Synthesis and Fungicidal Activity of 2-Substituted-3-(4-Fluorophenyl)-benzofuro [3,2-d] Pyrimidin-4(3H)-ones

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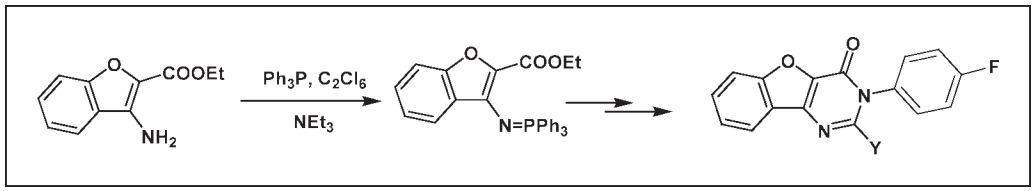
Received July 7, 2009
DOI 10.1002/jhet.277
Published online 5 January 2010 in Wiley InterScience (www.interscience.wiley.com).



Carbodiimide, obtained from aza-Wittig reaction of iminophosphorane with 4-fluorophenyl isocyanate, reacted with various nucleophiles under mild conditions to give a series of 2-substituted-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones in satisfactory yield. Their structures were confirmed using NMR, EI-Ms, IR, and elementary analysis, and compound **7b** was further analyzed by single-crystal. The preliminary bioassays indicated that these compounds showed moderate fungicidal activities against six kinds of fungi at a concentration of 50 mg/L.

J. Heterocyclic Chem., **47**, 219 (2010).

INTRODUCTION

Benzofuropyrimidinones are important heterocycles bearing remarkable biological activities. Some of them have shown good analgesic, anti-inflammatory, and antimicrobial activities [1–3], whereas others exhibited good anticoccidial and blood sugar-lowering activities [4,5]. On the other hand, many examples have been demonstrated that incorporation of fluorine atom in molecular structure of heterocyclic compounds often resulted in the improvement of pharmacological properties of the compounds as compared to their non-fluorine analogs [6,7]. The introduction of a fluorine atom to the benzofuropyrimidinone system is expected to influence the biological activities significantly. However, there is no report of a generally useful synthesis of 2-substituted-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones.

The aza-Wittig reactions of functionalized iminophosphoranes with isocyanates have been applied to produce carbodiimides, functional groups consisting of the formula N=C=N, able to undergo a plethora of heterocyclization reactions [8,9]. Here, in continuation of our earlier work [10,11], we wish to report a new method of the previously unreported incorporation of fluorine atom in molecular structure of benzofuropyrimidinones *via* the aza-Wittig reactions of functionalized iminophosphorane with 4-fluorophenyl isocyanate under mild condition, which synthesized 2-substituted-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones.

RESULT AND DISCUSSION

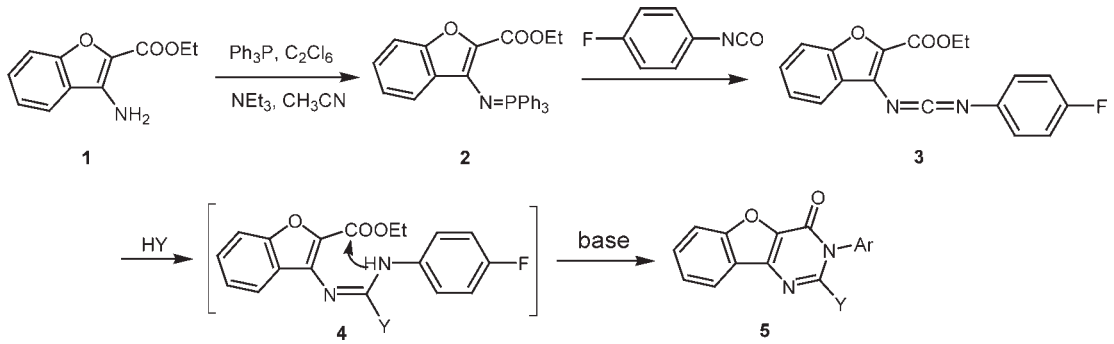
Synthesis. The iminophosphorane 2 reacted with *p*-fluorophenyl isocyanate to give carbodiimide 3, which were allowed to react with secondary amines to provide guanidine intermediates 4 ($Y=R_2N$). In the presence of catalytic amount of sodium ethoxide, 4 were converted easily to 2-dialkylamino-3-*p*-fluorophenyl-benzofuro [3,2-d] pyrimidin-4(3H)-ones 5 in satisfactory yields at room temperature (Scheme 1).

The reaction of carbodiimide 3 with phenols produced 2-aryloxy-3-*p*-fluorophenyl-benzofuro [3,2-d] pyrimidin-4(3H)-ones 5 (Y = ArO) in the presence of catalytic amount of potassium carbonate in good yields. The direct reaction of carbodiimide 3 with primary alcohol (ROH) gave 2-alkoxy-3-*p*-fluorophenyl-benzofuro [3,2-d] pyrimidin-4(3H)-ones 5 (Y = RO) in excellent yields in the presence of catalytic amount of RO^-Na^+. The results are listed in Table 1.

The reaction of carbodiimide 3 with primary amine RNH_2 in the presence of EtO^-Na^+ produced only 2-alkylamino-3-*p*-fluorophenyl-benzofuro [3,2-d] pyrimidin-4(3H)-ones 7, and the other isomer 8 was not found (Scheme 2). The same selectivity was also observed in similar cases [11]. The results are also listed in Table 1.

The structures of all products were confirmed using NMR, IR, elemental analysis, and MS. The structure of **7** was deduced from its ^{1}H NMR data. Among the possible regioisomers, we obtained only **7** from the reaction mixture after recrystallization; the other isomer **8** was

Scheme 1



not found by ^{1}H NMR analysis of the reaction mixture. Furthermore, a single crystal of **7b** was obtained from a CH_2Cl_2 solution of **7b**. X-ray structure analysis verified again the proposed structure [12] (Fig. 1), which showed that all ring atoms in the benzofuro [3,2-d] pyrimidinone system are essentially coplanar; the C15-C20 phenyl ring is twisted with respect to it, with a dihedral angle of 87.35(3)°. Intermolecular C---H. . .O and N---H. . .O hydrogen bonds link the molecules, helping to stabilize the crystal structure. Further stability the crystal structure is provided by offset π–π stacking interactions involving the fused benzofuro [3,2-d] pyrimidin system moieties.

Fungicidal activity. The fungicidal activities of compounds **5** and **7** were screened against six kinds of fungi, *Fusarium oxysporum, Rhizoctonia solani, Botrytis cinerea, Gibberella zeae, Dothiorella gregaria,* and *Colletotrichum gossypii* at a concentration of 50 mg/L according to the reported method [13] and the results are also listed in Table 2. It was found that the compounds showed moderate fungicidal activities when fluorine atom was introduced. As a result, fluorine containing compounds **5i** (79%) displayed better fungicidal activities than non-substituted phenyl compounds **5j** (42%) to *B. cinerea*.

In conclusion, we have developed an efficient synthesis of 2-substituted-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones *via* the aza-Wittig reactions of functionalized iminophosphorane with 4-fluorophenyl isocyanate. Because of the mild reaction condition, good yields, easily accessible starting material, and straightforward product isolation, we think that the versatile synthetic approach discussed here in many cases compares favorably with other existing methods. The preliminary bioassay indicated that all compounds showed moderate fungicidal activities against six kinds of fungi, *F. oxysporum, R. solani, B. cinerea, G. zeae, D. gregaria,* and *C. gossypii* at a concentration of 50 mg/L.

Table 1

Yields of compounds **5** and **7**.

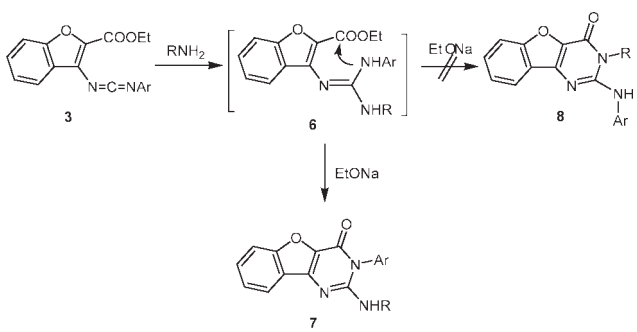
Compounds	Ar	Y(R)	Yield (%)[a]
5a	p-F-Ph		84
5b	p-F-Ph		85
5c	p-F-Ph	—N(C_2H_5)$_2$	87
5d	p-F-Ph	—N(i-C_3H_7)$_2$	80
5e	p-F-Ph	3,4-dimethylphenoxy	87
5f	p-F-Ph	4-Chloro-2-methyl-phenoxy	81
5g	p-F-Ph	4-Methyl-phenoxy	88
5h	p-F-Ph	Methoxy	87
5i	p-F-Ph	Ethoxy	89
5j[b]	Ph	Ethoxy	82
7a	p-F-Ph	*n*-Propyl	83
7b	p-F-Ph	*n*-Butyl	79
7c	p-F-Ph	Cyclohexyl	88
7d[b]	Ph	*n*-Propyl	83

[a] Yields of isolated products based on iminophosphorane **2**.
[b] Ref. 11.

EXPERIMENTAL

The NMR spectrums ($CDCl_3$) were recorded on Varian XL-400 spectrometer with TMS as an internal standard, and IR spectrum was taken on a Shimadzu IR-408 Infrared spectrometer in KBr Pellets (ν in cm^{-1}). The mass spectra were meas-

Scheme 2



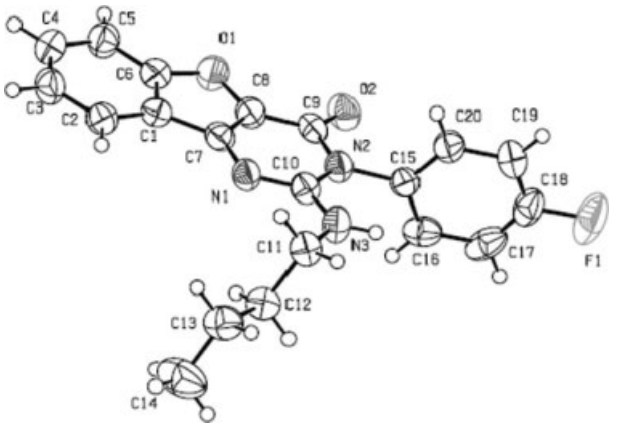


Figure 1. X-ray crystal structure of **7b**.

ured on a Finnigan Trace MS spectrometer. Elemental analyses were taken on a Vario EL III elementary analysis instrument. The melting points were determined on X4 microscopic melting apparatus (uncorrected). All the solvents and materials were reagent grade and purified as required.

General procedure for the preparation of 2-dialkylamino-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones 5a–5d. To a solution of iminophosphorane **2** (0.93 g, 2 mmol) in dry methylene chloride (15 mL) was added *p*-Fluorophenyl isocyanate (2 mmol) under nitrogen at room temperature. After the reaction mixture was stood for 8–12 h at 0–5°C, the solvent was removed off under reduced pressure and ether/petroleum ether (1:2, 20 mL) was added to precipitate triphenylphosphine oxide. After filtration, the solvent was removed to give carbodiimide **3**, which was used directly without further purification. To the solution of **3** prepared above in methylene chloride (15 mL) was added dialkylamine (2 mmol). After the reaction mixture was allowed to stand for 0.5–4 h, the solution was condensed and anhydrous ethanol (10 mL) with several drops of EtO^-Na^+ in EtOH was added. The mixture was stirred for 1–4 h at room temperature. The solution was concentrated under reduced pressure and the residual was recrystallized from ethanol and dichloromethane (v/v = 1:1) at room temperature to give 2-substituted-benzofuro [3,2-d] pyrimidin-4(3H)-ones **5a–5d.**

2-(4-Morpholinyl)-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5a). White crystals (yield: 0.61 g, 84%), Mp: 233–234°C. ^{1}H NMR ($CDCl_3$, 400 MHZ) δ = 3.15 (t, *J* = 4.8, 4H, 2 × OCH_2), 3.47 (t, *J* = 4.8, 4H, 2 × NCH_2), 7.21–8.03 (m, 8H, Ar-H); IR (KBr): 1701 (C=O), 1538, 1253, 1109 cm^{-1}; MS (70 eV) *m*/*z* (%): 365 (M^+, 60), 320 (69), 308 (93), 214 (40), 130 (56), 102 (47), 86 (48); Anal. Calcd for $C_{20}H_{16}FN_3O_3$ (365.4): C, 65.75; H, 4.41; N, 11.50; Found: C, 65.83; H, 4.50; N, 11.43.

2-(1-Piperidinyl)-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5b). White crystals (yield: 0.62 g, 85%), Mp: 253–255°C. ^{1}H NMR ($CDCl_3$, 400 MHZ) δ =1.27–1.47 (m, 6H, 3 × CH_2), 3.11–3.14 (m, 4H, 2 × NCH_2), 7.19–8.03 (m, 8H, Ar-H); IR (KBr): 1703 (C=O), 1540, 1248, 1098 cm^{-1}; MS (70 eV) *m*/*z* (%): 363 (M^+, 100), 320 (27), 254 (32), 223 (24), 178 (89), 130 (21), 102 (69), 84 (51); Anal. Calcd for $C_{21}H_{18}FN_3O_2$ (363.4): C, 69.41; H, 4.99; N, 11.56; Found: C, 69.50; H, 5.12; N, 11.44.

2-Diethylamino-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5c). White crystals (yield: 0.61 g, 87%), Mp: 177–179°C. ^{1}H NMR ($CDCl_3$, 400 MHZ) δ = 0.88 (t, *J* = 7.2 Hz, 6H, 2 × CH_3), 3.11 (q, *J* = 7.2 Hz, 4H, 2 × NCH_2), 7.18–8.03 (m, 8H, Ar-H); IR (KBr): 1704 (C=O), 1537, 1245, 1112 cm^{-1}; MS (70 eV) *m*/*z* (%): 351 (M^+, 90), 322 (100), 254 (46), 228 (77), 184 (48), 130 (66), 102 (75), 94 (52); Anal. Calcd for $C_{20}H_{18}FN_3O_2$ (351.4): C, 68.36; H, 5.16; N, 11.96; Found: C, 68.43; H, 5.25; N, 11.85.

2-Diisopropylamino-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5d). White crystals (yield: 0.61 g, 80%), Mp: 171–172°C; ^{1}H NMR ($CDCl_3$, 400 MHZ) δ = 1.13 (d, *J* = 6.4 Hz, 12H, 4 × CH_3), 3.52 (m, 2H, 2 × NCH), 7.17–8.00 (m, 8H, Ar-H); IR (KBr): 1702 (C=O), 1539, 1245, 1098 cm^{-1}; MS (70 eV) *m*/*z* (%): 379 (M^+, 14), 336 (100), 322 (22), 130 (9.5), 102 (4), 99 (17); Anal. Calcd for

Table 2

The fungicidal activities of **5** and **7** (50 mg/L).

Compounds	Relative inhibition %					
	Fusarium oxysporium	*Rhizoctonia solani*	*Botrytis cinerea*	*Gibberella zeae*	*Dothiorella gregaria*	*Colletotrichum gossypii*
5a	21.1	30.2	45.0	41.4	50.5	31.1
5b	47.5	68.5	78.0	62.9	32.8	43.3
5c	48.5	62.2	75.0	28.6	22.9	48.5
5d	42.2	17.1	25.0	38.6	37.7	28.5
5e	54.3	62.4	50.0	31.4	24.7	48.5
5f	55.6	66.4	58.8	56.1	39.5	65.2
5g	31.1	12.0	30.0	42.9	34.7	64.4
5h	38.5	18.1	75.0	15.7	25.9	32.2
5i	60.7	62.4	79.0	60.0	53.5	60.7
5j	39.8	53.6	42.0	31.2	26.5	47.8
7a	45.9	17.1	57.0	18.6	40.6	21.1
7b	35.9	17.1	35.0	18.6	10.0	38.5
7c	32.2	42.2	55.0	21.4	15.9	38.5
7d	28.5	45.1	35.0	28.6	27.9	48.5

$C_{22}H_{22}FN_3O_2$ (379.4): C, 69.64; H, 5.84; N, 11.07; Found: C, 69.71; H, 5.92; N, 11.00.

General procedure for the preparation of 2-aroxy-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones 5e–5g. To the solution of carbodiimide **3** (ca. 2 mmol) prepared above in CH_3CN (15 mL) was added K_2CO_3 (0.2 mmol) and ArOH (2 mmol) in anhydrous CH_3CN (10 mL). The mixture was stirred for 6–8 h at 50–60°C. The solution was concentrated under reduced pressure and the residue was recrystallized from dichloromethane and ethanol (v/v = 2:1) at room temperature to give **5e–5g**.

2-(3,4-Dimethylphenoxy)-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5e). White crystals (87% yields), Mp: 172–173°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 2.25 (s, 6H, 2 × CH_3), 6.91–7.84 (m, 11H, Ar-H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 19.1, 19.8, 112.7, 116.4, 116.6, 118.2, 121.7 (1), 122.3, 123.5, 129.5, 129.8 (2), 130.2, 130.5, 134.3, 135.5, 138.0, 142.0, 149.7, 153.6, 157.2, 161.4, 163.8; IR (KBr): 1698 (C═O), 1536, 1332, 1112 cm^{-1}; MS (70 eV) *m*/*z* (%): 400 (47), 262 (100),130 (30),102 (16), 95 (6); Anal. Calcd for $C_{19}H_{16}FN_3O_2$ (400.4): C, 71.99; H, 4.28; N, 7.00. Found: C, 72.05; H, 4.34; N, 6.96.

2-(4-Chloro-2-methyl-phenoxy)-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5f). White crystals (81% yield), Mp: 241–242°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 2.18 (s, 3H, Ar-CH_3), 7.16–7.82 (m, 13H, Ar-H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 16.5, 112.8, 116.8, 121.8, 122.2, 123.7, 127.5, 127.7, 129.4, 129.8, 130.2, 131.6, 134.1, 135.7, 142.0, 145.1, 151.5, 153.4, 157.3, 161.6, 164.1. IR (KBr): 1701 (C═O), 1543, 1328, 1098 cm^{-1}; MS (70 eV) *m*/*z* (%): 420 (M$^+$, 22), 282 (100), 130 (21), 95 (4); Anal. Calcd for $C_{23}H_{14}ClFN_2O_3$ (420.1): C, 65.64; H, 3.35; N, 6.66. Found: C, 65.61; H, 3.37; N, 6.59.

2-(4-Methyl-phenoxy)-3-(4-fluro-phenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5g). White crystals (88% yield), Mp: 170–172°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 2.37 (s, 3H, Ar-CH_3), 7.04–7.86 (m, 13H, Ar-H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 20.8, 112.8, 116.4, 116.7, 120.9, 121.3, 122.9, 123.2, 129.6, 129.8 (2), 130.5, 135.5, 135.7, 142.0, 149.6, 153.5, 157.3, 161.4, 163.9. IR (KBr): 1705 (C═O), 1539, 1346, 1108 cm^{-1}; MS (70 eV) *m*/*z* (%): 386 (M$^+$, 44), 249 (100), 130 (27), 95 (6); Anal. Calcd for $C_{23}H_{15}FN_2O_3$ (386.4): C, 71.50; H, 3.91; N, 7.25. Found: C, 71.42; H, 3.88; N, 7.19.

General procedure for the preparation of 2-alkoxy-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-ones 5h–5i. To the solution of carbodiimide **3** (ca. 2 mmol) prepared above in anhydrous ROH (8 mL) was added RO^-Na^+ (0.2 mmol, 10% equiv) in ROH. The mixture was stirred for 4–6 h at room temperature. The solution was condensed and the residue was recrystallized from ROH to give **5h–5i**.

2-Methoxy-3-(4-florophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5h). White crystals (yield: 0.54 g, 87%), Mp: 236–237°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 4.04 (s, 3H, CH_3), 7.19–8.03 (m, 8H, Ar-H); IR (KBr): 1701 (C═O), 1541, 1340, 1108 cm^{-1}; MS (70 eV) *m*/*z* (%): 310 (100), 136 (33), 130 (47), 108 (98), 102 (68), 95 (28), 75 (16); Anal. Calcd for $C_{19}H_{16}FN_3O_2$ (310.3): C, 65.81; H, 3.57; N, 9.03. Found: C, 65.87; H, 3.62; N, 8.98.

2-Ethoxy-3-(4-florophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (5i). White crystals (yield: 0.56 g, 89%), Mp: 202–204°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.28 (t, *J* = 7.2, 3H, CH_3), 4.50 (d, *J* = 7.2, 2H, CH_2), 7.19–8.02 (m, 8H, Ar-H); IR (KBr): 1699 (C═O), 1540, 1339, 1112 cm^{-1}; MS (70 eV) *m*/*z* (%): 324 (M$^+$, 96), 295 (46), 185 (68), 158 (100), 130 (20), 102 (70), 95 (10); Anal. Calcd for $C_{18}H_{13}FN_2O_3$ (324.3): C, 66.66; H, 4.04; N, 8.64. Found: C, 66.71; H, 4.10; N, 8.60.

General procedure for the preparation of 2-alkylamino-benzofuro [3,2-d] pyrimidin-4(3H)-ones 7a–7c. To the solution of carbodiimide **3** (ca. 2 mmol) prepared above in methylene chloride (15 mL) was added alkylamine (2 mmol). After the reaction mixture was allowed to stand for 0.5–2 h, the solution was condensed and anhydrous ethanol (10 mL) with several drops of EtO^-Na^+ in EtOH was added. The mixture was stirred for 1–4 h at room temperature. The solution was concentrated under reduced pressure and the residual was recrystallized from ethanol and dichloromethane (v/v = 1:2) at room temperature to give 2-alkylamino-benzofuro [3,2-d] pyrimidin-4(3H)-ones **7a–7c**.

3-(4-Fluorophenyl)-2-(n-propylamino)-benzofuro [3,2-d] pyrimidin-4(3H)-one (7a). White crystals (yield: 0.56 g, 83%), Mp: 199–200°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 0.87 (t, *J* = 7.2 Hz, 3H, CH_3), 1.54–1.60 (m, 2H, CH_2), 3.42–3.47 (m, 2H, NCH_2), 4.11 (s, 1H, NH), 7.30–8.02 (m, 8H, Ar-H); IR (KBr): 3341 (N─H), 1699 (C═O), 1540, 1342, 1111 cm^{-1}; MS (70 eV) *m*/*z* (%): 337 (M$^+$, 32), 294 (100), 185 (35), 160 (64), 130 (71), 102 (82), 95 (53); Anal. Calcd for $C_{19}H_{16}FN_3O_2$ (337.4): C, 67.65; H, 4.78; N, 12.46. Found: C, 67.71; H, 4.84; N, 12.37.

3-(4-Fluorophenyl)-2-(n-butylamino)-benzofuro [3,2-d] pyrimidin-4(3H)-one (7b). White crystals (yield: 0.56 g, 79%), Mp: 191–192°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 0.89 (t, *J* = 7.2 Hz, 3H, CH_3), 1.25–1.54 (m, 4H, 2 × CH_2), 3.43–3.47 (m, 2H, NCH_2), 4.14 (s, 1H, NH), 7.29–8.01 (m, 8H, Ar-H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 13.6, 19.8, 31.0, 41.8, 112.6, 117.6 (2), 121.5, 122.9, 123.0, 129.2, 130.8 (1), 132.9, 144.6, 151.8, 153.6, 157.2, 161.7,164.2. IR (KBr): 3336 (N─H), 1704 (C═O), 1533, 1340, 1115 cm^{-1}; MS (70 eV) *m*/*z* (%): 351 (M$^+$, 78), 334 (41),308 (35), 294 (100), 185 (48), 130 (70),102 (82), 95 (52); Anal. Calcd for $C_{20}H_{18}FN_3O_2$ (351.4): C, 68.36; H, 5.16; N, 11.96. Found: C, 68.33; H, 5.20; N, 11.89.

2-(Cyclohexylamino)-3-(4-fluorophenyl)-benzofuro [3,2-d] pyrimidin-4(3H)-one (7c) White crystals (yield: 0.66 g, 88%), Mp: 188–190°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 1.05–1.42 (m, 6H, 3 × CH_2), 1.60–1.62 (m, 4H, 2 × CH_2), 1.96–1.99 (m, 1H, CH), 4.02–4.05 (m, 1H, NH), 7.19–8.04 (m, 9H, Ar-H); IR (KBr): 1704 (C═O), 1533, 1340, 1115 cm^{-1}; MS (70 eV) *m*/*z* (%): 377 (M$^+$, 22), 294 (100), 185 (20), 130 (29),102 (30), 98 (27), 55 (26); Anal. Calcd for $C_{22}H_{20}FN_3O_2$ (377.4): C, 70.01; H, 5.34; N, 11.13. Found: C, 69.97; H, 5.37; N, 11.08.

Fungicidal testing. *F. oxysporium, R. solani, B. cinereapers, G. zeae, D. gregaria,* and *C. gossypii* were provided through the courtesy of the Center for bioassay, Central China Normal University. The tested samples were dissolved in 0.5 mL of DMF, added to a drop of emulsifying agent (Tween 80) and sterile water at a concentration of 500 mg/L. The solutions (1 mL) were mixed rapidly with thawed potato glucose agar culture medium (9 mL) under 50°C. The mixtures were poured into Petri dishes. After the dishes were cooled, the solidified plates were incubated with 4 mm mycelium disk, inverted, and incubated at 28°C for 48 h. The mixed medium without

sample was used as the blank control. Three replicates of each test were carried out. The mycelial elongation radius (mm) of fungi settlements was measured after 48 h of culture. The growth inhibition rates were calculated with the following equation: $I = [(C-T)/C] \times 100\%$. Here, I is the growth inhibition rate (%), C is the control settlement radius (mm), and T is the treatment group fungi settlement radius (mm).

Crystal structure determination. Single crystal X-ray diffraction data for **7b** at 292 K on a Bruker Smart Apex Area CCD equipped with Mo Ka radiation ($\lambda = 0.71073$ A°). Crystallographic data (excluding structure factors) for the structures in this article have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication No. CCDC 671114. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge CB2 1EZ.

Acknowledgments. The authors acknowledge the financial support of this work by the Key Science Research Project of Hubei Provincial Department of Education (No. D200724001), the Science Research Project of Yunyang Medical College (No. 2006QDJ16), and the Science Innovation Team Research Project of Yunyang Medical College (No. 2008 CXG01).

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[12] Crystal data of **7b**. $C_{20}H_{18}FN_3O_2$, Mr = 351.37; Crystal system: tetragonal; space group: P-42(1)c; unit cell dimensions: a = 11.0922(6), b = 11.0922(6), c = 28.6271(15)Å, V = 3522.2(3) Å3, Z = 8, Dc = 1.325, F (000) = 1472, $\mu = 0.095$ mm^{-1}, MoKa radiation ($\lambda = 0.71073$), $R = 0.0498$, wR = 0.1238 for 2336 observed reflections with $I > 2\sigma(I)$.

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