REACTIONS OF CYCLOHEXYL AND ARYL PYRAZINYL SULFOXIDES WITH TRIFLUOROACETIC ANHYDRIDE

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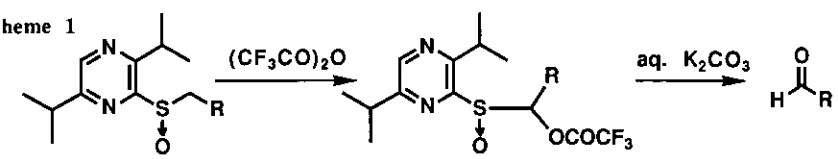
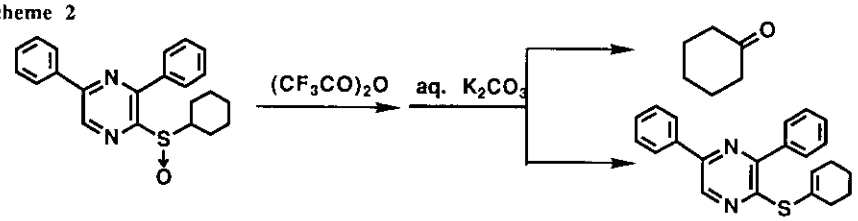
Abstract---Cyclohexyl pyrazinyl sulfoxides reacted with trifluoroacetic anhydride to give 1-cyclohexenyl pyrazinyl sulfides and/or cyclohexyl hydroxypyrazinyl sulfides. The presence of alkyl groups on the pyrazine ring is essential to obtain the latter compounds.

The reaction of alkyl phenyl sulfoxides with carboxylic anhydride gives α-acyloxyalkyl phenyl sulfides and is well known as the Pummerer rearrangement.[1] Recently, we reported[2] that primary alkyl pyrazinyl sulfoxides give aldehydes in good yields via this rearrangement (Scheme 1). We then attempted to synthesize ketones using secondary alkyl pyrazinyl sulfoxides by this procedure. The reaction of 2-cyclohexylsulfinyl-3,5-diphenylpyrazine with trifluoroacetic anhydride (TFAA) did not yield the desired cyclohexanone but produce 2-(1-cyclohexenylthio)-3,5-diphenylpyrazine (Scheme 2). On the other hand, 2-cyclohexylsulfinyl-3,6-dipropylpyrazine was converted to 2-cyclohexylthio-5-hydroxy-3,6-dipropylpyrazine by the reaction with TFAA and successive work-up with water (Scheme 3). We now present the reactions of various pyrazinyl sulfoxides with TFAA.

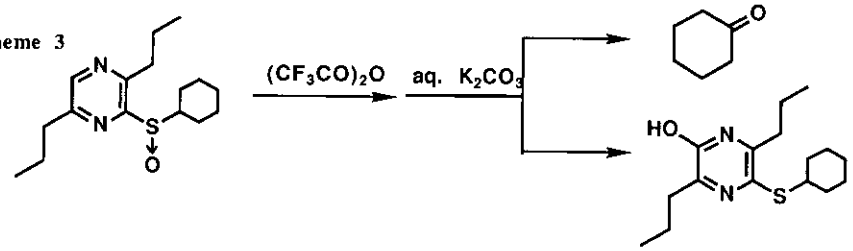
Scheme 1



Scheme 2

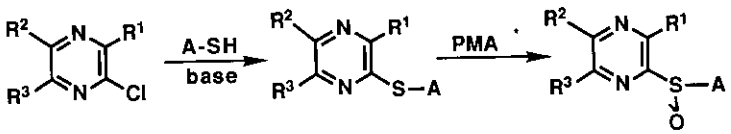


Scheme 3



The starting materials, cyclohexyl and aryl pyrazinyl sulfoxides (3a-h), were prepared from 2-chloropyrazines and the corresponding mercaptans according to the procedure shown in Table 1.

Table 1



Entry No.	2-Chloropyrazines	R^1	R^2	R^3	Mercaptans A	Compd No. (Yields %) Sulfides	Sulfoxides
1	**1a**[5]	H	H	H	Cy	**2a** (86)	**3a** (66)
2	**1b**[6]	Ph	Ph	H	Cy	**2b** (46)	**3b** (98)
3	**1c**[5]	Me	H	Me	Cy	**2c** (64)	**3c** (99)
4	**1d**[7]	Et	H	Et	Cy	**2d** (74)*	**3d** (99)
5	**1e**[8]	n-Pr	H	n-Pr	Cy	**2e** (66)	**3e** (71)
6	**1a**	H	H	H	Ph	**2f** (70)	**3f** (75)
7	**1c**	Me	H	Me	Ph	**2g** (54)	**3g** (89)
8	**1c**	Me	H	Me	Py	**2h** (67)	**3h** (89)

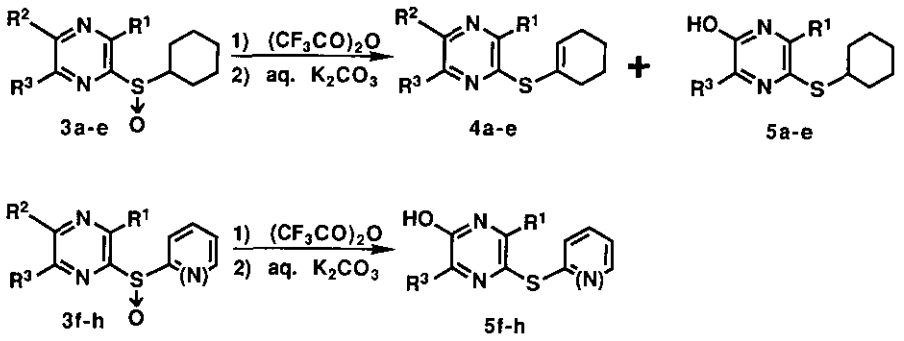
Cy = Cyclohexyl Ph = Phenyl Py = 2-Pyridyl

* This yield was calculated from a ^{1}H-nmr spectrum of the mixture of **1d** and **2d**.

PMA = Permaleic Acid[2]

The results of the reactions of 3a-h with TFAA are shown in Table 2. The products were vinyl pyrazinyl sulfides (4) and/or 5-hydroxypyrazin-2-yl sulfides (5). The compounds (3a and 3f) with no alkyl groups on their pyrazine ring did not give 5. The yields of 4c-e decreased while the yields of 5c-e increased as the size of their alkyl groups became larger.

Table 2



Entry No.	Sulfoxides	Products (Yields %) Compd 4	Compd 5
1	3a	4a (74)	5a (trace)
2*	3b	4b (58)	5b****
3	3c	4c (56)	5c (45)
4	3d	4d (42)	5d (56)
5	3e	4e (37)	5e (68)
6**	3f	4f****	5f (trace)
7	3g	4g****	5g (56)
8***	3h	4h****	5h (0)

* None of 2-cyclohexylthio-6-hydroxy-3,5-diphenylpyrazine was detected.

** The starting material (3f) was recovered (88%).

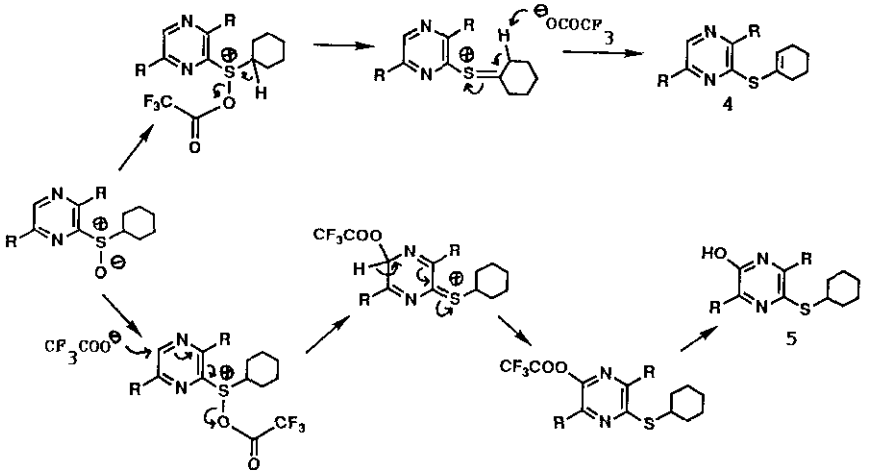
*** The starting material (3h) was recovered (60%).

**** These compounds cannot be produced theoretically.

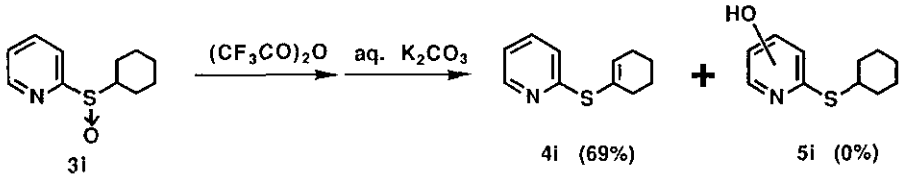
We suggest that these reactions proceed via the routes described in Scheme 4 and the alkyl groups substituted at the 3-position of the pyrazine ring opposes the reaction pathway to 4 by the attack of the trifluoroacetate anion on the ß-hydrogen of the sulfur ylides. The isolation of 5-trifluoroacetoxy-2-cyclohexylthiopyrazines, which must be intermediates on the way to 5, was attempted, but could not be accomplished.

The unstability of acyloxypyrazines to bases has been reported[3] and it is thought that the strong electron-withdrawing ability of the trifluoromethyl group significantly affects this unstability. The reaction of 3,6-dimethyl-2-phenylthiopyrazine with acetic anhydride was then carried out with the expectation of obtaining 5-acetoxy-3,6-dimethyl-2-phenylthiopyrazine. However, this reaction did not proceed even under reflux in acetic anhydride. The starting sulfoxide and only a few 2-acetoxy-3,6-dimethylpyrazine were obtained.

Scheme 4

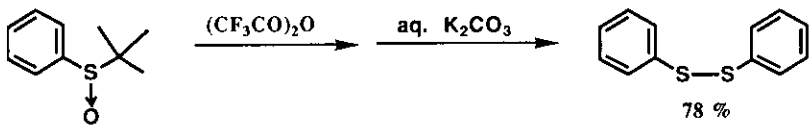


The reaction of cyclohexyl pyridyl sulfoxide (3i), which was prepared from bromocyclohexane and 2-mercaptopyridine, with TFAA was also examined. The main product was 1-cyclohexenyl 2-pyridyl sulfide (4i) in 69 % yield and the corresponding hydroxy compound (5i) was not obtained. It was suggested from the results of entry 8 in Table 2 and this experiment using 3i that the presence of a pyridine ring gives an adverse effect to the preparation of hydroxyaryl compounds.



3i 4i (69%) 5i (0%)

In the present reaction of aryl sulfoxides with TFAA in acetonitrile, tert-butyl phenyl sulfoxide, which was prepared by the oxidation of tert-butyl phenyl sulfide[4] with permaleic acid, gave an interesting result. The main product was diphenyl disulfide against our expectation. This mechanism is now in study.



EXPERIMENTAL

The melting and boiling points are uncorrected. ^{1}H-Nmr spectra were obtained using a Varian Gemini-300 (300 MHz) with TMS as the internal standard and $CDCl_3$ as the solvent. The following instruments were used to obtain the other spectral data. Ir spectra: Japan Spectroscopic Co. A100; ms: Hitachi M-80B spectrometer.

General Procedure for the Synthesis of 2-Cyclohexylthiopyrazines (2a-e)

To a MeOH solution of NaOMe prepared from 60% NaH (0.44 g, 11 mmol) and anhydrous MeOH (50 ml) were successively added cyclohexylmercaptan (1.28 g, 11 mmol) and chloropyrazines[5-8] (1a-e: 10 mmol). The solution was refluxed for 5 h, the solvent was removed in vacuo and the residue was extracted with Et_2O. After drying over Na_2SO_4, Et_2O was removed to obtain crude products, which were purified by silica gel column chromatography (Wakogel C-200, n-hexane/AcOEt (9/1)).

2-Cyclohexylthiopyrazine (2a)

Colorless oil; bp 115-120°C / 5 torr; ms: m/z 194 (M^+); ^{1}H-nmr: δ 1.20-2.13 (m, 10H, cyclohexyl H), 3.60-4.00 (m, 1H, SCH), 8.06 (d, J = 3.0 Hz, 1H, pyrazine 6-H), 8.30 (dd, J = 2.0 and 3.0 Hz, 1H, pyrazine 5-H), 8.40 (d, J = 2.0 Hz, 1H, pyrazine 3-H) ppm; high resolution ms: Calcd for $C_{10}H_{14}N_2S$: 194.0876. Found: 194.0852.

2-Cyclohexylthio-3,5-diphenylpyrazine (2b)

Colorless viscous oil; ms: m/z 346 (M^+); ^{1}H-nmr: δ 1.33-2.13 (m, 10H, cyclohexyl H), 3.67-4.03 (m, 1H, SCH), 7.33-7.43 (m, 6H, benzene H X 2), 7.70-7.80 (m, 2H,

benzene H), 7.92-8.02 (m, 2H, benzene H), 8.70 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{22}H_{22}N_2S$: 346.1502. Found: 346.1483.

2-Cyclohexylthio-3,6-dimethylpyrazine (**2c**)

Colorless oil; bp 125-130°C / 3 torr; ms: m/z 222 (M^+); ^{1}H-nmr: δ 1.27-2.08 (m, 10H, cyclohexyl H), 2.40 (s, 6H, CH_3 X 2), 3.62-4.03 (m, 1H, SCH), 7.82 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{12}H_{18}N_2S$: 222.1190. Found: 222.1206.

2-Cyclohexylthio-3,6-diethylpyrazine (**2d**)

This compound could not be isolated from the reaction mixture. The content of this compound in the reaction mixture was measured from the ratio of peak areas based on 5-H of pyrazine rings of **1d** and **2d** in the ^{1}H-nmr spectrum of the mixture of them and the following oxidation (from **2d** to **3d**) was carried out without isolation of **2d**.

2-Cyclohexylthio-3,6-dipropylpyrazine (**2e**)

Colorless oil; bp 120-123°C / 3 torr; ms: m/z 278 (M^+); ^{1}H-nmr: δ 0.97 (t, J = 7 Hz, 3H, $CH_2CH_2C\underline{H}_3$), 1.00 (t, J = 7.0 Hz, 3H, $CH_2CH_2C\underline{H}_3$), 1.39-2.10 (m, 14H, $CH_2C\underline{H}_2CH_3$ X 2 and cyclohexyl H), 2.67 (t, J = 7.0 Hz, 2H, $C\underline{H}_2CH_2CH_3$), 2.70 (t, J = 7.0 Hz, 2H, $C\underline{H}_2CH_2CH_3$), 3.86-3.98 (m, 1H, SCH), 7.97 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{16}H_{26}N_2S$: 278.1814. Found: 278.1793.

General Procedure for the Synthesis of 2-Arylthiopyrazines (2f-h)

A mixture of 60 % NaH (0.44 g, 11 mmol), aryl mercaptans (11 mmol) and 2-chloropyrazines[5] (**1a,c**: 10 mmol) was refluxed for 5 h in Me_2SO (50 ml). The reaction mixture was poured into water (300 ml) and extracted with Et_2O. The Et_2O solution was treated according to the synthesis of **2a-e**.

2-Phenylthiopyrazine (**2f**)

Colorless oil; bp 110-115°C / 2 torr; ms: m/z 188 (M^+); ^{1}H-nmr: δ 7.44-7.48 (m, 3H, benzene H), 7.60-7.63 (m, 2H, benzene H), 8.20 (d, J = 2.0 Hz, 1H, pyrazine 3-H), 8.24 (d, J = 3.0 Hz, 1H, pyrazine 6-H), 8.35 (dd, J = 2.0 and 3.0 Hz, 1H, pyrazine 5-H) ppm; high resolution ms: Calcd for $C_{10}H_8N_2S$: 188.0407. Found: 188.0384.

3,6-Dimethyl-2-phenylthiopyrazine (**2g**)

Colorless viscous oil; ms: m/z 216 (M^+); ^{1}H-nmr: δ 2.30 (s, 3H, CH_3), 2.51 (s, 3H, CH_3), 7.30-7.53 (m, 5H, benzene H), 8.03 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{12}H_{12}N_2S$: 216.0720. Found: 216.0736.

3,6-Dimethyl-2-(2-pyridylthio)pyrazine (**2h**)

Pale yellow viscous oil; ms: m/z 217 (M^+); ^{1}H-nmr: δ 2.43 (s, 3H, CH_3), 2.60 (s, 3H, CH_3), 7.03-7.70 (m, 3H, pyridine 3-, 4- and 5-H), 8.17 (s, 1H, pyrazine H), 8.45 (dd, J = 2.0 and 6.0 Hz, 1H, pyridine 6-H) ppm; high resolution ms: Calcd for $C_{11}H_{11}N_3S$: 217.0675. Found: 217.0672.

Synthesis of 2-Cyclohexylthiopyridine (2i)

A mixture of 2-mercaptopyridine (1.16 g, 10 mmol), bromocyclohexane (1.79 g, 11 mmol) and 60% NaH (0.44 g, 11 mmol) was refluxed in 1,2-dimethoxyethane (50 ml) for 3 h. The reaction mixture was treated according to the synthesis of **2f-h**. Colorless viscous oil; yield: 64 %; ms: m/z 193 (M^+); ^{1}H-nmr: δ 1.25-2.25 (m, 10H, cyclohexyl H), 3.60-4.00 (m, 1H, SCH), 6.80-7.63 (m, 3H, pyridine 3-, 4- and 5-H), 8.36 (dd, J = 2.0 and 6.0 Hz, 1H, pyridine 6-H) ppm; high resolution ms: Calcd for $C_{11}H_{15}NS$: 193.0926. Found: 193.0915.

General Procedure for the Synthesis of 2-Cyclohexylsulfinylpyrazines (3a-e), 2-Arylsulfinylpyrazines (3f-h) and 2-Phenylsulfinylpyridine (3i)

Sulfoxides (**3a-i**) were prepared by oxidation of **2a-i** with permaleic acid (PMA) according to the previous report.[2]

2-Cyclohexylsulfinylpyrazine (**3a**)

Colorless viscous oil; ir (neat): 1055 cm^{-1} (ν_{so}); ms: m/z 210 (M^+); ^{1}H-nmr: δ 1.15-2.25 (m, 10H, cyclohexyl H), 2.70-3.20 (m, 1H, SCH), 8.63 (d, J = 3.0 Hz, 1H, pyrazine 6-H), 8.69 (dd, J = 2.0 and 3.0 Hz, 1H, pyrazine 5-H), 9.16 (d, J = 2.0 Hz, 1H, pyrazine 3-H) ppm; high resolution ms: Calcd for $C_{10}H_{14}N_2OS$: 210.0828. Found: 210.0833.

2-Cyclohexylsulfinyl-3,5-diphenylpyrazine (**3b**)

Colorless prisms; mp 134-135°C ($isoPr_2O$); ir (KBr): 1050 cm^{-1} (ν_{so}); ms: m/z 362 (M^+); ^{1}H-nmr: δ 1.00-1.95 (m, 10 H, cyclohexyl H), 3.00-3.30 (m, 1H, SCH), 7.45-7.55 (m, 6H, benzene H X 2), 7.70-7.88 (m, 2H, benzene H), 8.10-8.23 (m,

2H, benzene H), 9.16 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{22}H_{22}N_2OS$: 362.1450. Found: 362.1440.

2-Cyclohexylsulfinyl-3,6-dimethylpyrazine (3c)

Colorless viscous oil; ir (neat): 1050 cm^{-1} (ν_{so}); ms: m/z 238 (M^+); ^{1}H-nmr: δ 1.102.10 (m, 10H, cyclohexyl H), 2.62 (s, 3H, CH_3), 2.70 (s, 3H, CH_3), 2.83-3.33 (m, 1H, SCH), 8.33 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{12}H_{18}N_2OS$: 238.1139. Found: 238.1146.

2-Cyclohexylsulfinyl-3,6-diethylpyrazine (3d)

Colorless viscous oil; ir (neat): 1055 cm^{-1} (ν_{so}); ms: m/z 266 (M^+); ^{1}H-nmr: δ 1.102.10 (m, 10H, cyclohexyl H), 1.32 (t, J = 7.0 Hz, 6H, $CH_2C\underline{H}_3$ X 2), 2.90 (q, J = 7.0 Hz, 2H, $C\underline{H}_2CH_3$), 3.04 (q, J = 7.0 Hz, 2H, $C\underline{H}_2CH_3$), 3.10-3.43 (m, 1H, SCH), 8.46 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{14}H_{22}N_2OS$: 266.1451. Found: 266.1439.

2-Cyclohexylsulfinyl-3,6-dipropylpyrazine (3e)

Colorless viscous oil; ir (neat); 1055 cm^{-1} (ν_{so}); ms: m/z 294 (M^+); ^{1}H-nmr: δ 1.00 (t, J = 7.0 Hz, 3H, $CH_2CH_2C\underline{H}_3$), 1.05 (t, J = 7.0 Hz, 3H, $CH_2CH_2C\underline{H}_3$), 1.30-2.20 (m, 14H, $CH_2C\underline{H}_2CH_3$ X 2 and cyclohexyl H), 2.88 (t, J = 7.0 Hz, 2H, $C\underline{H}_2CH_2CH_3$), 3.00 (t, J = 7.0 Hz, 2H, $C\underline{H}_2CH_2CH_3$), 3.25-3.38 (m, 1H, SCH), 8.49 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{16}H_{26}N_2OS$: 294.1764. Found: 294.1787.

2-Phenylsulfinylpyrazine (3f)

Colorless prisms; mp 76-78°C (isoPr$_2$O); ir (KBr): 1040 cm^{-1} (ν_{so}); ms: m/z 204 (M^+); ^{1}H-nmr: δ 7.48-7.54 (m, 3H, benzene H), 7.80-7.86 (m, 2H, benzene H), 8.52 (d, J = 2.0 Hz, 1H, pyrazine 3-H), 8.64 (d, J = 4.0 Hz, 1H, pyrazine 6-H), 9.25 (dd, J = 2.0 and 4.0 Hz, 1H, pyrazine 5-H) ppm; Anal. Calcd for $C_{10}H_8N_2OS$: C, 58.80; H, 3.95; N, 13.72. Found: C, 58.63; H, 3.96; N, 13.74.

3,6-Dimethyl-2-phenylsulfinylpyrazine (3g)

Colorless plates; mp 76-77°C (n-heptane); ir (KBr): 1055 cm^{-1} (ν_{so}); ms: m/z 232 (M^+); ^{1}H-nmr: δ 2.36 (s, 3H, CH_3), 2.44 (s, 3H, CH_3), 7.20-7.30 (m, 3H, benzene H), 7.467.60 (m, 2H, benzene H), 8.16 (s, 1H, pyrazine H) ppm; Anal. Calcd for $C_{12}H_{12}N_2OS$: C, 62.04; H, 5.21; N, 12.06. Found: C, 61.99; H, 5.23; N, 11.99.

3,6-Dimethyl-2-(2-pyridylsulfinyl)pyrazine (**3h**)

Colorless prisms; mp 93-94°C (isoPr$_2$O); ir (KBr): 1050 cm^{-1} (ν_{SO}); ms: m/z 233 (M$^+$); ^{1}H-nmr: δ 2.51 (s, 3H, CH$_3$), 2.88 (s, 3H, CH$_3$), 7.34 (ddd, J = 1.5, 4.0 and 6.0 Hz, 1H, pyridine 5-H), 7.94 (dt, J = 3.0 and 6.0 Hz, 1H, pyridine 4-H), 8.16 (dd, J = 1.5 and 6.0 Hz, 1H, pyridine 3-H), 8.38 (s, 1H, pyrazine H), 8.48 (dd, J = 3.0 and 4.0 Hz, 1H, pyridine 6-H) ppm; Anal. Calcd for $C_{11}H_{11}N_3OS$: C, 56.63; H, 4.75; N, 18.01. Found: C, 56.63; H, 4.78; N, 17.99.

2-Cyclohexylsulfinylpyridine (**3i**)

Colorless viscous oil; ir (neat): 1050 cm^{-1} (ν_{SO}); ms: m/z 209 (M$^+$); ^{1}H-nmr: δ 1.002.25 (m, 10H, cyclohexyl H), 2.70-3.10 (m, 1H, SCH), 7.35 (dd, J = 4.0 and 6.0 Hz, 1H, pyridine 5-H), 7.80-7.95 (m, 2H, pyridine 4- and 3-H), 8.60 (dd, J = 3.0 and 4.0 Hz, 1H, pyridine 6-H) ppm; high resolution ms: Calcd for $C_{11}H_{15}NOS$: 209.0880. Found: 209.0895.

General Procedure for the Reaction of 3a-i with TFAA

To a solution of **3a-i** (1 mmol) in anhydrous CH$_3$CN (20 ml) was added (CF$_3$CO)$_2$O (2 ml). The mixture was allowed to stand overnight at room temperature and poured into water (100 ml). The aqueous solution was neutralized with powdered K$_2$CO$_3$ and extracted with Et$_2$O. After dryness over Na$_2$SO$_4$, the solvent was removed to obtain crude products, which were purified by column chromatography (Kieselgel 60, 230-400 mesh, n-hexane/AcOEt (9/1) or recrystallization in the case of solid products.

2-(1-Cyclohexenylthio)pyrazine (**4a**)

Pale yellow viscous oil; ms: m/z 192 (M$^+$); ^{1}H-nmr: δ 1.60-1.80 (m, 4H, cyclohexenyl 4- and 5-H), 2.20-2.30 (m, 4H, cyclohexenyl 3- and 6-H), 6.40 (m, 1H, cyclohexenyl 2-H), 8.24 (d, J = 3.0 Hz, 1H, pyrazine 6-H), 8.38 (dd, J = 2.0 and 3.0 Hz, 1H, pyrazine 5-H), 8.43 (d, J = 2.0 Hz, 1H, pyrazine 3-H) ppm; high resolution ms: Calcd for $C_{10}H_{12}N_2S$: 192.0721. Found: 192.0724.

2-(1-Cyclohexenythio)-3,5-diphenylpyrazine (**4b**)

Colorless prisms; mp 114-115°C (MeOH); ^{1}H-nmr: δ 1.45-1.75 (m, 4H, cyclohexenyl 4 and 5-H), 2.10-2.30 (m, 4H, cyclohexenyl 3- and 6-H), 6.16-6.30 (m, 1H, cyclohexenyl 2-H), 7.73-7.83 (m, 5H, benzene H), 7.96-8.10 (m, 5H, benzene H), 8.80 (s, 1H, pyrazine H) ppm; Anal. Calcd for $C_{22}H_{20}N_2S$: C, 76.71; H, 5.85; N, 8.13. Found: C, 76.38; H, 5.93; N, 8.14.

2-(1-Cyclohexenylthio)-3,6-dimethylpyrazine (**4c**)

Pale yellow viscous oil; ms: m/z 220 (M^+); ^{1}H-nmr: δ 1.65-1.80 (m, 4H, cyclohexenyl 4- and 5-H), 2.20-2.35 (m, 4H, cyclohexenyl 3- and 6-H), 2.48 (s, 6H, CH_3 X 2), 6.23-6.28 (m, 1H, cyclohexenyl 2-H), 8.00 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{12}H_{16}N_2S$: 220.1033. Found: 220.1016.

2-(1-Cyclohexenylthio)-3,6-diethylpyrazine (**4d**)

Pale yellow viscous oil; ms: m/z 248 (M^+); ^{1}H-nmr: δ 1.28 (t, J = 7.0 Hz, 6H, $CH_2\underline{CH}_3$ X 2), 1.60-1.80 (m, 4H, cyclohexenyl 4- and 5-H), 2.20-2.40 (m, 4H, cyclohexenyl 3- and 6-H), 2.74 (q, J = 7.0 Hz, 2H, $\underline{CH}_2CH_3$), 2.76 (q, J = 7.0 Hz, 2H, $\underline{CH}_2CH_3$), 6.23-6.30 (m, 1H, cyclohexenyl 2-H), 8.03 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{14}H_{20}N_2S$: 248.1346. Found: 248.1363.

2-(1-Cyclohexenylthio)-3,6-dipropylpyrazine (**4e**)

Pale yellow viscous oil; ms: m/z 274 (M^+); ^{1}H-nmr: δ 0.96 (t, J = 7.0 Hz, 3H, $CH_2CH_2\underline{CH}_3$), 1.00 (t, J = 7.0 Hz, 3H, $CH_2CH_2\underline{CH}_3$), 1.60-1.80 (m, 8H, $CH_2\underline{CH}_2CH_3$ X 2 and cyclohexenyl 4- and 5-H), 2.18-2.30 (m, 4H, cyclohexenyl 3- and 6-H), 2.69 (q, J = 7.0 Hz, 2H, $\underline{CH}_2CH_2CH_3$), 2.73 (q, J = 7.0 Hz, 2H, $\underline{CH}_2CH_2CH_3$), 6.23-6.28 (m, 1H, cyclohexenyl 2-H), 8.00 (s, 1H, pyrazine H) ppm; high resolution ms: Calcd for $C_{16}H_{24}N_2S$: 276.1662. Found: 276.1681.

2-(1-Cyclohexenylthio)pyridine (**4i**)

Pale yellow viscous oil; ms: m/z 191 (M^+), ^{1}H-nmr: δ 1.50-1.80 (m, 4H, cyclohexenyl 4- and 5-H), 2.10-2.30 (m, 4H, cyclohexenyl 3- and 6-H), 6.26-6.33 (m, 1H, cyclohexenyl 2-H), 6.86-7.26 (m, 3H, pyridine 3-, 4- and 5-H), 8.40 (dd, J = 2.0 and 6.0 Hz, 1H, pyridine 6-H) ppm; high resolution ms: Calcd for $C_{11}H_{13}NS$: 191.0767. Found: 191.0762.

2-Cyclohexylthio-5-hydrox-3,6-dimethylypyrazine (**5c**)

Colorless plates; mp 150-151°C ($isoPr_2O$); ir (KBr): 1650 cm^{-1} (ν_{CO}); ms: m/z 238 (M^+); ^{1}H-nmr: δ 1.24-1.93 (m, 10H, cyclohexyl H), 2.46 (s, 6H, CH_3 X 2), 3.21-3.27 (m, 1H, SCH) ppm; Anal. Calcd for $C_{12}H_{18}N_2OS$: C, 60.47; H, 7.61; N, 11.75. Found: C, 60.38; H, 7.65; N, 11.61.

2-Cyclohexylthio-3,6-diethyl-5-hydroxypyrazine (**5d**)

Colorless prisms; mp 116-117°C ($isoPr_2O$); ir (KBr): 1650 cm^{-1} (ν_{CO}); ms: m/z 266 (M^+); ^{1}H-nmr: δ 1.26 (t, J = 7.0 Hz, 6H, $CH_2\underline{CH}_3$ X 2), 1.10-2.00 (m, 10H,

cyclohexyl H), 2.76 (q, J = 7.0 Hz, 4H, $C\underline{H}_2CH_3$ X 2), 3.23-3.33 (m, 1H, SCH) ppm; Anal. Calcd for $C_{14}H_{22}N_2OS$: C, 63.12; H, 8.32; N, 10.52. Found: C, 63.17; H, 8.27; N, 10.60.

2-Cyclohexylthio-5-hydroxy-3,6-dipropylpyrazine (**5e**)

Colorless prisms; mp 137-138°C (isoPr$_2$O); ir (KBr): 1650 cm^{-1} (ν_{CO}); ms: m/z 294 (M^+); ^{1}H-nmr: δ 0.98 (t, J = 7.0 Hz, 3H, $CH_2CH_2C\underline{H}_3$), 1.01 (t, J = 7.0 Hz, 3H, $CH_2CH_2C\underline{H}_3$), 1.25-1.95 (m, 14H, $CH_2C\underline{H}_2CH_3$ X 2 and cyclohexyl H), 2.73 (t, J = 7.0 Hz, 2H, $C\underline{H}_2CH_2CH_3$), 2.77 (t, J = 7.0 Hz, 2H, $C\underline{H}_2CH_2CH_3$), 3.30-3.40 (m, 1H, SCH) ppm; Anal. Calcd for $C_{16}H_{26}N_2OS$: C, 65.26; H, 8.90; N, 9.51. Found: C, 64.93; H, 8.79; N, 9.47.

5-Hydroxy-3,6-dimethyl-2-phenylthiopyrazine (**5g**)

Colorless prisms; mp 162-164°C (isoPr$_2$O); ir (KBr): 1650 cm^{-1} (ν_{CO}); ms: m/z 232 (M^+); ^{1}H-nmr: δ 2.43 (s, 3H, CH_3), 2.46 (s, 3H, CH_3), 7.10-7.23 (m, 5H, benzene H) ppm; Anal. Calcd for $C_{12}H_{12}N_2OS$: C, 62.04; H, 5.21; N, 12.06. Found: C, 61.96; H, 5.23; N, 12.10.

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