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Synthesis and Crystal Structure Studies of a New Complex of Co (III)-Schiff Base Derivative Derived from Isonicotinohydrazide

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A new Co(III) complex prepared by the reaction of *N*-(1-(pyridin-2-yl)ethylidene)isonicotinohydrazide (H₂L) with Co(II) ion is reported in this paper. The H₂L ligand is structurally characterized by elemental analysis, NMR, and infrared spectroscopies. The mononuclear complex [Co(HL)₂].Cl·3H₂O (1), is characterized by infrared spectroscopy, elemental analysis, conductance,

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magnetic room temperature measurement and single X-ray diffraction. The complex crystallizes in the monoclinic system with space group P21/c. The parameters of the unit cell are $a = 9.6818(3) \text{ \AA}$; $b = 25.1587(6) \text{ \AA}$; $c = 11.5481(3) \text{ \AA}$; $\beta = 101.797(3)^\circ$; $Z = 4$; $R_{\text{int}} = 0.0313$ and $wR(F_2) = 0.0812$. The asymmetric unit of the compound contains a discrete $[\text{Co}(\text{HL})_2]^+$ cation one free chloride anion and three uncoordinated water molecules. In the discrete cation one Co^{3+} ion two organic ligand molecules are present. The coordination polyhedron around the Co^{3+} center is best described as a distorted octahedral with CoN_4O_2 chromophore. The crystal structure of the complex is stabilized by intramolecular and intermolecular hydrogen bonds.

Keywords: Schiff base; isonicotinohydrazide; cobalt; X-ray diffraction; complex; mononuclear.

1. INTRODUCTION

In recent years, the chemical properties and biological activity of acylhydrazones have attracted much attention from chemists [1,2]. Acylhydrazones, due to their azometine moieties $-\text{C}=\text{N}-\text{NH}-\text{CO}-$, are good intermediates in the synthesis of various heterocyclic compounds [3-8] and they are also effective organic compounds in their own right due to their biological activities [9] and their chemical and industrial versatility [10-13]. "Acylhydrazones are easily synthesized and can be obtained by a condensation reaction of an aldehyde or a ketone with a derivative of the hydrazide class in the presence of an alcoholic solvent, generally at reflux, and in an acidic medium [14-19] or in neutral medium" [20-22]. "They can appear structurally in the form of four isomers, two of which are geometric isomers (E/Z) and are due to the $\text{C}=\text{N}$ double bond, and two are conformers (syn/anti) and are due to the N-N bond" [7,23]. Acylhydrazones have significant importance in the pharmaceutical field thanks to their numerous biological properties with multiple therapeutic indications. In recent studies performed with these derivatives, the following properties have been reported: antitumor [24-29], cytotoxic [30], antibacterial [6,31-34], antifungal [35,36], antiviral [37,38], antiparasitic [39-41], anti-inflammatory [42-44], analgesic [45-47], enzyme inhibition [48-49], antioxidant [50-52], antidiabetic [53], and anticonvulsant [54]. In coordination chemistry, acylhydrazones derived from isonicotinohydrazine have been widely used as Schiff bases to synthesize stable complexes with transition metal or lanthanide ions [55-57]. In this paper, we report the synthesis, spectroscopic characterization, and crystal structure of a new complex $[\text{Co}(\text{HL})_2] \cdot \text{Cl} \cdot 3\text{H}_2\text{O}$ derived from a Schiff base (H_2L) obtained from a condensation reaction between isonicotinohydrazide and acetylpyridine in the presence of acetic acid.

2. MATERIALS AND METHODS

2.1 Starting Materials and Instrumentations

"Commercially available 2-acetylpyridine, isonicotinohydrazine and cobalt chloride salt were purchased from Aldrich and used without further purification. The solvents were reagent grade and were purified by usual methods. Elemental analyses were carried out using a VxRio EL Instrument. The IR spectra were recorded on a FTIR Perkin-Elmer UV/Visible spectrophotometer Lambda 365(1000-200 nm). The ^1H and ^{13}C NMR spectra of the Schiff bases were recorded in $\text{DMSO}-d_6$ on a BRUKER 500 MHz spectrometer at room temperature using TMS as an internal reference. The molar conductance of 10^{-3} M solutions of the metal complexes in DMF was measured at 25°C using a WTW LF-330 conductivity meter with a WTW conductivity cell" [3]. Room temperature magnetic susceptibilities of the powdered samples were measured using a Johnson Matthey scientific magnetic susceptibility balance (Calibrant: $\text{Hg}[\text{Co}(\text{SCN})_4]$).

2.2 Synthesis of the Ligand H_2L

In a round bottomed flask containing 20 mL of methanol, 2 g (14.58 mmol) of isonicotinic acid hydrazide were introduced and stirred until completely dissolved. Thus 1.668 mL (14.58 mmol) of 2-acetylpyridine and a few drops of acetic acid were added, and an orange color was developed. The reaction mixture was refluxed for 4 hours to obtain a brown precipitate which was recovered by filtration and washing with 2 x 10 mL of methanol. M.P. 154°C . Yield 74%. Anal. calcd. for $\text{C}_{13}\text{H}_{12}\text{N}_4\text{O}$: C, 64.99; H, 5.03; N, 23.32. Found: C, 64.96; H, 5.01; N, 23.30 %. FT-IR (ATR, ν , cm^{-1}): 3182, 1667, 1622, 1581, 1563, 1550, 1495, 1455, 1428, 1217, 1150, 990, 622. ^1H NMR (500 MHz, $\text{DMSO}-d_6$, δ , ppm): 2.49 (S,

3H, -CH₃); 7.40–8.93 (m, 8H, H_{Py}); 11.23 (s, 1H, HN–C=O). ¹³C NMR (DMSO-d₆, δ, ppm) 163.35 (C=O); 156.77 (C_{ipso},Py); 155.35 (C=N); 151.33 (CPy); 149.98 (CPy); 141.47 (C_{ipso},Py); 137.12 (CPy); 124.85 (CPy); 122.42 (CPy); 121.02 (CPy). 13.37 (-CH₃).

2.3 Synthesis of the Complex [Co(HL)₂·Cl·3H₂O

To methanolic solution (10 mL) of the ligand H₂L, 0.2 g (0.832 mmol) a solution of the CoCl₂·6H₂O salt 0.989 g (0.416 mmol) in methanol (10 mL) was added. The solution was stirred under reflux for two hours. The dark red solution obtained was filtered and left to slow evaporation. After one week, dark red crystals suitable for X-ray analysis were collected. M.p.: 240 °C. Yield: 70.42 %. Anal. Calc for C₂₆H₂₈N₈O₅ClCo: C, 49.81, H, 4.50, N, 17.87, Cl, 5.56. Found: C, 49.79; H, 4.47; N, 17.90; Cl, 5.58. IR (cm⁻¹): 3400 (OH), 3180 (NH), 1615 (O–C=N)_{iminol}, 1603 (C=N)_{imine}, 1567 (C_{Ar}=N), 1548-1438 (C_{Ar}=C_{Ar}); 1313 (O–C)_{enol}, 1054 (N–N), 824 δ(H₂O). Diamagnetic. UV-vis (solution, DMF, λ (nm)): 215-255; 302; 438. Λ (Ω⁻¹·cm²·mol⁻¹): 69.15 (fresh solution) and 70.51 (two weeks after).

2.4 Crystal Structure Determination

“Crystals suitable for X-diffraction, of the reported compound, were grown by slow evaporation of MeOH solution of the complex. Details of the X-rays crystal structure solution and refinement are given in Table 1. Diffraction data were collected using a Rigaku Oxford diffractometer with graphite monochromatized Mo Kα radiation (λ = 0.71073 Å). All data were corrected for Lorentz and polarization effects. No absorption correction was applied. Using Olex2 the structures were solved by intrinsic phasing methods with SHELXT and SHELXL was used for full matrix least squares refinement”. [58-60] “The hydrogen atoms of water molecules and NH groups were located in the Fourier difference maps and refined. Others H atoms were geometrically optimized and refined as riding model by AFIX instructions. Molecular graphics were generated using ORTEP-3” [61].

3. RESULTS AND DISCUSSION

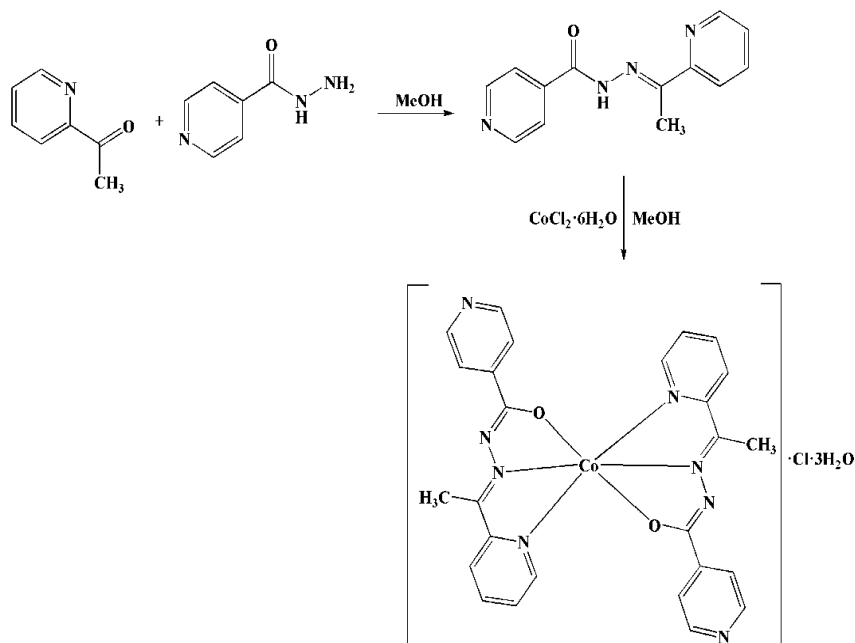
3.1 General Study

The synthesis of the Schiff base H₂L is achieved in a one-step procedure using the direct condensation of isonicotohydrazine and 2-

acetylpyridine in 1/1 ratio. The coordination abilities of the H₂L with cobalt (II) chloride salt was investigated in 2:1 ligand/metal ratio in methanol solutions (Scheme 1). The Co(III) complex prepared at reflux gave a solution which after evaporation gave single crystals. The crystal structure of the complex is confirmed by X-ray diffraction. The complex is characterized by elemental analysis, infrared and UV-visible spectroscopies, and molar conductivity. The ¹H and ¹³C NMR spectra of the ligand N'-(1-(pyridin-2-yl)ethylidene)isonicotinohydrazide (H₂L) are recorded in DMSO-d₆ as shown in the experimental section. The ¹H NMR spectrum shows a complex signal in the range 8.13-7.40 ppm integrating a total of 9 protons attributed to the protons of the two pyridine rings. The singlet signal at 2.49 ppm representing 3 protons is assigned to the methyl group. The broad signal centered at 11.23 ppm is due to a –OH group which reveals the iminolisation of the ligand in DMSO. The ¹³C NMR spectrum shows the presence of a signal at 153 ppm attributed to the carbon atom carrying the iminol function. The solid state IR spectrum of the ligand reveals bands at 3182 cm⁻¹, 1677 cm⁻¹, 1622 cm⁻¹ and 1582 cm⁻¹ which are respectively assigned to ν(NH), ν(C=O), ν(C=N)_{imine} and ν(C_{Ar}=N) [62, 63] indicating the non-iminolisation of the ligand in its solid form. Upon reaction of the ligand and cobalt (II) chloride the spectrum of the resulting complex shows a shift of the bands ν(C=N)_{imine} and ν(C_{Ar}=N) towards low frequencies and the disappearance of the ν(C=O). The ν(C=N)_{imine} and ν(C_{Ar}=N) appear, respectively, at 1603 cm⁻¹ and 1567 cm⁻¹ on the spectrum of the complex. This is indicative of the involvement of the nitrogen atoms of the imine function and pyridine ring in the coordination of the metal ion. The absence of the ν(NH), ν(C=O) and ν(OH)_{enol} vibration bands and the appearance of the ν(C=O)_{enol} band at 1313 cm⁻¹ show that iminolisation of the ligand undergoes during complexation and that the atom of oxygen enol participates in the coordination of the metal ion. The broad band which appears at 3400 cm⁻¹ on the spectrum of the complex is due to the presence of uncoordinated water molecules. The molar conductivity measurements of the complex taken from a fresh solution of DMF and after fifteen days of storage [69.15 Ω⁻¹·cm²·mol⁻¹ and 70.51 Ω⁻¹·cm²·mol⁻¹] indicate that the complex is 1:1 electrolyte type according to Geary [64]. “The small variation in the values obtained shows that the complex is stable in the DMF solution. The electronic spectrum of the complex shows three broad bands at 215 nm, 302 nm and 438 nm. The bands at 215 nm and 302 nm are due to the

intraligand transitions $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$, respectively. The band centered at 438 nm is attributed to LMCT" [65]. "Room temperature

magnetic susceptibility measurement shows that the complex **1** is diamagnetic as expected for low-spin cobalt (III) complexes" [66].



Scheme 1. Synthetic pathway of the ligand and the complex

Table 1. Crystal data and structure refinement for $[\text{Co}(\text{HL})_2] \cdot \text{Cl} \cdot 3\text{H}_2\text{O}$

Empirical formula	$\text{C}_{26}\text{H}_{28}\text{ClCoN}_8\text{O}_5$
Formula weight	626.94
Temperature (K)	175.00(10)
Radiation MoK α (λ)	0.7107(3)
Crystal system	Monoclinic
Space group	$P2_1/c$
a (\AA)	9.6818(3)
b (\AA)	25.1587(6)
c (\AA)	11.5481(3)
α ($^\circ$)	90
β ($^\circ$)	101.797(3)
γ ($^\circ$)	90
Volume (\AA^3)	2753.49(13)
Z	4
ρ_{calc} (g/cm^3)	1.512
μ (mm^{-1})	0.773
F(000)	1296.0
Crystal size (mm^3)	0.24 \times 0.06 \times 0.03
2 θ range for data collection/ $^\circ$	4.298 to 57.398
Index ranges	$-12 \leq h \leq 13, -27 \leq k \leq 33, -15 \leq l \leq 15$
Reflections collected	44070
Independent reflections	7110 [$R_{\text{int}} = 0.0313, R_{\text{sigma}} = 0.0253$]
Data/restraints/parameters	7109/0/381
Goodness-of-fit on F^2	1.060
Final R indexes [$l \geq 2\sigma(l)$]	$R_1 = 0.0309, wR_2 = 0.0779$
Final R indexes [all data]	$R_1 = 0.0383, wR_2 = 0.0812$

3.2 Description of the Crystal Structure of the Complex [Co(HL)₂]-Cl·3H₂O (1)

The complex crystallizes in the monoclinic system with the space group of $P2_1/c$. The crystallographic data and refinement of the complex are recorded in the Table 1. The selected bond distances and angles are listed in Table 2, and the ORTEP representation of the structure is illustrated in Fig. 2. The asymmetric unit of the complex contains a discrete [Co(HL)₂]⁺ cation, three uncoordinated water molecules and one chloride ion ensuring the neutrality of the complex. In the discrete cation, one Co(III) ion and two molecules of the ligand are present. Each ligand molecule acts in its monodeprotonated iminol form in tridentate fashion. It coordinates the ion Co(III) through one enol oxygen atom, one azomethine nitrogen atom, and one pyridine ring nitrogen atom, yielding and hexacoordinated metal ion. The coordination geometry around the Co(III) cation is best described as a distorted octahedral geometry. The two enolic oxygen atoms [O1, O2] and the two pyridine nitrogen atoms [N1, N5] form the basal plane (rms 0.2410) with Co1 0.054 (4) Å out of this plane. The apical positions are occupied by two azomethine nitrogen atoms. The *cisoid* angles values in the basal plane deviated from the ideal value of 90° [O1–Co1–O2 = 90.39 (4); O1–Co1–N5 = 92.86 (5); N1–Co1–N5 = 90.21 (5); N1–Co1–O2 = 91.02 (5)] with a sum of 364.48°. The angle subtended by the atoms in apical positions (N2–Co1–N6 = 179.12(5)°) is slightly different of the ideal value

of 180°. Each ligand forms two five membered rings of type CoNCCCN and CoOCNN upon coordination. The bites angles subtended by the atom of the five membered rings coordinated to the Co ion are in the range [81.72(5)°–82.17 (5)°]. The ligand molecules are quite planar [rms 0.1170 and 0.0875] with O1 out of plane of 0.1170 Å for one ligand and C16 0.0875 Å out of plane for the second ligand. In the complex the two coordinated ligand molecules are quite perpendicular and form a dihedral angle of 86.12 (1)°. These observations indicate the slight distortion of the octahedral polyhedron. The distances Co–N_{pyridine}, and Co–N_{imine} falls in the range [1.9413 (12) Å–1.9231 (12) Å] and [1.8584 Å–1.8605 (11) Å], respectively, and agree with the values reported for similar compounds [67]. The distances O–C [Co1–O1 = 1.9164 (10) Å and Co1–O2 = 1.9390 (10) Å] are characteristic of a single bond confirming the enol form of the ligand in the complex. The crystal packing of the compound is stabilized by unclassical intramolecular and intermolecular hydrogen bonds C14–H14...N2 and C1–H1...N6 and intermolecular, C1–H1...O3ⁱ (i = x–1, –y+3/2, z–1/2), C23–H23...O2ⁱⁱ (ii = x, –y+3/2, z–1/2), C15–H15...Cl1ⁱⁱⁱ (iii = –x+2, y+1/2, –z+3/2), C4–H4...O4^{iv} (iv = x–1, –y+3/2, z+1/2), C17–H17...O5^v (v = –x+2, y+1/2, –z+1/2), C12–H12...Cl1^{vi} (vi = –x+2, –y+1, –z+1), C25–H25...Cl1^{vii} (vii = –x+1, –y+1, –z+1)]. These hydrogen bonds connect the units forming a two-dimensional planar structure in the *ab* plane (Fig. 1, Table 3).

Table 2. Selected bond distances [Å] and angles [°] for the Co(III) complex

Co1–O1	1.9167 (10)	O1–Co1–O2	90.39 (4)
Co1–O2	1.9392 (10)	O1–Co1–N5	92.86 (5)
Co1–N5	1.9413 (12)	N6–Co1–O1	97.07 (5)
Co1–N6	1.8581 (12)	N6–Co1–O2	81.72 (5)
Co1–N1	1.9232 (12)	N6–Co1–N5	81.92 (5)
Co1–N2	1.8603 (12)	N6–Co1–N1	98.67 (5)
O1–C8	1.2987 (17)	N1–Co1–N5	90.20 (5)
O2–C21	1.2977 (17)	N2–Co1–O2	98.56 (5)
N2–Co1–N5	97.82 (5)	N2–Co1–N1	82.16 (5)
N2–Co1–O1	82.11 (4)	O1–Co1–N1	164.23 (5)
N1–Co1–O2	91.02 (5)	O2–Co1–N5	163.59 (5)
N6–Co1–N2	179.12 (5)		

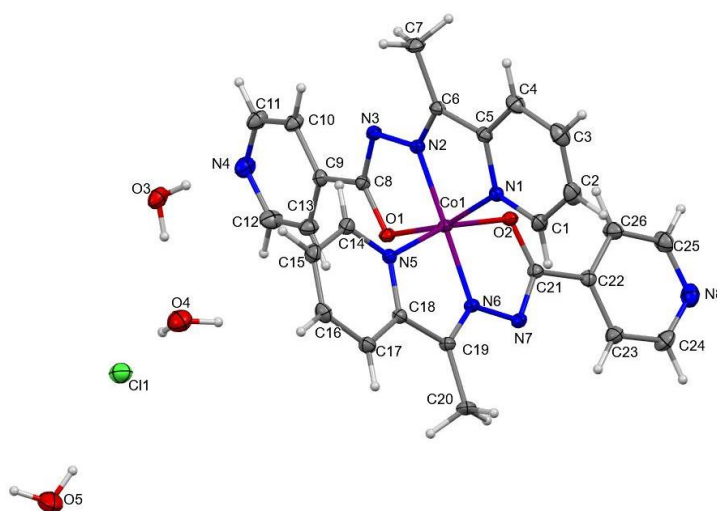


Fig. 1. Crystal structure of the complex $[\text{Co}(\text{HL})_2]\cdot\text{Cl}\cdot 3\text{H}_2\text{O}$ (1)

Table 3. Hydrogen-bond geometry (\AA , $^\circ$) for $[\text{Co}(\text{HL})_2]\cdot\text{Cl}\cdot 3\text{H}_2\text{O}$

D–H...A	D–H	H...A	D...A	D–H...A
C14–H14...N2	0.95	2.65	3.1213 (19)	110.8
C1–H1...N6	0.95	2.65	3.119 (2)	110.8
C1–H1...O3 ⁱ	0.95	2.27	3.056 (2)	139.6
C23–H23...O2 ⁱⁱ	0.95	2.64	3.385 (2)	135.3
C15–H15...Cl1 ⁱⁱⁱ	0.95	2.95	3.6005 (17)	126.6
C4–H4...O4	0.95	2.57	3.445 (2)	153.1
C17–H17...O5 ^{iv}	0.95	2.54	3.484 (2)	170.8
C12–H12...Cl1 ^v	0.95	2.97	3.7156 (19)	136.5
C25–H25...Cl1 ^{vi}	0.95	2.95	3.7736 (18)	146.2

Symmetry codes: (i) $x, y, z-1$; (ii) $x, -y+3/2, z-1/2$; (iii) $-x+1, -y+1, -z+1$; (iv) $-x+1, -y+1, -z$; (v) $-x+1, y+1/2, -z+1/2$; (vi) $-x, y+1/2, -z+1/2$.

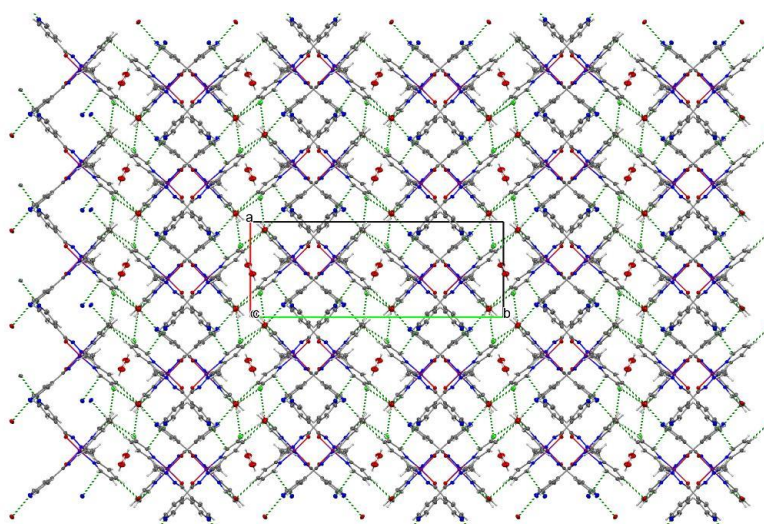


Fig. 2. Packing diagram of the complex $[\text{Co}(\text{HL})_2]\cdot\text{Cl}\cdot 3\text{H}_2\text{O}$ (1)

4. CONCLUSION

The complex $[\text{Co}(\text{HL})_2]\cdot\text{Cl}\cdot 3\text{H}_2\text{O}$ synthesized by the reaction of the Schiff base N -(1-(pyridin-2

yl)ethylidene)isonicotinohydrazide (H_2L) and hexahydrate cobalt dichloride have been characterized by IR and UV spectroscopies, conductivity and room temperature magnetic

moment measurements and X-ray diffraction. Considering the conductance, the complex is stable in DMF solution. The complex is diamagnetic in nature indicating a high-spin cobalt (III) complex. The X-ray diffraction study shows that the Co(III) complex is mononuclear and the metal atom is situated in an octahedral geometry, surrounded by two molecules acting in tridentate ligand. The structure of complex is consolidated by extensive unclassical intermolecular hydrogen bonds of type C–H...N, C–H...O and C–H...Cl which produce a three-dimensional network in the solid.

SUPPORTING INFORMATION

CCDC-2342789 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via <https://www.ccdc.cam.ac.uk/structures/>, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44(0)1223-336033.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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