Regioselective alkylation of saccharin with alcohols under Mitsunobu conditions

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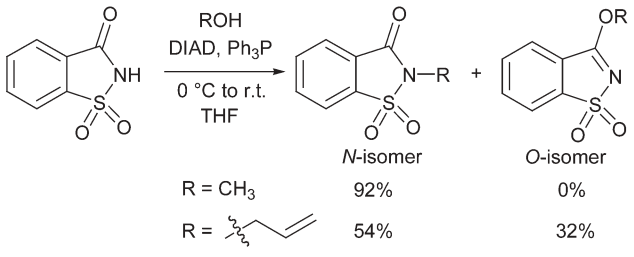
The regioselective Mitsunobu alkylation of saccharin with various alcohols has been examined. The N/O-alkylation is dependent on the steric hindrance of the alcohols, that is, less sterically hindered alcohol preferentially afford N-alkylated saccharin and *vice versa*.

Keywords: saccharin, Mitsunobu reaction, alkylation, steric effect, regioselectivity

Saccharin is a well-known heterocyclic compound and has been used as a sweetener in the form of its sodium salt. It is also found as a key structural element in various biologically active compounds, such as human leukocyte elastase (HLE) inhibitors, analgesics and tyrosinase inhibitors.[1] The *N*-alkyl derivatives of saccharin, normally prepared by the reaction of sodium saccharin with alkyl halides, have been used as important intermediates in the preparation of bioactive molecules.[2] Since saccharin is an organic acid, we reasoned that the *N*-alkylation of saccharin could be achieved by the Mitsunobu reaction[3,4] using readily available alcohols as alkylating agents, as opposed to alkyl halides that may not be commercially available.

A survey of the literature revealed that a rare case of Mitsunobu reaction of saccharin has been examined by Robinson and coworkers.[5] However, only two alcohols (benzyl alcohol and 2-bromoethanol) were investigated in this work and the regiochemistry was reported to favour the corresponding *O*-alkylation product. This regiochemical result seemed to be atypical and one-sided. In connection with our ongoing studies on the regioselective Mitsunobu reaction, herein we wish to present a systematic investigation of the Mitsunobu alkylation of saccharin with a series of alcohols.

Initially, under the same Mitsunobu conditions used in our previous research,[6] we employed methanol to attempt the regioselective alkylation of saccharin with a molar ratio of alcohol/saccharin/DIAD/Ph_3P of 1:1:1.5:1.5 equiv. To our surprise, this reaction proceeded in a completely regioselective manner to provide the *N*-methylated saccharin in 92% yield. No trace of the *O*-methylated isomer could be detected on TLC and by NMR spectroscopy (Scheme 1). Evidently, the regioselectivity observed in this case was quite different from that reported by Robinson and coworkers.[5] Next, when the same reaction was performed with allyl alcohol instead of methanol, both *N*- and *O*-allylated isomers were obtained and could be easily isolated by column chromatography in 54% and 32% yields, respectively (Scheme1). The structures of these products were conveniently confirmed by comparing their melting points and NMR data with the literature values.[7,8]



Scheme 1

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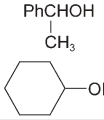
Thus, we reasoned that steric effects could play an important role on the *N*/*O* selectivity in the Mitsunobu alkylation of saccharin. In order to further determine the regioselectivity of this methodology, other commercially available alcohols were subjected to the protocol using the same reaction conditions noted above. The starting materials, products, and data obtained are summarised in Table 1. As expected, the Mitsunobu alkylation of saccharin with ethanol showed high regioselectivity for the NH group, providing the *N*-ethylated isomer as the major product in 89% yield along with a trace amount of *O*-regioisomer (Table 1, entry 3). The alkylation with 2-phenylethanol proceeded similarly well wherein the *N*-alkylated derivative was also favoured over the *O*-isomers (Table 1, entry 4). In the cases of 1-butanol and 1-octanol, however, the coupling reactions provided approximately equal amounts of *N*- and *O*-alkylated isomers (Table 1, entries 5 and 6). The alkylations of saccharin with 1-dodecanol, benzyl alcohol and 2-methyl-1-propanol showed a slight preference for the *O*-regioisomers (Table 1, entries 7–9). As anticipated, when more sterically hindered alcohols such as 2-propanol, 2-butanol, 1-phenylethanol and cyclohexanol were used, the Mitsunobu coupling reactions were clearly regioselective in favour of *O*-alkylated derivatives (Table 1, entries 10–13). Accordingly, the results obtained above indicated that the regioselectivity for the *N*/*O*-alkylation of saccharin is generally dependent on the steric hindrance of the alcohols, wherein less sterically hindered alcohol should favourably afford *N*-alkylated saccharin and vice versa. With an aim to prepare

Table 1 Regioselective alkylation of saccharin with alcohols under Mitsunobu conditions[a]

Entry	Alcohol	Yield of *N*-isomer/%[b]	Yield of *O*-isomer/%[b]
1	CH_3OH	92	0
2		54	32
3	CH_3CH_2OH	89	trace
4	$PhCH_2CH_2OH$	52	39
5	$CH_3(CH_2)_3OH$	46	43
6	$CH_3(CH_2)_7OH$	42	45
7	$CH_3(CH_2)_{11}OH$	48	45
8	$PhCH_2OH$	41	50
9	CH_3CHCH_2OH (CH3 branch)	40	47
10	$(CH_3)_2CHOH$	20	68
11	CH_3CH_2CHOH (CH3 branch)	17	62
12	$PhCHOH$ (CH3 branch)	24	58
13		22	56

[a] Standard reaction conditions: saccharin (1 equiv.), ROH (1 equiv.), Ph_3P (1.5 equiv.), DIAD (1.5 equiv.), THF (25 mL).
[b] Isolated yield by column chromatography.

the *O*-alkylated isomer exclusively, we also examined the highly hindered *t*-butanol as alkylating agent. Unfortunately, no product was observed perhaps due to the bulkiness of *t*-butanol. In all the cases listed in Table 1, the products were easily purified by column chromatography on silica gel and were characterised on the basis of physical and spectroscopic data and also by comparison with authentic samples.[5,7–10]

In conclusion, we have systematically examined the alkylation of saccharin with various alcohols under Mitsunobu conditions. It was found for the first time that the regioselectivity for the *N*/*O*-alkylation in this protocol is clearly determined by steric effects wherein the less sterically hindered alcohols tend to favour the *N*-alkylation and vice versa. This protocol has several advantages, such as mild reaction conditions, good product yields, simplicity in operation and easy availability of the substrates. Thus, we believe that this methodology will offer an important complement to the reported methods for alkylation of saccharin and will further expand the utilities of saccharin in the field of synthetic and medicinal chemistry.

Experimental

Reagents and solvents were all from commercial sources and were used without further purification. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Mercury Plus 400 MHz spectrometer. Chemical shifts were reported relative to internal tetramethylsilane (δ 0.00 ppm) or $CDCl_3$ (δ 7.26 ppm) for ^{1}H and $CDCl_3$ (δ 77.0 ppm) for ^{13}C. Melting points were measured on a Kofler apparatus and uncorrected. Column chromatography was performed on 200–300 mesh silica gel. Analytical TLC was performed on silica gel GF_{254} plates. HRMS were recorded on a Bruker Daltonics APEX II 47e spectrometer.

Alkylation of saccharin under Mitsunobu conditions, general procedure:

Diisopropyl azodicarboxylate (DIAD, 4.5 mmol) was placed in a 50 mL round-bottomed flask equipped with a stirring bar. Then triphenylphosphine (Ph_3P, 4.5 mmol) and dry tetrahydrofuran (THF, 20 mL) were added and the solution was cooled in an ice bath. Then the alcohol (3.0 mmol) was added. The mixture was then stirred for 10 min and a solution of saccharin (3.0 mmol) in dry THF (5 mL) was added dropwise. After being stirred for 30 min, the flask was removed from the ice bath and the solution was stirred at room temperature, and monitored by TLC. When the reaction was judged to be complete, the organic solvent was evaporated under reduced pressure. The residue was purified by column chromatography on silica gel using petroleum ether/EtOAc (v/v = 10:1) as the eluent to give the products. All the isolated products were characterised by physical and spectroscopic data and also by comparison with authentic samples.[5,7–10] The physical and spectral data of the products are shown as follows.

2-Methyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 132–133 °C (lit.[7] 129–130 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.26 (s, 3H), 7.83 (m, 2H), 7.93 (dd, *J* = 7.2, 1.6 Hz, 1H), 8.05 (dd, *J* = 7.2, 1.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.2, 120.9, 125.1, 127.5, 134.3, 134.6, 137.5, 158.6.

2-Allyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 88–90 °C (lit. 77–82 °C[8] or 89–90 °C[9]); ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.37 (d, *J* = 6.0 Hz, 2H), 5.30 (d, *J* = 10.0 Hz, 1H), 5.44 (d, *J* = 17.2 Hz, 1H), 5.96 (m, 1H), 7.84 (m, 2H), 7.92 (d, *J* = 7.2 Hz, 1H), 8.05 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 41.2, 119.7, 120.9, 125.1, 127.3, 130.5, 134.3, 134.7, 137.8, 158.5.

3-Allyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 139–140 °C (lit.[8] 140 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.06 (d, *J* = 6.0 Hz, 2H), 5.43 (d, *J* = 10.4 Hz, 1H), 5.52 (d, *J* = 17.2 Hz, 1H), 6.10 (m, 1H), 7.74 (m, 3H), 7.87 (d, *J* = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 72.2, 121.3, 121.8, 123.3, 126.9, 129.9, 133.4, 134.1, 143.6, 168.9.

2-Ethyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 92–94 °C (lit.[9] 93.5–94.5 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.46 (t, *J* = 7.2 Hz, 3H), 3.86 (d, *J* = 7.2 Hz, 2H), 7.87 (m, 3H), 8.05 (d, *J* = 6.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 34.7, 121.0, 125.2, 127.7, 134.4, 134.8, 138.0, 158.8.

2-(2-Phenylethyl)-1,2-benzisothiazol-3(2H)-one1,1-dioxide: Colourless solid, m.p. 138–139 °C (lit.[9] 138–139 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.15 (t, *J* = 8.2 Hz, 2H), 4.00 (t, *J* = 8.2 Hz, 2H), 7.28 (m, 5H), 7.83 (m, 2H), 7.92 (d, *J* = 7.2 Hz, 1H), 8.03 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 34.7, 40.4, 120.9, 125.1, 126.8, 127.3, 128.6, 128.9, 134.3, 134.7, 137.4, 137.7, 158.6.

3-(2-Phenylethyloxy)-1,2-benzisothiazole 1,1-dioxide: Colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.20 (t, *J* = 6.8 Hz, 2H), 4.78 (t, *J* = 6.8 Hz, 2H), 7.29 (m, 5H), 7.73 (m, 3H), 7.86 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 34.6, 72.1, 121.8, 123.2, 126.9, 127.0, 128.7, 128.9, 133.4, 134.0, 136.4, 143.5, 169.0; HRMS Calcd for $C_{15}H_{14}NO_3S$ $[M+H]^+$: 288.0689. Found: 288.0683.

2-Butyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 38–40 °C (lit.[9] 39–40 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.91 (t, *J* = 7.2 Hz, 3H), 1.37 (m, 2H), 1.77 (m, 2H), 3.71 (t, *J* = 7.6 Hz, 2H), 7.78 (m, 3H), 7.97 (dd, *J* = 6.8, 1.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.3, 19.8, 30.2, 38.9, 120.6, 124.8, 127.2, 134.1, 134.5, 137.5, 158.7.

3-Butyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 94–96 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.98 (t, *J* = 7.2 Hz, 3H), 1.48 (m, 2H), 1.86 (m, 2H), 4.58 (t, *J* = 6.8 Hz, 2H), 7.73 (m, 3H), 7.85 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.5, 18.9, 30.2, 72.0, 121.7, 123.2, 127.0, 133.4, 134.0, 143.5, 169.2; HRMS Calcd for $C_{11}H_{14}NO_3S$ $[M+H]^+$: 240.0689; found: 240.0695.

2-Octyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless oil[10]; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.86 (t, *J* = 6.8 Hz, 3H), 1.35 (m, 10H), 1.84 (m, 2H), 3.75 (t, *J* = 7.2 Hz, 2H), 7.84 (m, 3H), 8.04 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 22.6, 26.8, 28.4, 28.9, 29.0, 31.7, 39.4, 120.8, 125.0, 127.4, 134.2, 134.6, 137.7, 158.9; HRMS Calcd for $C_{15}H_{22}NO_3S$ $[M+H]^+$: 296.1315; found: 296.1309.

3-Octyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.84 (t, *J* = 6.8 Hz, 3H), 1.36 (m, 10H), 1.84 (m, 2H), 4.53 (t, *J* = 6.8 Hz, 2H), 7.69 (m, 3H), 7.81 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.8, 22.4, 25.5, 28.1, 28.9, 31.5, 72.1, 121.5, 123.2, 126.8, 133.3, 133.9, 143.3, 169.0; HRMS Calcd for $C_{15}H_{22}NO_3S$ $[M+H]^+$: 296.1315; found: 296.1326.

2-Dodecyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 49–51 °C (lit.[9] 48–50 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, *J* = 6.6 Hz, 3H), 1.34 (m, 18H), 1.85 (m, 2H), 3.77 (t, *J* = 7.6 Hz, 2H), 7.84 (m, 2H), 7.92 (d, *J* = 7.6 Hz, 1H), 8.05 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 22.6, 26.8, 28.4, 29.0, 29.3, 29.4, 29.5, 29.6, 31.9, 39.5, 120.8, 125.0, 127.5, 134.2, 134.6, 137.7, 158.9.

3-Dodecyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 54–55 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, *J* = 6.4 Hz, 3H), 1.39 (m, 18H), 1.89 (m, 2H), 4.59 (t, *J* = 6.8 Hz, 2H), 7.73 (m, 3H), 7.88 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 22.6, 25.6, 28.2, 29.1, 29.2, 29.4, 29.5, 29.6, 31.8, 72.3, 121.8, 123.2, 127.1, 133.3, 134.0, 143.5, 169.2; HRMS Calcd for $C_{19}H_{30}NO_3S$ $[M+H]^+$: 352.1941; found: 352.1933.

2-Benzyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 108–110 °C (lit.[5] 108–110 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.91 (s, 2H), 7.33 (m, 3H), 7.51 (d, *J* = 7.2 Hz, 2H), 7.84 (m, 2H), 7.93 (d, *J* = 7.6 Hz, 1H), 8.05 (d, *J* = 6.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 42.9, 121.3, 125.5, 127.5, 128.5, 128.9, 129.0, 134.6, 134.7, 135.0, 138.0, 159.1.

3-Benzyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 131–133 °C (lit.[5] 128–129 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.59 (s, 2H), 7.47 (m, 5H), 7.74 (m, 3H), 7.88 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 73.5, 121.9, 123.4, 126.9, 128.8, 129.1, 129.3, 133.39, 133.43, 134.1, 143.6, 169.0.

2-Isobutyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 56–58 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.02 (d, *J* = 6.4 Hz, 6H), 2.30 (m, 1H), 3.59 (d, *J* = 8.0 Hz, 2H), 7.85 (m, 2H), 7.93 (d, *J* = 7.2 Hz, 1H), 8.06 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 20.0, 27.6, 46.6, 120.8, 125.1, 127.3, 134.2, 134.6, 137.6, 159.2; HRMS Calcd for $C_{11}H_{14}NO_3S$ $[M+H]^+$: 240.0689; found: 240.0697.

3-Isobutyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 101–102 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.07 (d, *J* = 6.8 Hz, 6H), 2.23 (m, 1H), 4.37 (d, *J* = 6.8 Hz, 2H), 7.74 (m, 3H), 7.87 (d, *J* = 6.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 18.8, 27.6, 77.8, 121.8, 123.2, 127.0, 133.4, 134.0, 143.5, 169.2; HRMS Calcd for $C_{11}H_{14}NO_3S$ $[M+H]^+$: 240.0689; found: 240.0693.

2-Isopropyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 65–66 °C (lit.[5] 63–64 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.62 (d, *J* = 7.2 Hz, 6H), 4.53 (m, 1H), 7.84 (m, 3H), 8.02 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 20.3, 47.1, 120.5, 124.8, 127.4, 134.1, 134.5, 137.9, 158.7.

3-Isopropyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 139–140 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.48 (d, *J* = 6.4 Hz, 6H), 5.40 (m, 1H), 7.74 (m, 3H), 7.84 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.4, 76.9, 121.6, 123.3, 127.4, 133.3, 133.9, 143.2, 168.3; HRMS Calcd for $C_{10}H_{12}NO_3S$ $[M+H]^+$: 226.0532; found: 226.0525.

2-Sec-butyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 83–84 °C (lit.[9] 80–81 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.98 (t, *J* = 7.2 Hz, 3H), 1.57 (d, *J* = 6.8 Hz, 3H), 1.87 (m, 1H), 2.15 (m, 1H), 4.20 (m, 1H), 7.83 (m, 3H), 8.01 (d, *J* = 6.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 11.3, 18.4, 27.1, 52.9, 120.6, 124.9, 127.4, 134.1, 134.5, 137.7, 158.8.

3-Sec-butyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless oil; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.97 (t, *J* = 7.6 Hz, 3H), 1.44 (d, *J* = 6.0 Hz, 3H), 1.78 (m, 2H), 5.21 (m, 1H), 7.71 (m, 3H), 7.83 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 9.3, 18.8, 28.4, 81.4, 121.5, 123.2, 127.3, 133.3, 133.9, 143.2, 168.5; HRMS Calcd for $C_{11}H_{14}NO_3S$ $[M+H]^+$: 240.0689; found: 240.0684.

2-(1-Phenylethyl)-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 99–101 °C (lit.[5] 96–97 °C); ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.02 (d, *J* = 7.2 Hz, 3H), 5.45 (q, *J* = 7.2 Hz, 1H), 7.31 (m, 3H), 7.59 (d, *J* = 7.2 Hz, 2H), 7.78 (m, 2H), 7.88 (d, *J* = 7.6 Hz, 1H), 7.95 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 17.9, 53.2, 120.9, 125.2, 127.5, 127.8, 128.4, 128.7, 134.4, 134.8, 138.0, 138.9, 158.7.

3-(1-Phenylethyloxy)-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 104–106 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.81 (d, *J* = 6.4 Hz, 3H), 6.29 (q, *J* = 6.4 Hz, 1H), 7.39 (m, 5H), 7.71 (m, 3H), 7.85 (d, *J* = 7.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.5, 80.8, 121.7, 123.3, 126.5, 127.3, 128.8, 128.9, 133.3, 134.0, 139.0, 143.4, 168.3; HRMS Calcd for $C_{15}H_{14}NO_3S$ $[M+H]^+$: 288.0689; found: 288.0697.

2-Cyclohexyl-1,2-benzisothiazol-3(2H)-one 1,1-dioxide: Colourless solid, m.p. 125–126 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.22–2.21 (m, 10H), 4.15 (m, 1H), 7.83 (m, 3H), 8.02 (d, *J* = 7.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 25.0, 26.0, 30.3, 54.8, 120.5, 124.9, 127.4, 134.1, 134.4, 137.8, 158.6; HRMS Calcd for $C_{13}H_{16}NO_3S$ $[M+H]^+$: 266.0845; found: 266.0852.

3-Cyclohexyloxy-1,2-benzisothiazole 1,1-dioxide: Colourless solid, m.p. 102–104 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.33–2.09 (m, 10H), 5.20 (m, 1H), 7.74 (m, 3H), 7.87 (d, *J* = 8.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.4, 25.0, 31.0, 81.5, 121.6, 123.3, 127.5, 133.3, 133.9, 143.3, 168.3; HRMS Calcd for $C_{13}H_{16}NO_3S$ $[M+H]^+$: 266.0845; found: 266.0848.

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