39b. Basidia longer than 40  $\mu\text{m}$ ; cap up to 10 mm diam.; context reddening; spores (6.9)7.1-7.39-7.7(7.9)  $\times$  (4.0)-4.1-4.42-4.7(5.0)  $\mu\text{m}$ , Q = (1.4)1.5-1.68-1.8(1.9)..  
..... *C. alboroseus*
- 40a. Hymenophore smooth or nearly so.....*C. cibarioides*
- 40b. Hymenophore with well-developed gill-folds or anastomosing veins ....41
- 41a. Fruit bodies pale yellowish ochre, ochraceous or greyish brown, ochraceous orange, never vivid yellow, orange or vivid orange.....42
- 41b. Fruit bodies orange, vivid orange or vivid yellow .....44
- 42a. Hymenophore composed of crowded gill folds (L+1 = 20-40/cm), originally described from the equatorial rain forest area, often reported from woodlands..... *C. densifolius*
- 42b. Hymenophore composed of distinctly more spaced gill folds. Cap and stipe with grayish yellow to brownish tones.....43
- 43a. Hymenophore pale brownish with pink hue. Basidia four-spored. Spores 8-8.78-10  $\times$  5-5.82-6.5  $\mu\text{m}$ . Q = 1.42-1.51-1.67..... *C. isabellinus*
- 43b. Hymenophore safran colored. Basidia two-spored. Spores 7-8.36-10  $\times$  5.5-6.10-7  $\mu\text{m}$ , Q = 1.14-1.32-1.54 .....*C. croceifolius*
- 44a. Hymenophore composed of crowded gill folds (L+1 = 20-40/cm) .....45
- 44b. Hymenophore composed of distinctly more spaced gill folds .....48
- 45a. Clamps absent (or doubtful, see Heinemann 1958).....46
- 45b. Clamps present.....47
- 46a. Cap smooth, vivid orange, up to 3.5 cm diameter; gill folds 25/cm .....  
..... *C. pseudofriesii*
- 46b. Cap centre with punctate squamules, lemon yellow, 3-8cm diameter; gill folds much denser (35-40/cm)..... *C. luteopunctatus*
- 47a. Cap up to 10 cm diam. Cap finely tomentose-squamose, margin lobate – crenulate ..... *C. miniatescens*
- 47b. Cap at most 1.5cm diam. Cap smooth, margin smooth ..... *C. tenuis*

- 48a. Fruit bodies firm and fleshy, up to 15 cm diam or more, vivid orange, with punctate squamules all over cap and stipe surface ..... *C. rufopunctatus*  
 48b. Fruit bodies either much smaller or not fleshy and more fragile, lacking punctate squamules all over cap and stipe surface .....49
- 49a. Spores ellipsoid to narrowly ellipsoid,  $Q = (1.5)1.6-1.79-1.9(2.1)$ ; clamps present; cap orange-yellow, often with red fibrils in cap center and extreme margin; gill folds much paler..... *C. miniatescens*  
 49b. Spores subglobose,  $Q < 1.2$ ; clamps absent; cap orange; gill folds concolorous..  
 ..... *C. pseudocibarius*

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