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Polyphasic taxonomy of *Aspergillus* section *Fumigati* and its teleomorph *Neosartorya*

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Abstract: The taxonomy of *Aspergillus* section *Fumigati* with its teleomorph genus *Neosartorya* is revised. The species concept is based on phenotypic (morphology and extrolite profiles) and molecular (β-tubulin and calmodulin gene sequences) characters in a polyphasic approach. Four new taxa are proposed: *N. australensis N. ferenczii, N. papuaensis* and *N. warcupii*. All newly described and accepted species are illustrated. The section consists of 33 taxa: 10 strictly anamorphic *Aspergillus* species and 23 *Neosartorya* species. Four other *Neosartorya* species described previously were not available for this monograph, and consequently are relegated to the category of doubtful species.

Taxonomic novelties: *Neosartorya australensis*, *N. ferenczii*, *N. papuaensis*, *N. warcupii*.
Key words: *Aspergillus* section *Fumigati*, extrolite profiles, *Neosartorya*, phylogenetics, polyphasic taxonomy.

INTRODUCTION

Aspergillus section *Fumigati* includes species characterised by uniseriate aspergilli, columnar conidial heads in shades of green and flask shaped vesicles (Raper & Fennell 1965). Teleomorphic species belonging to the "*Aspergillus fischeri* series" of the *A. fumigatus* group (Raper & Fennell 1965) were placed in the genus *Neosartorya* (family Trichocomaceae) by Malloch & Cain (1972). Section *Fumigati* includes more than 20 *Neosartorya* species and 10 anamorphic species (Pitt *et al.* 2000; Samson 2000; Horie *et al.* 2003; Hong *et al.* 2005, 2006, 2007).

Aspergillus fumigatus Fresenius is an ubiquitous filamentous fungus in the environment, and also an important human pathogen (Raper & Fennell 1965). Several *Neosartorya* species have been described as causal agents of human diseases including invasive aspergillosis, osteomyelitis, endocarditis and mycotic keratitis (Coriglione *et al.* 1990; Summerbell *et al.* 1992; Padhye *et al.* 1994; Lonial *et al.* 1997; Jarv *et al.* 2004; Balajee *et al.* 2005, 2006). All of the *Neosartorya* species produce heat-resistant ascospores that are frequently encountered in different food products (Gomez *et al.* 1994; Samson 1989; Tournas 1994). The several mycotoxins produced by these species may cause serious health hazard (Fujimoto *et al.* 1993; Frisvad & Samson 1990; Larsen *et al.* 2007). Some species also have valuable properties for mankind; e.g. *N. fischeri* strains produce fiscalins which effectively inhibit the binding of substance P to the human neurokinin receptor (Wong *et al.* 1993), while *A. fumigatus* strains produce pyripyropenes, potent inhibitors of acyl-CoA:cholesterol acyltransferase (Tomoda *et al.* 1994), the immunosuppressant restrictocins (Müllbacher & Eichner 1984), ribotoxins (Lin *et al.* 1995) and fumagillin that has amebicidal activity (McCowen *et al.* 1951). *Neosartorya spinosa* can be used for the complete enzymatic recovery of ferulic acid from corn residues (Shin *et al.* 2006).

Here we present an overview of the species belonging to *Aspergillus* section *Fumigati* based on analysis of macro- and micromorphology, extrolite profiles and β-tubulin, calmodulin, ITS and actin gene sequences of the isolates. We also describe four new homothallic *Neosartorya* species found in soil samples in Australia and Papua New Guinea using this polyphasic approach and list synonymies.

MATERIALS AND METHODS

Source of microorganisms

The fungi examined included type strains or representatives of all species available for examination in *Aspergillus* section *Fumigati*. Some atypical isolates collected in Australia and Papua New-Guinea were also examined to clarify their taxonomic status (Table 1).

Morphology and physiology

The strains (Table 1) were grown for 7 d as 3-point inoculations on Czapek agar, Czapek yeast autolysate agar (CYA), oat meal agar (OA) and malt extract agar (MEA) plates at 25 °C, and on CYA at 37 °C. For *Neosartorya* species Hay infusion agar and SNA agar have also been used for inducing the anamorphs (medium compositions in Samson *et al*. 2004). In some species e.g. *N. tatenoi* the anamorph could only be produced when growing the cultures at 30 or 37 °C on MEA + 40 % sucrose.

Table 1. *Aspergillus* section *Fumigati* isolates used in this study.

Species	Isolate No.*	Source
A. brevipes	CBS 118.53^T	Soil, Australia
A. duricaulis	CBS 481.65^T	Soil, Buenos Aires, Argentina
A. fumigatiaffinis	IBT12703^T	Soil, U.S.A.
A. fumigatus	CBS 133.61^T = NRRL 163	Chicken lung, U.S.A.
A. fumisynnematus	IFM 42277^T	Soil, Venezuela
A. lentulus	CBS 117887^T = NRRL 35552 = KACC 41940	Man, U.S.A.
A. novofumigatus	IBT 16806^T	Soil, Ecuador
A. unilateralis	CBS 126.56^T	Rhizosphere, Australia
A. viridinutans	CBS 127.56^T	Rabbit dung, Australia
A. turcosus	KACC 42090 = IBT 27920	Air conditioner, Inchen,Korea
	KACC 42091^T = IBT 27921	Air conditioner, Seoul, Korea
	KACC 41955 = CBS 117265= IBT 3016	Car air conditioner, Seoul, Korea
N. assulata	KACC 41691^T	Tomato soil, Buyeo, Korea
N. aurata	CBS 466.65^T	Jungle soil, Brunei
N. aureola	CBS 105.55^T	Soil, Tafo, Ghana
N. australensis sp. nov	CBS 112.55^T = NRRL 2392 = IBT 3021	Garden soil, Adelaide, Australia
N. coreana	KACC 41659^T = NRRL 35590 = CBS 121594	Tomato soil, Buyeo, Korea
N. denticulata	CBS 652.73^T = KACC 41183	Soil under *Elaeis guineensis*, Suriname
	CBS 290.74 = KACC 41175	*Acer pseudoplatanus*, Netherlands
N. fennelliae	CBS 598.74^T	Eye ball of *Oryctolagus cuniculus*, U.S.A.
	CBS 599.74	Eye ball of *Oryctolagus cuniculus*, U.S.A.
N. ferenczii **sp. nov.**	CBS 121594^T = IBT 27813 = NRRL 4179	Soil, Australia
N. fischeri	CBS 544.65^T = NRRL 181	Canned apples
N. galapagensis	CBS 117522^T = IBT 16756 = KACC 41935	Soil, Ecuador
	CBS 117521 = IBT 16763 = KACC 41936	Soil, Ecuador
N. glabra	CBS 111.55^T	Rubber scrab from old tire, Iowa, U.S.A.
N. hiratsukae	CBS 294.93^T	Aloe juice, Tokyo, Japan
N. laciniosa	KACC 41657^T = NRRL 35589 = CBS 117721	Tomato soil, Buyeo, Korea
N. multiplicata	CBS 646.95^T = IBT 17517	Soil, Mouli, Taiwan
N. nishimurae	IFM 54133 = IBT 29024	Forest soil, Kenya
N. nishimurae	CBS 116047	Cardboard, Netherlands
N. papuensis **sp. nov.**	CBS 841.96^T = IBT 27801	Bark of *Podocarpus* sp. (Podocarpaceae), bark, Myola, Owen Stanley Range, Northern Province, Papua New Guinea
N. pseudofischeri	NRRL 20748^T = CBS 208.92	Human vertebrate, U.S.A.
N. quadricincta	CBS 135.52^T = NRRL 2154	Cardboard, York, U.K.
	CBS 107078	Soil, Korea
	CBS 100942	Fruit juice, Netherlands
	CBS 253.94	Canned oolong tea beverage, Japan (type strain of *N. primulina*)
N. spathulata	CBS 408.89^T	Soil under *Alocasia macrorrhiza*, Taiwan
N. spinosa	CBS 483.65^T	Soil, Nicaragua
N. stramenia	CBS 498.65^T	Soil from maple-ash-elm forest, Wisconsin, U.S.A.
N. tatenoi	CBS 407.93^T	Soil of sugarcane, Timbauba, Brazil
	CBS 101754	Fruit, Yunnan, China (type strain of *N. delicata*)
N. udagawae	CBS 114217^T	Soil, Brazil
	CBS 114218	Soil, Brazil
N. warcupii **sp. nov.**	NRRL 35723^T	Arid soil, Finder"s Range, Australia

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