

Title

New secondary 8-hydroxyquinoline-7-carboxamide derivatives.

The present invention provides new secondary 8-hydroxyquinoline-7-carboxamide derivatives and pharmaceutically acceptable salts thereof, which are useful as antifungal agents, and a process for their preparation. Specifically, these compounds were tested against *Tricophyton Rubrum*, *Tricophyton Mentagrophytes*, *Aspergillus Niger* and *Scopulariopsis Brevicaulis*. Many of these compounds are active against *Candida* species such as *Candida Albicans* and *Candida Glabrata*.

Background of the invention

Pathogenic fungi can be divided in two categories: fungi that are able to induce diseases in normal subjects and less invasive fungi that are able to produce diseases only in critically ill hosts. In the past two decades there was a significant increase in the incidence of invasive opportunistic fungal infections and associated morbidity and mortality. This is mainly due to the major advances in modern medicine that have increased the survival of critical patients such as those in intensive care units (ICU) with intravascular and urinary catheters, total parenteral nutrition and hemodialysis or connected to ventilatory systems.

Candida species commonly cause nosocomial blood stream infections among patients in the ICU. The UK hospitalized incidence of candidemia is about 3 per 100,000 bed days, and 40% to 52% of all cases occur in ICU (Schelenz S., *J. Antimicrob. Chemother.* **2008**; 61, Suppl 1, 31-34). This kind of mycoses is frequently associated with considerable morbidity and mortality. The attributable mortality rate is about 38%, although it can vary between 5% and 71%. During recent years there was a rising incidence of invasive

pulmonary aspergillosis in patients admitted to ICU. The disease incidence ranges from 0.3% to 5.8% with an overall mortality rate exceeding 80% (Trof R. J. et al, *Intensive Care Med.*, **2007**; 33, 1694-1703). Critically ill patients are at risk to develop disturbances in immunoregulation during their stay in the ICU, which render them more vulnerable to fungal infections. Risk factors such as chronic obstructive pulmonary disease, prolonged use of steroids, advanced liver disease, chronic renal replacement therapy, near-drowning and diabetes mellitus have been described.

There was a dramatic increase also in the number of immunocompromised patients especially in the fields of solid organ and bone marrow transplantation, autoimmune syndromes, acquired immune deficiency syndrome (AIDS) and oncology.

About 40% of bone marrow transplant population develops invasive fungal infection (Khan S. A., Wingard J. R., *Natl. Cancer Inst. Monogr.* **2001**; 29, 31-36). *Candida* and *Aspergillus* species are the most common pathogens responsible for nosocomial superficial and invasive mycoses in hematologic malignancies and bone marrow transplanted patients. In these patients the mortality associated with the systemic candidosis is very high (50-90%).

Regarding solid organs transplantation, infective complications are more frequent in lung-transplanted patients. In addition to the immunosuppressive regimen, the increased susceptibility is mainly due to the constant exposure to the external environment. Parallel to immunosuppressive treatment intensity, invasive fungal infection may occur during the first days after surgical operation, its frequency is highest in the first two months and decreases after 6 months but it can occur also years after transplantation (Hamacher J. et al, *Eur. Respir. J.*, **1999**; 13, 180-186).

Invasive fungal infections are also frequent in other kind of solid organ transplantation such as kidney and liver transplants for which incidence of 5

to 50% are reported (Dictar M. O. et al, *Med Mycol.*, **2000**; 38 Suppl. 1, 251-258).

Mycoses are one of the major causes of morbidity in patients with AIDS and the incidence and severity of these infections increase with disease progression and the consequent impairment of T-cell-mediated immunity. The incidence of the different mycoses is closely related to the endemic opportunistic fungi present in the area of residence. Generally speaking the most frequent mycoses that affect AIDS patients are histoplasmosis, blastomycosis, coccidioidomycosis and paracoccidiomycosis (Sarosi G. A., Davies S. F., *West J. Med.*, **1996**; 164, 335-340).

Mucosal *Candida* infections are also extremely common. In normal patients all these mycosis are usually self-limited but in immunodepressed patients become highly invasive resulting in progressive and widespread dissemination.

Moreover, the increase of mycosis caused by organism resistant to current therapies became evident over recent years. This phenomenon is particularly evident for fungal infections caused by *Candida albicans* and fluconazole and other azoles (Bastert J. et al, *Int. J. Antimicrob. Agents*, **2001**; 17, 81-91).

The antimycotic drugs currently available are not fully satisfactory due to their limited activity spectrum and to the heavy side effects associated to their use.

The polyene drug Amphotericin B, for example, is active against *Aspergillus*, *Zygomycete* and other molds anyway, and due to its toxicity the licensed dosage for treatment of invasive mycosis is 3-5 mg/kg per day. In highly immunocompromised patients with invasive aspergillosis, liposomal encapsulated Amphotericin B, daily administered at 3 mg/kg, gave a favorable response in 50% of patients and 12-week survival rate of 72% (Cornely O. A. et al, *Clin. Infect. Dis.*, **2007**; 44, 1289-1297). The drug induced nephrotoxicity and hypokalemia in 14-16% of the patients.

When daily administered at 10 mg/kg, Amphotericin B did not give any additional benefit and caused higher rates of nephrotoxicity (31%).

Azoles, introduced in the second half of the 1970s, are blockers of ergosterol synthesis. The use of the drugs belonging to this family is limited by their narrow spectrum of activity. Voriconazole, for example, is more active than Amphotericin B for the treatment of invasive aspergillosis but has no activity against zygomycetes (Johnson L. B., Kauffman C. A., *Clin. Infect. Dis.*, **2003**, 36, 630-637). The azoles employment is also limited by the induction of several side effects. Azoles interact with mammalian p450 enzymes resulting in interference with the metabolism of other drugs and, in addition, some azoles such as ketoconazole are able to block the cardiac potassium channel Kv1.5 causing Q-T prolongation and 'torsade de pointes' (Dumaine R., Roy M. L., Brown A. M., *J. Pharmacol. Exp. Ther.*, **1998**; 286, 727-735).

Allylamines such as Terbinafine bind to and inhibit squalene epoxidase resulting in a block of ergosterol synthesis. These drugs are very potent against *Dermatophytes* while their activity against *Candida* species is very poor. In some cases treatment with allylamines is followed by severe cutaneous adverse reactions. A recent multinational case-control study (euroSCAR) (Sidoroff A. et al, *Br. J. Dermatol.*, **2007**; 15, 989-996) revealed that Terbinafine systemic treatment is strongly associated with the development of an acute generalized exanthematous pustolosis (AGEP). This disease is characterized by the rapid occurrence of many sterile, nonfollicular pustules, usually accompanied by leucocytosis and fever. AGEP is generally attributed to the patient treatment with particular drugs and seems to be related to an altered T cells activity. Terbinafine treatment might also induce dermatomyositis, a severe autoimmune connective tissue disease characterized by erythema, muscle weakness and interstitial pulmonary fibrosis (Magro C. M. et al, *J. Cutan. Pathol.*, **2008**; 35, 74-81). In addition, as

a variety of antifungal medications, Terbinafine might cause severe liver injuries (Perveze Z. et al, *Liver Transpl.*, **2007**; 13, 162-164).

Griseofulvin is a benzofurane introduced in 1960 for the treatment of dermatophyte infections. The compound induces its fungistatic activity by interfering with microtubule production. Griseofulvin displays limited activity in the treatment of onychomycoses and frequently causes severe side effects such as nausea, diarrhea, headache, confusion and fatigue (Korting H. C. et al, *Antimicrob. Agents Chemother.*, **1993**; 37, 2064-2068) that can cause the treatment discontinuation.

The two *N*-Hydroxy pyridones, Ciclopirox olamine and Octopirox, seem to mainly act by chelating polyvalent cations, resulting in the inhibition of the metal-dependent enzymes. They are employed against different fungal infections but their use is limited to topical treatment.

The echinocandins (Caspofungin, Micafungin, Anidulafungin) are semi-synthetic lipo-peptides and are the most recently introduced antimycotic drugs. They act by non-competitively inhibiting β -(1-3)-Dglucan synthase, an enzyme essential for the maintenance of the cell wall and are mainly used for intravenous treatment of invasive candidiasis and aspergillosis. They are fungicidal against yeast but only fungistatic against filamentous fungi; in addition, they are quite inactive against dimorphic fungi such as *Blastomyces* and *Histoplasma*. Echinocandins are generally well tolerated but animal reproduction studies showed adverse effects on fetus. For this reason FDA lists echinocandins as a pregnancy-risk category C (http://www.fda.gov/medwatch/SAFETY/2004/mar_PI/Candidas_PI.pdf; http://www.fda.gov/medwatch/safety/2007/Aug_PI/Mycamine_PI.pdf).

EP1375486 discloses a generic and very broad class of compounds having HIV integrase inhibitory activity. This broad generic class includes 8-hydroxy-quinoline derivatives substituted by a wide variety of substituents, e.g., substituted carboxamide groups at the 7-position. None of the specific

compounds disclosed in this reference are structurally similar to the compounds of the present invention.

EP1541558 discloses a generic and very broad class of compounds having HIV integrase inhibitory activity. As a matter of fact, the specific compounds disclosed in this reference always bear a substituent on the pyridyl ring and preferably are 3-(4-fluorobenzyl)-8-hydroxyquinolines. None of the specific compounds disclosed in this reference are structurally similar to the compounds of the present invention.

WO98/11073 (US6310211) discloses a generic class of anti-viral compounds having HIV integrase inhibitory activity. None of the specific compounds disclosed in this reference are structurally similar to the compounds of the present invention.

WO02/30426 discloses a generic class of compounds having HIV integrase inhibitory activity. As a matter of fact, most of the specific compounds disclosed in this reference bear a naphthydrinyl residue. None of the specific compounds disclosed in this reference are structurally similar to the compounds of the present invention.

WO02/30930 discloses a generic and very broad class of compounds having HIV integrase inhibitory activity. None of the specific compounds disclosed in this reference are structurally similar to the compounds of the present invention.

US0326330 and US0326328 disclose fungicidal compositions comprising a combination of two fungicides, one of which is a quinoline or cinnoline compound. None of the specific compounds disclosed in this reference are structurally similar to the compounds of the present invention.

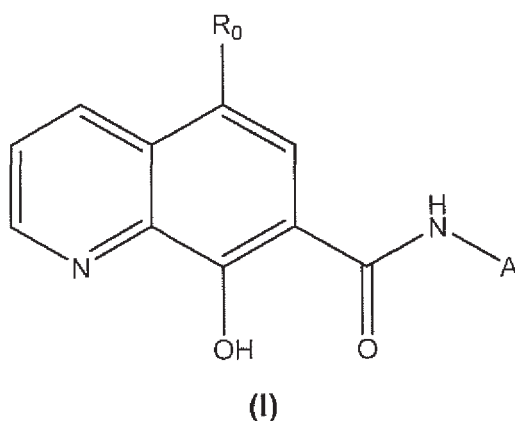
WO96/32015 discloses synergistic fungicidal compositions made of quinoline derivatives and cytochrome complex III inhibitors. None of the specific compounds disclosed in this reference are structurally similar to the compounds of the present invention.

EP1669348 discloses antifungal agents defined by a very broad formula which includes certain secondary amides.

From what described above, it is evident that the clinical need for efficacious antifungal drugs has dramatically increased in the few last years. Unfortunately the drugs actually available are not satisfactory due to their narrow spectrum of action, pharmacokinetic properties and severe side effects.

Description of the invention

The present invention particularly provides compounds of general formula (I), endowed with a potent antifungal activity



wherein R_0 is:

- -H,
- -F,
- -Cl,
- -Br,
- -NO₂,
- -CF₃,
- -C₁-C₆ alkyl,
- -(CH₂)_m-NR₁R₂,
- -(SO₂)-NR₁R₂,

- $-(C=O)-NR_1R_2$,
- $-(N-C=O)-NR_1R_2$,
- $-CN$,
- $-W-R_3$,
- $-(CH_2)_m$ -aryl, optionally substituted by one or two R_4 , or
- $-(CH_2)_m$ -heterocycle, optionally substituted by one or two R_4 ;

wherein R_1 and R_2 , independently from each other, are selected from:

- $-H$,
- $-C_1-C_6$ alkyl,
- $-(CH_2)_m$ -aryl, optionally substituted by one or two R_4 ,
- $-(CH_2)_m$ -cycloalkyl, optionally substituted by one or two R_5 ,
- $-(CH_2)_m$ -heterocycle, optionally substituted by one or two R_4 ,
- $-(CH_2)_m-W-R_3$,
- $-(CH_2)_m-CN$,
- taken together with the nitrogen atom to which they are bound to form an optionally substituted 5- to 8-membered heteromonocycle containing from one to three heteroatoms selected from the group consisting of nitrogen, oxygen and sulphur, or
- taken together with the nitrogen atom to which they are bound to form an optionally substituted 5- to 8-membered heteromonocycle which is fused to one or two optionally substituted saturated or unsaturated rings or to other optionally substituted heterocycles containing from one to three heteroatoms selected from the group consisting of nitrogen, oxygen and sulphur;

wherein W is:

- -O-, or
- -S-;

wherein R_3 is:

- -H,
- -C₁-C₆ alkyl,
- -(CH₂)_m-aryl, optionally substituted by one or two R₄,
- -(CH₂)_m-cycloalkyl, optionally substituted by one or two R₅, or
- -(CH₂)_m-heterocycle, optionally substituted by one or two R₄;

wherein R_4 is:

- -F,
- -Br,
- -NO₂,
- -C₁-C₆ alkyl,
- -(CH₂)_m-NR₁R₂,
- -(SO₂)-NR₁R₂,
- -(C=O)-NR₁R₂,
- -(N-C=O)-NR₁R₂,
- -CN,
- -W-R₃, with the proviso that when W is -O-, R₃ is different from hydrogen or methyl,
- -(CH₂)_m-aryl, optionally substituted by one or two R₇, or
- -(CH₂)_m-heterocycle, optionally substituted by one or two R₇;

wherein R_5 is:

- -C₁-C₄ alkyl,
- -W-H,
- -CH₂-W-H,
- -(CH₂)_m-aryl, optionally substituted by one or two R₇, or

- $-(CH_2)_m$ -heterocycle, optionally substituted by one or two R_7 ;

wherein R_6 is:

- -H,
- -F,
- -Cl,
- -Br,
- -OH, or
- -O-C₁-C₃ alkyl;

wherein R_7 is:

- -H,
- -F,
- -Cl,
- -Br,
- -CF₃,
- -W-R₃,
- -C₁-C₆ alkyl,
- $-(CH_2)_m$ -aryl, optionally substituted by one or two R_6 ,
- $-(CH_2)_m$ -heterocycle, optionally substituted by one or two R_6 , or
- $-(CH_2)_m$ -C₃-C₈ cycloalkyl;

wherein m is an integer from 0 to 6;

wherein A is: $-(CH_2)_n$ -X;

wherein n is an integer from 0 to 1 with the proviso that:

when $n = 0$, X is:

- an optionally substituted monocyclic heterocycle or a 2,3-dihydrobenzo[b][1,4]dioxine residue, with the proviso that the heterocycle is other than optionally substituted pyridine, thiadiazole, thiophene, furane or benzo[d][1,3]dioxole, or
- an aryl group, substituted in *para* position by NR_1R_2 ;

wherein **R₁** and **R₂** are as defined above;

when **n = 1**, **X** is:

- an optionally substituted heterocycle, preferably a 2,3-dihydrobenzo[b][1,4]dioxine residue, with the proviso that the heterocycle is other than optionally substituted 3-pyridine, thiadiazole, thiophene, furane or benzothiazole, or
- an aryl group, substituted in *para* position by **R₄**, with the proviso that **R₄** is not -NO₂,

wherein **R₄** is as defined above;

or pharmaceutically acceptable salts or derivatives thereof.

As used herein, the term **C₁-C₆ alkyl** means linear or branched chain alkyl groups having from 1 to 6 carbon atoms and includes all of the hexyl and pentyl alkyl isomers as well as n-, iso-, sec- and t-butyl, n- and isopropyl, ethyl and methyl.

The term **cycloalkyl** means a cyclic ring of an alkane selected from cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl and cyclooctyl.

The term **aryl** refers to aromatic mono- and poly-carbocyclic ring systems, wherein the individual carbocyclic rings in the polyring systems may be fused or attached to each other via a single bond. Suitable aryl groups include, but are not limited to, phenyl, naphthyl and biphenyl.

The term **heterocycle** (and variations thereof such as "heterocyclic") broadly refers to a 4- to 8-membered monocyclic rings, 7- to 12-membered bicyclic ring systems or an 11- to 16-membered tricyclic ring system, any ring of which is saturated or unsaturated, and which consists of carbon atoms and one or more heteroatoms selected from N, O and S, and wherein the nitrogen and sulphur heteroatoms may optionally be oxidized and the nitrogen heteroatom may optionally be quaternized. The heterocyclic ring may be attached at any heteroatom or carbon atom, provided that attachment results in the creation of a stable structure. When the heterocyclic ring has

substituents, it is understood that the substituents may be attached to any atom in the ring, whether a heteroatom or a carbon atom, provided that a stable chemical structure results.

The term **heteromonocycle** (and variations thereof such as "heteromonocyclic") refers to a 4- to 8-membered monocyclic ring which is saturated or unsaturated, and which consists of carbon atoms and one or more heteroatoms selected from N, O and S, and wherein the nitrogen and sulphur heteroatoms may optionally be oxidized, and the nitrogen heteroatom may optionally be quaternized. The heterocycle ring may be attached at any heteroatom or carbon atom, provided that attachment results in the creation of a stable structure. When the heterocycle ring is an aromatic heterocycle ring it can be defined "heteroaromatic ring".

Unless expressly set forth to the contrary, an "unsaturated" ring is a partially or fully unsaturated ring. For example, an "unsaturated monocyclic C₆ carbocycle" refers to cyclohexene, cyclohexadiene and benzene.

The term **substituted** includes mono- and poly-substitution by a named substituent to the extent such single and multiple substitution is chemically allowed. For example, a carbocycle or heterocycle substituted with more than one substituent can have multiple substituents on the same ring atom to the extent it is chemically permitted. A ring sulphur atom in a saturated heterocycle can, for example, typically be substituted with one (-S(=O)-) or two oxo groups (-SO₂-).

"Pharmaceutically acceptable salts" or derivatives refers to those salts or derivatives which possess the biological effectiveness and properties of the parent compound and which are not biologically or otherwise undesirable. Such salts include those with inorganic or organic acids, as for instance, the hydrobromide, hydrochloride, sulfate, phosphate, sodium salt, magnesium salt; such derivatives include the esters, the ethers and the N-oxides.

The compounds of the present invention and their pharmaceutical acceptable salts or derivatives may have asymmetric centres and may occur, except when specifically noted, as mixtures of stereoisomers or as individual diastereomers, or enantiomers, with all isomeric forms being included in the present invention.

The phrase "pharmaceutically acceptable", as used in connection with the formulations containing the compounds of the invention, refers to molecular entities and other ingredients of such formulations that are physiologically tolerable and do not typically produce untoward reactions when administered to an animal such as a mammal (*e.g.*, a human). Preferably, as used herein, the term "pharmaceutically acceptable" means approved by a regulatory agency, such as the FDA or the EMEA, or listed in the U.S. or European Pharmacopeia or other generally recognized pharmacopeia for use in mammals, and more particularly in humans.

Preferably in formula (I):

R₀ is:

- -H,
- -Br, or
- -NO₂.

Further preferably in formula (I):

R₀ is -H;

R₁ and **R₂**, independently from each other, are selected from:

- -C₁-C₆ alkyl, or
- taken together with the nitrogen atom to which they are bound to form an optionally substituted 5- to 8-membered heteromonocycle containing from one to three heteroatoms selected from the group consisting of nitrogen, oxygen and sulphur;

R₃ is -C₁-C₆ alkyl;

R₄ is:

- -Br,
- -(CH₂)_m-NR₁R₂, or
- -W-R₃, with the proviso that when W is -O-, R₃ is different from hydrogen or methyl;

W is -O-;

and/or **m** is an integer from 0 to 1.

Preferred compounds of the invention include, but are not limited to, compounds selected from the group consisting of:

8-Hydroxy-N-(1,1-dioxidotetrahydrothien-3-yl)quinoline-7-carboxamide (Ex. 3);

8-Hydroxy-N-(tetrahydro-2H-pyran-4-yl)quinoline-7-carboxamide (Ex. 5);

8-Hydroxy-N-(4-morpholinophenyl)quinoline-7-carboxamide (Ex. 6);

8-Hydroxy-N-(thiazol-2-yl)quinoline-7-carboxamide (Ex. 8);

8-Hydroxy-N-(isoxazol-3-yl)quinoline-7-carboxamide (Ex. 13);

8-Hydroxy-N-((5-methylpyrazin-2-yl)methyl)quinoline-7-carboxamide (Ex. 15);

8-Hydroxy-N-((1-methyl-1H-imidazol-2-yl)methyl)quinoline-7-carboxamide (Ex. 16);

8-Hydroxy-N-((4-phenylthiazol-2-yl)methyl)quinoline-7-carboxamide (Ex. 17);

8-Hydroxy-N-(pyridin-4-ylmethyl)quinoline-7-carboxamide (Ex. 18);

8-Hydroxy-N-(2,3-dihydrobenzo[b][1,4]dioxin-6-yl)quinoline-7-carboxamide (Ex. 9);

8-Hydroxy-N-(4-(dimethylamino)benzyl)quinoline-7-carboxamide (Ex. 4);

8-Hydroxy-N-(4-bromobenzyl)quinoline-7-carboxamide (Ex. 2);

8-Hydroxy-N-(benzo[d]thiazol-2-ylmethyl)quinoline-7-carboxamide (Ex. 14);

8-Hydroxy-N-(4-morpholinobenzyl)quinoline-7-carboxamide (Ex. 10);

8-Hydroxy-N-((4-methylthiazol-2-yl)methyl)quinoline-7-carboxamide (Ex. 12);

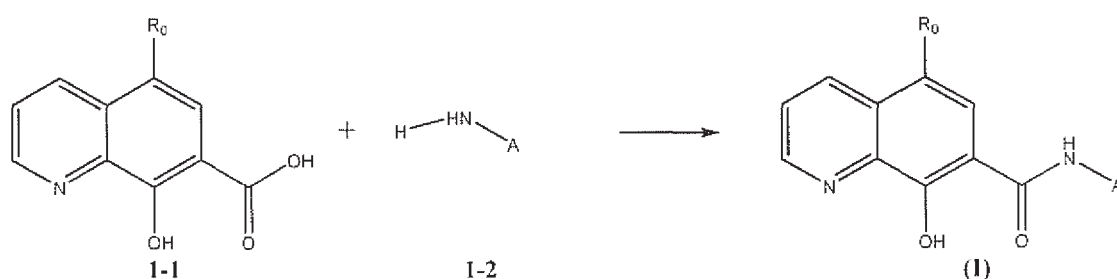
8-Hydroxy-N-(pyridin-2-ylmethyl)quinoline-7-carboxamide (Ex. 1);

8-Hydroxy-N-(4-(1H-1,2,4-triazol-1-yl)phenyl)quinoline-7-carboxamide (Ex. 7);

8-Hydroxy-N-((5-methylisoxazol-3-yl)methyl)quinoline-7-carboxamide (Ex. 11).

The compounds of the present invention can be prepared by the coupling of suitable 8-hydroxyquinolin-7-carboxylic acids **1-1** (or acid derivatives such as acid halides or esters) with the appropriate amines **1-2**, as represented by the following general Chart 1:

CHART 1



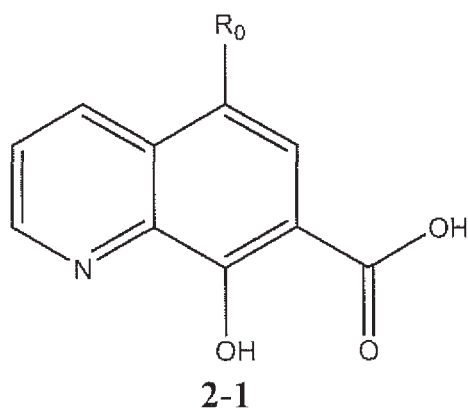
Alternatively the hydroxyl group of the carboxylic acid can be protected (as described in *Bioorg.Med.Chem.*, **14**, **2006**, 5742-5755 or *Synthesis*, **12**, **1997**, 1425-1428 or DE540842) before performing the coupling with the amine and deprotected in the final stage.

Methods for coupling carboxylic acids with amines to form carboxamides are well known in the art. Suitable methods are described, for example, in Jerry March, *Advanced Organic Chemistry*, 4th edition, John Wiley & Sons, 1992, pp. 417-425.

Methods for protecting and deprotecting aromatic hydroxyl groups are well known in the art. Protecting groups are manipulated according to standard methods of organic synthesis (Green T.W. and Wuts P.G.M. (1991) *Protecting Groups in Organic Synthesis*, John Wiley et Sons).

Chart 2 below illustrates and expands upon the chemistry portrayed in Chart 1.

CHART 2



When R_1 is Br, the carboxylic acid **2-1** is obtained by reaction of commercially available 8-hydroxyquinoline-7-carboxylic acid with one equivalent of bromine in acetic acid (International Publication WO98/11073, published 19 March 1998).

When R_1 is F or Cl, the carboxylic acids **2-1** can be prepared from the corresponding commercially available starting materials 5-halo-8-hydroxyquinolines using the methods described in International Publication WO98/11073, published 19 March 1998.

When R_1 is NO_2 , the carboxylic acid **2-1** was prepared by reaction of the corresponding ethyl ester with a mixture of HNO_3 and H_2SO_4 followed by alkaline hydrolysis. Alternatively, carboxylic acid **2-1** with $R_1=\text{NO}_2$ was prepared by reaction of 3-amino-2-hydroxy-5-nitrobenzoic acid with propenal in 6N HCl.

It will be apparent to those skilled in the art that the described synthetic procedures are merely representative in nature and that alternative synthetic processes are known to one of ordinary skill in organic chemistry.

The following examples serve only to illustrate the invention and its practice. The examples are not to be constructed as limitation on the scope or spirit of the invention.

EXPERIMENTAL SECTION

1. CHEMICAL SYNTHESIS

Unless otherwise indicated, all the starting reagents were found to be commercially available and were used without any prior purification. The compounds of the present invention can be readily prepared using conventional synthetic procedure. In these reactions, it is also possible to make use of variants which are themselves known to those of ordinary skill in this art, but are not mentioned in greater detail. Furthermore, other methods for preparing compounds of this invention will be readily apparent to the person of ordinary skill in the art in light of the following reaction schemes and examples. Unless otherwise indicated, all variables are as defined above.

Where reference is made to the use of an "analogous" procedure, as will be appreciated by those skilled in the art, such a procedure may involve minor variation, for example reaction temperature, reagent/solvent amount, reaction time, work-up conditions or chromatographic purification conditions.

Abbreviations used in the instant specification, particularly in the Tables and in the Examples, are summarized in Table 1.

TABLE 1

LC-MS (Liquid Chromatography Mass Spectrum)	ESI (Electro Spray Ionization)
UPLC (Ultra Performance Liquid Chromatography)	R _t (retention time in minutes)
TFA (Trifluoroacetic acid)	min (minutes)
μm (micrometers)	h (hours)
mmol (millimoles)	RT (room temperature)
μL (microlitres)	CH ₃ CN (Acetonitrile)
THF (Tetrahydrofuran)	DCM (Dichloromethane)
DMSO (Dimethyl sulfoxide)	Na ₂ SO ₄ (Sodium sulphate)
SPE-SI (Solid phase extraction with Silica gel)	CFU (Colony Forming Unit)

Except where otherwise indicated, all temperatures are expressed in °C (degrees centigrade) or K (Kelvin).

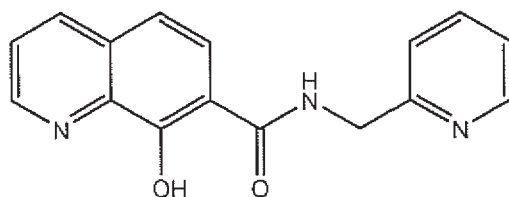
Proton Nuclear Magnetic Resonance (¹H-NMR) spectra were recorded on a Bruker 300MHz. Chemical shifts are expressed in parts of million (ppm, δ units). Splitting patterns describe apparent multiplicities and are designated as s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), sxt (sextet), m (multiplet), br. s (broad singlet).

LC-MS were recorded under the following conditions:

UPLC with Sample Manager and 2996 PDA Detector (Waters) interfaced with a Mass Spectrometer Single Quadrupole ZQ (Waters). ZQ interface: ESI positive mode. Full scan from 102 to 900 amu. Capillary 3.2V, cone 25V, extractor 3V, RF 0.3V, source temperature 115°C, desolvation temperature 350°C, gas flow 800 L/h, cone 100 L/h.

- Method A: Column Aquity UPLC-BEH C18 (50x2.1 mm, 1.7 μm). Flow rate 0.6 mL/min, column at 40°C, injection 2 μL. Mobile phases: A phase = water/CH₃CN 95/5 + 0.1% TFA, B phase = water/CH₃CN = 5/95 + 0.1% TFA. Gradient: 0-0.25 min (A: 95%, B: 5%), 3.30 min (A: 0%, B: 100%), 3.30-4.00 min (A: 0%, B: 100%), 4.10 min (A: 95%, B: 5%), 4.10-5.00 min (A: 95%, B: 5%).

- Method B: Column Atlantis dC18 (100x2.1 mm, 3.0 μ m). Flow rate 0.3 mL/min, column at 40°C, injection 2 μ L. Mobile phases: A phase = water/CH₃CN 95/5 + 0.1% TFA, B phase = water/CH₃CN = 5/95 + 0.1% TFA. Gradient: 0-0.20 min (A: 95%, B: 5%), 5.00 min (A: 0%, B: 100%), 5.00-6.00 min (A: 0%, B: 100%), 6.10 min (A: 95%, B: 5%), 6.10-7.00 min (A: 95%, B: 5%).

Example 1:**8-Hydroxy-N-(pyridin-2-ylmethyl)quinoline-7-carboxamide**

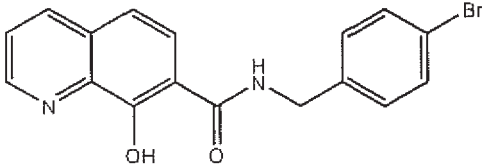
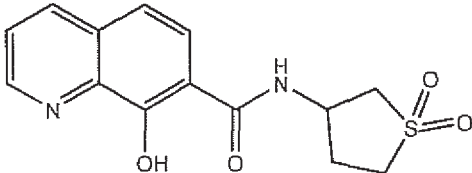
A mixture of 8-hydroxyquinoline-7-carboxylic acid (100 mg, 0.53 mmol) and di(1H-imidazol-1-yl)methanone (86 mg, 0.53 mmol) in THF (5 mL) was heated to 60°C for 3h, under nitrogen. The reaction mixture was allowed to cool to RT and pyridin-2-ylmethanamine (46 mg, 0.424 mmol) was added. The resulting mixture was heated to 40°C for 2h and then stirred at RT. The reaction mixture was quenched with H₂O and an aqueous saturated solution of sodium hydrogen carbonate, and twice extracted with DCM. The separated organics were dried over Na₂SO₄, filtered and concentrated under reduced pressure. The residue was purified by SPE-SI cartridge (2 g, DCM to DCM:MeOH 99:1) affording the title compound (73 mg, 0.26 mmol) as a off-white solid.

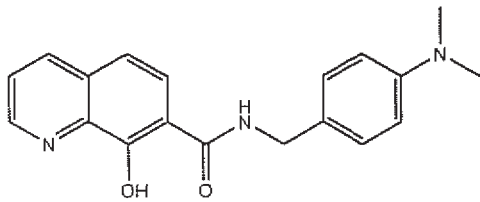
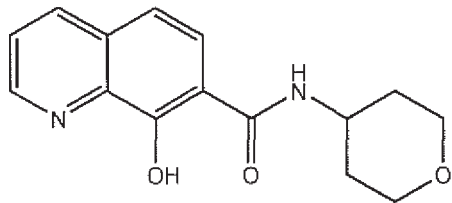
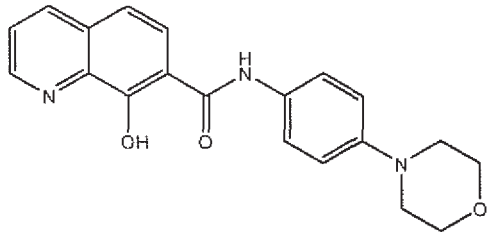
LC-MS m/z (ESI⁺): 280.14 (MH⁺), R_t=0.57 min (Method A).

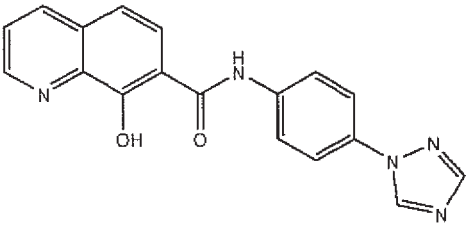
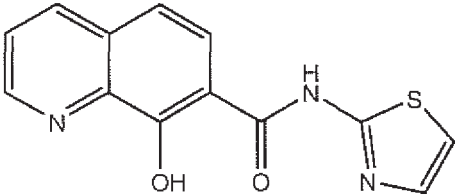
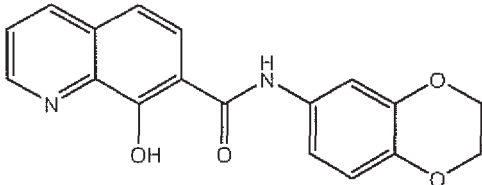
¹H-NMR (DMSO-d₆) δ : 9.46 (t, 1 H); 8.93 (dd, 1 H); 8.54 (ddd, 1 H); 8.37 (dd, 1 H); 8.06 (d, 1 H); 7.78 (td, 1 H); 7.66 (dd, 1 H); 7.45 (d, 1 H); 7.41 (d, 1 H); 7.29 (ddd, 1 H); 4.70 (d, 2 H).

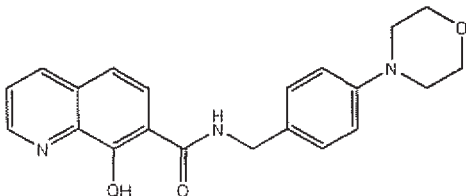
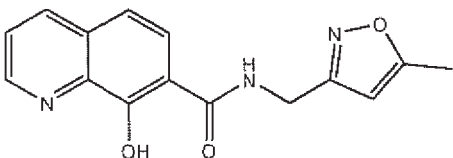
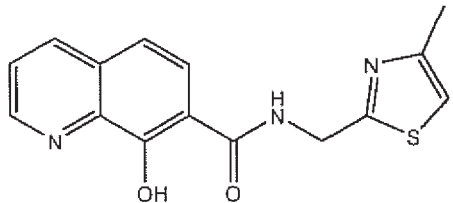
Following procedures analogous to the one described above, the additional compounds of the present invention were prepared (Table 2).

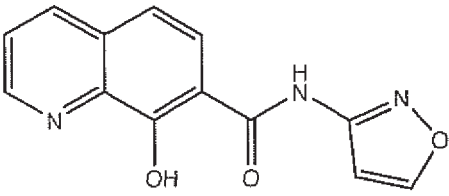
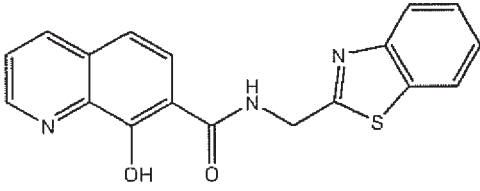
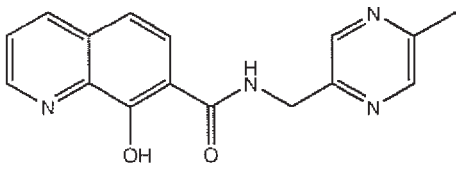
TABLE 2

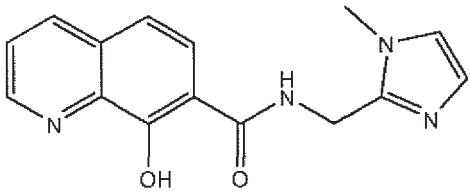
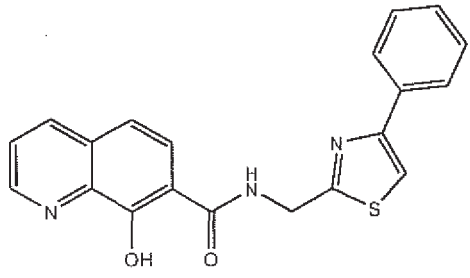
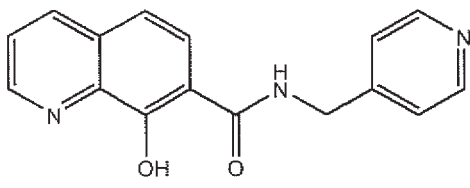
Ex.	Chemical name	¹ H NMR (DMSO-d ₆)	LC-MS method	R _i ; [MH ⁺]
2	 8-Hydroxy-N-(4-bromobenzyl)quinoline-7-carboxamide	δ : 9.35 (t, 1H); 8.92 (dd, 1H); 8.36 (dd, 1H); 8.00 (d, 1H); 7.66 (dd, 1H); 7.49-7.60 (m, 2H); 7.44 (d, 1H); 7.29-7.40 (m, 2H); 4.43-4.70 (m, 2H).	A	1.74; 357.0
3	 8-Hydroxy-N-(1,1-dioxidotetrahydrothien-3-yl)quinoline-7-carboxamide	δ : 9.09 (d, 1H); 8.92 (dd, 1H); 8.37 (dd, 1H); 7.97 (d, 1H); 7.66 (dd, 1H); 7.43 (d, 1H); 4.58-4.93 (m, 1H); 3.56 (dd, 1H); 3.37 (ddd, 1H); 3.09-3.30 (m, 2H); 2.55-2.61 (m, 1H); 2.14-2.40 (m, 1H).	A	0.77; 307.1

Ex.	Chemical name	¹ H NMR (DMSO-d ₆)	LC-MS method	R _i ; [MH ⁺]
4	 8-Hydroxy-N-(4-(dimethylamino)benzyl)quinoline-7-carboxamide	δ: 9.20 (t, 1H); 8.91 (dd, 1H); 8.34 (dd, 1H); 8.02 (d, 1H); 7.64 (dd, 1H); 7.41 (d, 1H); 7.21 (m, 2H); 6.71 (m, 2H); 4.46 (d, 2H); 2.86 (s, 6H).	A	0.79; 322.1
5	 8-Hydroxy-N-(tetrahydro-2H-pyran-4-yl)quinoline-7-carboxamide	δ: 8.91 (dd, 1H); 8.70 (d, 1H); 8.35 (dd, 1H); 8.01 (d, 1H); 7.64 (dd, 1H); 7.42 (d, 1H); 4.01-4.28 (m, 1H); 3.78-4.01 (m, 2H); 3.44 (td, 2H); 1.76-2.01 (m, 2H); 1.53-1.72 (m, 2H).	A	0.92; 273.1
6	 8-Hydroxy-N-(4-morpholinophenyl)quinoline-7-carboxamide	δ: 10.63 (br. s, 1H); 8.93 (dd, 1H); 8.43 (dd, 1H); 8.07 (d, 1H); 7.69 (dd, 1H); 7.52-7.65 (m, 2H); 7.44 (d, 1H); 6.86-7.11 (m, 2H); 3.61-3.89 (m, 4H); 2.95-3.27 (m, 4H).	A	1.05; 350.2

Ex.	Chemical name	¹ H NMR (DMSO-d ₆)	LC-MS method	R _i ; [MH ⁺]
7	 8-Hydroxy-N-(4-(1H-1,2,4-triazol-1-yl)phenyl)quinoline-7-carboxamide	δ: 11.28 (br. s, 1H); 9.25 (s, 1H); 8.94 (dd, 1H); 8.50 (dd, 1H); 8.22 (s, 1H); 8.05 (d, 1H); 7.90 (m, 4H); 7.74 (dd, 1H); 7.42 (d, 1H).	A	1.16; 332.1
8	 8-Hydroxy-N-(thiazol-2-yl)quinoline-7-carboxamide	(353K) δ: 8.90 (dd, 1H); 8.50 (dd, 1H); 8.13 (d, 1H); 7.74 (dd, 1H); 7.51 (d, 1H); 7.31 (d, 1H); 7.19 (d, 1H).	A	1.11; 272.0
9	 8-Hydroxy-N-(2,3-dihydrobenzo[b][1,4]dioxin-6-yl)quinoline-7-carboxamide	δ: 10.72 (br. s, 1H); 8.93 (dd, 1H); 8.45 (dd, 1H); 8.03 (d, 1H); 7.70 (dd, 1H); 7.43 (d, 1H); 7.40 (d, 1H); 7.11 (dd, 1H); 6.86 (d, 1H); 4.12-4.37 (m, 4H).	A	1.43; 323.2

Ex.	Chemical name	¹ H NMR (DMSO-d ₆)	LC-MS method	R _t ; [MH ⁺]
10	 8-Hydroxy-N-(4-morpholinobenzyl)quinoline-7-carboxamide	δ : 9.22 (t, 1H); 8.91 (dd, 1H); 8.35 (dd, 1H); 8.02 (d, 1H); 7.64 (dd, 1H); 7.42 (d, 1H); 7.25 (m, 2H); 6.92 (m, 2H); 4.49 (d, 2H); 3.60-3.90 (m, 4H); 2.93-3.18 (m, 4H).	A	1.10; 364.1
11	 8-Hydroxy-N-((5-methylisoxazol-3-yl)methyl)quinoline-7-carboxamide	δ : 9.38 (t, 1H); 8.92 (dd, 1H); 8.36 (dd, 1H); 7.99 (d, 1H); 7.66 (dd, 1H); 7.42 (d, 1H); 6.22 (s, 1H); 4.59 (d, 2H); 2.38 (s, 3H).	A	1.10; 284.2
12	 8-Hydroxy-N-((4-methylthiazol-2-yl)methyl)quinoline-7-carboxamide	δ : 9.59 (t, 1 H), 8.93 (dd, 1 H), 8.38 (dd, 1 H), 8.01 (d, 1 H), 7.67 (dd, 1 H), 7.44 (d, 1 H), 7.16 (q, 1 H), 4.83 (d, 2 H), 2.35 (s, 3 H)	A	1.08; 300.2

Ex.	Chemical name	¹ H NMR (DMSO-d ₆)	LC-MS method	R _i ; [MH ⁺]
13	 8-Hydroxy-N-(isoxazol-3-yl)quinoline-7-carboxamide	δ : 12.50 (br. s, 1H); 8.91 (dd, 1H); 8.85 (d, 1H); 8.61 (dd, 1H); 8.09 (d, 1H); 7.81 (dd, 1H); 7.30 (d, 1H); 7.13 (d, 1H).	A	1.11; 256.1
14	 8-Hydroxy-N-(benzo[d]thiazol-2-ylmethyl)quinoline-7-carboxamide	δ : 9.73 (t, 1H); 8.95 (dd, 1H); 8.39 (dd, 1H); 8.03-8.11 (m, 1H); 8.04 (d, 1H); 7.91-8.01 (m, 1H); 7.69 (dd, 1H); 7.35-7.58 (m, 3H); 5.02 (d, 2H).	A	1.50; 336.1
15	 8-Hydroxy-N-((5-methylpyrazin-2-yl)methyl)quinoline-7-carboxamide	δ : 9.46 (t, 1H); 8.93 (dd, 1H); 8.57 (d, 1H); 8.50 (d, 1H); 8.37 (dd, 1H); 8.02 (d, 1H); 7.66 (dd, 1H); 7.44 (d, 1H); 4.70 (d, 2H); 2.49 (br. s, 3H).	A	0.98; 295.2

Ex.	Chemical name	¹ H NMR (DMSO-d ₆)	LC-MS method	R _i ; [MH ⁺]
16	 8-Hydroxy-N-((1-methyl-1H-imidazol-2-yl)methyl)quinoline-7-carboxamide	δ : 9.28 (t, 1H); 8.92 (dd, 1H); 8.36 (dd, 1H); 8.05 (d, 1H); 7.66 (dd, 1H); 7.43 (d, 1H); 7.11 (d, 1H); 6.83 (d, 1H); 4.64 (d, 2H); 3.69 (s, 3H).	B	2.39; 283.2
17	 8-Hydroxy-N-((4-phenylthiazol-2-yl)methyl)quinoline-7-carboxamide	δ : 9.75 (t, 1H); 8.94 (dd, 1H); 8.38 (dd, 1H); 8.01-8.07 (m, 2H); 7.93-8.00 (m, 2H); 7.67 (dd, 1H); 7.40-7.52 (m, 3H); 7.27-7.39 (m, 1H); 4.94 (d, 2H).	A	1.74; 362.1
18	 8-Hydroxy-N-(pyridin-4-ylmethyl)quinoline-7-carboxamide	δ : 9.40 (t, 1H); 8.93 (dd, 1H); 8.44-8.61 (m, 2H); 8.37 (dd, 1H); 8.02 (d, 1H); 7.66 (dd, 1H); 7.45 (d, 1H); 7.28-7.41 (m, 2H); 4.63 (d, 2H).	B	2.04; 280.1

2. ACTIVITY TESTING: Methods and results

Organisms used to test antifungal activity

Trichophyton Rubrum (ATCC 28188, PBI International); *Trichophyton Mentagrophytes* (ATCC 9533, PBI International); *Aspergillus Niger* (ATCC 16404, PBI International); *Scopulariopsis Brevicaulis* (ATCC 36840, DSMZ); *Candida Albicans* (ATCC 90028, PBI International); *Candida Glabrata* (ATCC 90030, DSMZ).

Preparation and conservation

Strains were prepared from freeze-dried ampoules or freeze-dried pellets.

An isolation of the suspensions was made on Potato Dextrose Agar (PDA) to test the strains purity. A strains' massive growth was then made streaking microbial suspensions on PDA plates.

Incubation was at 30°C for 48-72Hours (*Candida* yeasts) and for 7-10 days (filamentous fungi).

The yeasts' colonies and the filamentous fungi's conidia were harvested with 3-5 mL of RPMI 1640 + 50% glycerol and the aliquots frozen at -80°C.

Antifungal susceptibility testing

Compounds' minimal inhibition concentration (MIC) was determined through broth micro-dilution susceptibility test using a method developed in agreement with the National Committee for Clinical Laboratory Standards (NCCLS) (National Committee for Clinical Laboratory Standards. Reference Method for Broth Dilution Antifungal Susceptibility Testing of Yeasts; Approved standard-Second Edition M27-A2. **2002**; Vol. 22, No. 15) (National Committee for Clinical Laboratory Standards. Reference Method for Broth Dilution Antifungal Susceptibility Testing of Filamentous Fungi; Approved standard M38-A. **2002**; Vol. 22, No. 16).

Assays were carried out in RPMI 1640 with L-glutamine medium buffered to pH 7 with 0.165M 3-(N-morpholino)propanesulfonic acid (MOPS) and 10M

NaOH and supplemented with 18 g glucose/litre. The tests were performed using 96 well sterile plates (inoculum size of 1×10^5 CFU/mL). Compounds stock solutions were prepared at 12.8 mg/mL in 100% DMSO. A series of twofold dilutions were prepared in plate using RPMI 1640. Final concentrations ranged from 0.125 to 128 μ g/mL at 1% DMSO.

MIC is defined as the lowest concentration of antifungal agent which prevents any visible growth and was determined after 48h of incubation for yeasts (35°C) and after five days of incubation for filamentous fungi (35°C).

Results

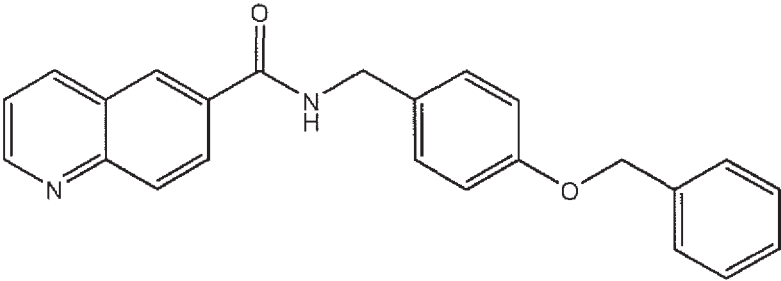
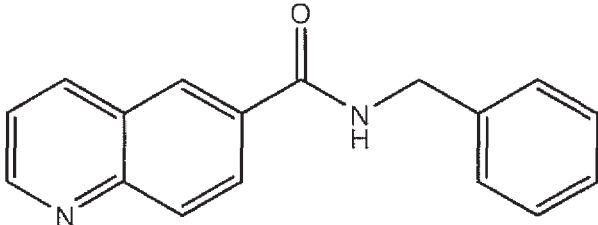
The MIC values for the most preferable compounds, calculated as the geometric means of the values obtained in two single experiments, are reported in Table 3.

TABLE 3

Ex	Trycophyton Rubrum ATCC 28188	Tricophyton Mentagrophytes ATCC 9533	Aspergillus Niger ATCC 16404	Scopulariopsis Brevicaulis ATCC 36840	Candida Albicans ATCC 90028	Candida Glabrata ATCC 90030
9	0.25	0.50	1.00	1.00	2.00	2.00
4	1.00	0.71	0.50	1.00	2.83	1.41
2	1.41	1.00	0.71	1.41	1.41	1.41
14	2.00	1.00	0.50	1.00	2.00	2.83
10	1.00	0.50	0.50	4.00	4.00	2.00
12	1.41	2.83	1.00	1.00	2.00	2.00
1	2.00	2.00	0.50	1.00	4.00	4.00
7	2.52	2.00	1.00	1.26	2.00	2.83
11	1.00	4.00	1.00	2.83	2.00	2.00

Furthermore, the compound codified as E8 in EP1669348A1 was synthesized together with a new compound (codified as NiK-29298), not included among those disclosed in EP1669348A1, nor in the present invention, that can be used as a link between the class of compound described in the present application and those described in EP1669348A1 (Table 4).

TABLE 4

E8	
NiK-29298	

The MIC values for these compounds, tested on the same organisms used to assess the potency of the derivatives described in the present application are reported in Table 5.

TABLE 5

Ex	Trycophyton Rubrum ATCC 28188	Tricophyton Mentagrophytes ATCC 9533	Aspergillus Niger ATCC 16404	Scopulariopsis Brevicaulis ATCC 36840	Candida Albicans ATCC 90028	Candida Glabrata ATCC 90030
E8	>128	75	2-128	>128	1.41	1.00
NiK- 29298	>128	128	64-128	>128	2.00	5.65

As it can be appreciated, all the compounds listed in table 3 are active on all the 6 strains tested, including yeasts, dermatophytes and molds. This broad spectrum of the compounds of the present invention accounts for a predicted efficacy on all kinds of fungal infections in humans or in animals, including skin, scalp and nail infections, mostly caused by dermatophytes; vaginal, mouth and intestinal infections, mostly caused by yeasts; ear, pulmonary, eye, and other systemic infections, mostly caused by molds.

Conversely, the compound E8, disclosed in EP1669348A1, and the compound NiK-29298, characterized by the same quinoline scaffold described in EP1669348A1, are active only on yeasts and do not display any appreciable activity against the other strains, including dermatophytes and molds.

Mechanism of action

It is known in the art that ciclopirox, one of the most potent and broad spectrum antifungal agents, kills the fungal cells by chelating Fe^{3+} , i.e. by subtracting the iron ions from the fungal cells, and its *in vitro* action is inhibited only by adding an adequate quantity of Fe^{3+} ions to the medium. Ciclopirox is also known in the art to be the only antifungal agent which, due to its peculiar mechanism of action, does not induce resistances in fungal strains.

Method for the assessment of the mechanism of action

To verify if the compounds mechanism of action is the chelation of iron ions, the MIC determination with *Candida glabrata* (ATCC 90030) strain was performed by the addition of excessive iron ions ($100\ \mu\text{M}\ \text{FeCl}_3$) in the test medium. The viability of cells exposed to drugs, with or without the metal ion Fe^{3+} , was evaluated by the OD measure at 540 nm.

Compounds described in Example 2, E8 and NiK-29298 were evaluated in presence and in absence of $100\ \mu\text{M}$ ($100\ \mu\text{M}$ micromoles) Fe^{3+} .

The results are reported in the following Figures 1, 2 and 3.

In all figures, the lines and dots represent the percent inhibition of the fungal growth (in ordinate) by adding different concentrations of antifungal agents (in abscissa). Blue lines and dots are the experiments performed without iron supplementation, while red lines and dots represent the results of the experiments performed in presence of $100\ \mu\text{M}\ \text{Fe}^{3+}$. As known from the art, ciclopirox effect is completely inhibited by presence of Fe^{3+} and *Candida glabrata* is able to grow normally (Figure 1). Conversely, Fe^{3+} has no effect on

amphotericin, an antifungal agent known in the art to have a mechanism of action different from that of ciclopirox.

All the compounds of the present invention have similar behavior to ciclopirox, i.e. their antifungal activity is completely inhibited by presence of Fe^{3+} (Figure 2).

On the contrary, the compound E8, disclosed by EP1669348A1, and the compound NiK-29298, with the quinolone scaffold described in EP1669348A1, unlike ciclopirox and unlike the compounds of the present invention, where not inhibited by the presence of Fe^{3+} ions in the medium culture.

In conclusion, the compounds disclosed in EP1669348A1 have a narrow spectrum of action, limited to yeasts, while they do not display antifungal activity against dermatophytes or molds. Moreover, their mechanism of action is independent on iron chelation.

On the contrary, the compounds of the present invention are superior to those disclosed in EP1669348A1, in that they have a potent antifungal activity with a wide spectrum of action, extended to yeasts, dermatophytes and molds. This characteristic makes their efficacy predictable in a variety of fungal infections, including skin, scalp, nail infections, moreover vaginal, mouth and intestinal infections, finally ear, pulmonary, eye, and other systemic infections. Furthermore, the compounds of the present invention are superior to those disclosed in EP1669348A1, in that their mechanism of action is iron chelation, a mechanism known in the art to avoid development of resistance in fungal cells.

CLAIMS

1. Compound selected from the group consisting of:

8-Hydroxy-N-(1,1-dioxidotetrahydrothien-3-yl)quinoline-7-carboxamide
8-Hydroxy-N-(tetrahydro-2H-pyran-4-yl)quinoline-7-carboxamide;
8-Hydroxy-N-(4-morpholinophenyl)quinoline-7-carboxamide;
8-Hydroxy-N-(thiazol-2-yl)quinoline-7-carboxamide;
8-Hydroxy-N-(isoxazol-3-yl)quinoline-7-carboxamide;
8-Hydroxy-N-((5-methylpyrazin-2-yl)methyl)quinoline-7-carboxamide;
8-Hydroxy-N-((1-methyl-1H-imidazol-2-yl)methyl)quinoline-7-carboxamide;
8-Hydroxy-N-((4-phenylthiazol-2-yl)methyl)quinoline-7-carboxamide;
8-Hydroxy-N-(pyridin-4-ylmethyl)quinoline-7-carboxamide;
8-Hydroxy-N-(2,3-dihydrobenzo[b][1,4]dioxin-6-yl)quinoline-7-carboxamide;
8-Hydroxy-N-(4-(dimethylamino)benzyl)quinoline-7-carboxamide;
8-Hydroxy-N-(4-bromobenzyl)quinoline-7-carboxamide;
8-Hydroxy-N-(benzo[d]thiazol-2-ylmethyl)quinoline-7-carboxamide;
8-Hydroxy-N-(4-morpholinobenzyl)quinoline-7-carboxamide;
8-Hydroxy-N-((4-methylthiazol-2-yl)methyl)quinoline-7-carboxamide;
8-Hydroxy-N-(pyridin-2-ylmethyl)quinoline-7-carboxamide;
8-Hydroxy-N-(4-(1H-1,2,4-triazol-1-yl)phenyl)quinoline-7-carboxamide;
8-Hydroxy-N-((5-methylisoxazol-3-yl)methyl)quinoline-7-carboxamide.

2. A pharmaceutical formulation containing at least a compound according to claim 1, together with at least a pharmaceutically acceptable carrier, excipient and/or adjuvant.