BROMINE OXIDATION OF N-(3 OR 4-SUBSTITUTED PHENYL)-N′-3-PHENYLPROPENOYLTHIOUREAS

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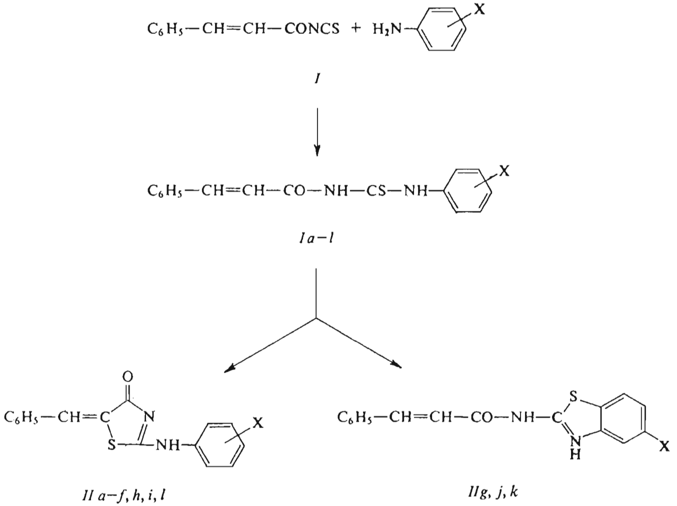
Bromine oxidation of N-(3- or 4-substituted phenyl)-N′-3-phenylpropenoylthioureas in chloroform afforded either derivatives of benzylidenethiazoline or benzothiazole depending on the structure of the aniline residue. The structure of the title products was proved by elemental analysis, IR, ^{1}H NMR and ^{13}C NMR spectral data.

2-Aminobenzo[*d*]thiazoles or thiazolines can be prepared by oxidation (with bromine, sulfuryl chloride, disulfur dichloride) of substituted thioureas. These reactions are described in detail in a review article[1].

Our preceding paper[2] dealt with the reaction of thioureas prepared by a bromine oxidation of α,β-unsaturated acyl isothiocyanates; as found, different products were obtained in relation to the structure of the amine residue. Therefore, we investigated the effects of substituents at the aniline ring on the course of this reaction starting from thioureas prepared from *trans*-3-phenylpropenoyl isothiocyanate (*I*, Scheme 1). Thioureas *Ia*–*If*, *Ih*, *Ii*, *Il* reacted at the ethylene double bond to yield 2-(3- or 4-substituted phenyl)-5-benzylidenethiazolin-4-ones *IIa*–*IIf*, *IIh*, *IIi*, *IIl*. Thioureas *Ig*, *Ij*, *Ik*, with an activated aromatic ring, react in acordance with the literature[3–8] to give benzothiazoles *IIm*, *IIj*, *IIk* (Scheme 1).

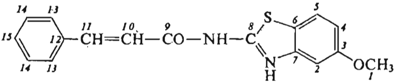
The structure of these products was elucidated by ^{1}H NMR and IR spectroscopies. Compounds *IIa*, *IIb*, *IIf*, *IIh*, *IIi*, *IIl* reveal a singlet of olefinic proton $=$CH—. A (Z) configuration of the above-mentioned derivatives can be ascribed on the basis of comparison of the experimental chemical shift value of the olefinic proton ($\delta_{CH} = 7{\cdot}70-8{\cdot}00$) with that calculated by the shielding increment method: ($\delta^{Z}_{CH} = 7{\cdot}48$ ppm, $\delta^{E}_{CH} = 6{\cdot}71$ ppm). The absorption bands of bending *trans*-ethylenic CH band vibrations γ(CH=CH) at 960–980 cm^{-1} present in the corresponding compounds *Ia*, *Ib*, *If*, *Ih*, *Ii*, *Il* disappeared, stretching ν(C=C) vibrations at 1 625 to 1 650 cm^{-1} corroborated the remaining double bond. Absorption bands ν(C=O) appeared at 1 660–1 700 cm^{-1}; compounds *IIa*, *IIc*–*IIe* had two absorption bands in the spectrum, what evidences the imine enamine tautomerism. The amino form is always indicative of a lower wavelength[10,11].

Compounds *IIg*, *IIj*, *IIk* were identified to be benzo[d]thiazoles. Their ^1H NMR spectra were characteristic of a doublet corresponding to the —CH=CH— group (6·90–8·15 ppm), their IR spectra of bending vibrations $\gamma(CH=CH)$ at 965–980 cm^{-1}, stretching vibrations $\nu(C=C)$ at 1 615–1 620 cm^{-1}, and $\nu(C=O)$ at 1 660 to 1 675 cm^{-1}. Even here the tautomerism is possible, nonetheless splitting of $\nu(C=O)$ bands was not observed. Decisive for the structure elucidation of 5-substituted 2-(3-phenylpropenoylimino)benzo[*d*]thiazoles *IIg*, *IIj*, *IIk*, was the ^{13}C NMR spectrum of 5-methoxy-2-(2-phenylpropenoylimino)benzo[*d*]thiazole (*IIm*), since two products could be formed in this reaction namely $C_{(5)}$, or $C_{(7)}$-substituted (Scheme 2).



In formulae: *I*, *IIX* = H (*a*), 4-CH_3O (*b*), 4-CH_3 (*c*), 4-Cl (*d*), 4-Br (*e*), 4-NO_2 (*f*), 3-CH_3O (*g*), 3-CH_3 (*h*), 3-Br (*i*), 3-OH (*j*), 3-NH_2 (*k*), 3-NO_2 (*l*).

SCHEME 1



SCHEME 2

The ^{13}C NMR spectrum showed three signals of —CH= carbons of benzothiazole ring: signals at 112·95 and 121·69 ppm in the off-resonance spectrum were split into doublet-doublet due to the interaction of C—C—H through two bonds. The signal of the third carbon at 104·07 ppm was formed by a doublet only. This kind of splitting indicated the presence of two vicinal and one isolated —CH— carbon, this being an evidence that the substituent was in position $C_{(5)}$ of the benzothiazole ring.

EXPERIMENTAL

trans-3-Phenylpropenoyl isothiocyanate[12] (*I*), N-phenyl-N'-3-phenylpropenoylthiourea[13] (*Ia*), N-(4-methoxyphenyl)-N'-3-phenylpropenoylthiourea[13] (*Ib*), N-(4-methylphenyl)-N'-3-phenylpropenoylthiourea[13] (*Ic*), N-(3-hydroxyphenyl)-N'-3-phenylpropenoylthiourea[13] (*Ij*), and 2-phenyl-5-benzylidenethiazolin-4-one[2] (*Ia*) were prepared according to the cited literature.

N-(3- or 4-Substituted Phenyl)-N'-3-phenylpropenoylthioureas *Id—Ii*, *Ik*, *Il*

Substituted aniline (1 mmol) in benzene (10—15 ml) was added dropwise to a stirred solution of 3-phenylpropenoyl isothiocyanate (*I*) in benzene (15 ml). The mixture was stirred for additional 30 min, the precipitate was filtered off and crystallized from an appropriate solvent.

N-(4-*Chlorophenyl*)-N'-3-*phenylpropenolylthiourea* (*Id*). Yield 70%, m.p. 217—219°C (methanol). For $C_{16}H_{13}ClN_2OS$ (316·8) calculated: 60·66% C, 4·14% H, 8·84% N; found: 60·34% C, 4·04% H, 8·78% N. IR spectrum, cm^{-1} ν(KBr): (NH) 3 405, ν(C=O) 1 675, ν(C=C) 1 635, γ(CH=CH) 980. ^1H NMR spectrum: 7·2 and 8·10 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·75 (m, C_6H_5).

N-(4-*Bromophenyl*)-N'-3-*phenylpropenoylthiourea* (Ie). Yield 85%, m.p. 218—220°C (chloroform). For $C_{16}H_{13}BrN_2OS$ (361·3) calculated: 53·20% C, 3·63% H, 7·75% N; found: 53·04% C, 3·60% H, 7·71% N. IR spectrum, cm^{-1} (KBr): ν(NH) 3 403, ν(C=O) 1 665, ν(C=C) 1 620, γ(CH=CH) 970. ^1H NMR spectrum: 7·50 and 8·25 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·75 (m, C_6H_5).

N-(4-*Nitrophenyl*)-N'-3-*phenylpropenoylthiourea* (If). Yield 86%, m.p. 205—207°C (benzene). For $C_{16}H_{13}N_3O_3S$ (327·4) calculated: 58·70% C, 4·00% H, 12·84% N; found: 58·69% C, 3·89% H, 12·92% N. IR spectrum, cm^{-1} ($CHCl_3$): ν(NH) 3 410, ν(C=O) 1 678, ν(C=C) 1 627, γ(CH=CH) 980. ^1H NMR spectrum ($CDCl_3$): 7·00 and 8·25 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·50 (m, C_6H_5), 11·60 (s, —NH—).

N-(3-*Methoxyphenyl*)-N'-3-*phenylpropenoylthiourea* (Ig). Yield 70%, m.p. 155—157°C (ethanol). For $C_{17}H_{16}N_2O_2S$ (312·4) calculated: 65·36% C, 5·16% H, 8·97% N; found: 65·11% C, 5·20% H, 8·78% N. IR spectrum, cm^{-1} ($CHCl_3$): ν(NH) 3 400, ν(C=O) 1 665, ν(C=C) 1 620, γ(CH=CH) 965. ^1H NMR spectrum ($CDCl_3$): 3·80 (s, CH_3), 6·63 and 7·85 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·35 (m, C_6H_5), 9·51 (s, —NH—).

N-(3-*Methylphenyl*)-N'-3-*phenylpropenoylthiourea* (Ih). Yield 80%, m.p. 200—201°C (methanol). For $C_{17}H_{16}N_2OS$ (296·4) calculated: 68·89% C, 5·44% H, 9·45% N; found: 68·72% C, 5·38% H, 9·32% N. IR spectrum, cm^{-1} ($CHCl_3$): ν(NH) 3 405, ν(C=O) 1 675, ν(C=C) 1 620, γ(CH=CH) 980. ^1H NMR spectrum: 2·35 (s, CH_3), 7·00 and 7·80 (dd, —CH=CH—, J_{AB} = = 16 Hz), 7·50 (m, C_6H_5), 11·30 (s, —NH—).

N-(3-*Bromophenyl*)-N′-3-*phenylpropenoylthiourea* (Ii). Yield 72%, m.p. 200—201°C (ethanol). For $C_{16}H_{13}BrN_2OS$ (361·3) calculated: 53·20% C, 3·63% H, 7·75% N; found: 53·28% C, 3·54% H, 7·82% N. IR spectrum, cm^{-1} (KBr): ν(NH) 3 400, ν(C=O) 1 670, ν(C=C) 1 620, γ(CH=CH) 970. ^{1}H NMR spectrum: 7·25 and 8·20 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·75 (m, C_6H_5).

N-(3-*Aminophenyl*)-N′-3-*phenylpropenoylthiourea* (Ik). Yield 76%, m.p. 177°C (benzene). For $C_{16}H_{15}N_3OS$ (297·4) calculated: 64·62% C, 5·08% H, 14·13% N; found: 64·42% C, 5·13% H, 14·01% N. IR spectrum, cm^{-1} (CHCl$_3$): ν(NH) 3 405, ν(C=O) 1 675, ν(C=C) 1 625, γ(CH=CH) 980. ^{1}H NMR spectrum (CDCl$_3$): 7·05 and 7·80 (dd, —CH=CH—, J_{AB} = 16 Hz). 7·25 (m, C_6H_5), 9·87 (s, —NH—).

N-(3-*Nitrophenyl*)-N′-3-*phenylpropenoylthiourea* (Il). Yield 75%, m.p. 208—210°C (methanol). For $C_{16}H_{13}N_3O_3S$ (327·4) calculated: 58·70% C, 4·00% H, 12·84% N; found: 58·64% C, 4·09% H, 12·76% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 672, ν(C=C) 1 625, γ(CH=CH) 980. ^{1}H NMR spectrum: 7·13 and 7·68 (dd, —CH=CH—, J_{AB} = 16 Hz), 8·25 (m, C_6H_5), 11·25 (s, —NH—).

2-(3- or 4-Substituted Phenyl)-5-benzylidenethiazolin-4-ones *IIb*—*IIf*, *IIh*, *IIi*, *IIl*

Bromine (2 mmol) was added to a stirred solution of the respective thiourea (2 mmol) in chloroform (30—70 ml). After 1 h the solvent was removed under diminished pressure and the solid was crystallized from a proper solvent. The ^{1}H NMR spectra of compounds *IIc*—*IIe* could not be measured because of their low solubility.

2-(4-*Methoxyphenyl*)-5-*benzylidenethiazolin*-4-*one* (IIb). Yield 52%, m.p. 178—180°C, (methanol–water). For $C_{17}H_{14}N_2O_2S$ (310·4) calculated: 65·79% C, 4·55% H, 9·03% N; found: 65·60% C, 4·85% H, 8·36% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 665, ν(C=C) 1 635, ν(C=N) 1 500. ^{1}H NMR spectrum: 7·25 (m, C_6H_5), 7·70 (s, —CH=).

2-(4-*Methylphenyl*)-5-*benzylidenethiazolin*-4-*one* (IIc). Yield 33%, m.p. 240°C (methanol–water). For $C_{17}H_{14}N_2OS$ (294·4) calculated: 69·36% C, 4·79% H, 9·52% N; found: 69·29% C, 4·70% H, 8·89% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 675, and 1 700, ν(C=C) 1 640, ν(C=N) 1 490.

2-(4-*Chlorophenyl*)-5-*benzylidenethiazolin*-4-*one* (IId). Yield 42%, m.p. 298°C (methanol–water). For $C_{16}H_{11}ClN_2OS$ (314·8) calculated: 61·05% C, 3·52% H, 8·90% N; found: 61·20% C, 3·20% H, 8·64% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 680 and 1 700, ν(C=C) 1 625, ν(C=N) 1 495.

2-(4-*Bromophenyl*)-5-*benzylidenethiazolin*-4-*one* (IIe). Yield 40%, m.p. 324°C (methanol–water). For $C_{16}H_{11}BrN_2OS$ (359·3) calculated: 53·49% C, 3·09% H, 7·80% N; found: 53·85% C, 3·02% H, 7·96% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 670 and 1 700, ν(C=C) 1 640), ν(C=N) 1 480.

2-(4-*Nitrophenyl*)-5-*benzylidenethiazolin*-4-*one* (IIf). Yield 60%, m.p. 325—328°C (methanol–water). For $C_{16}H_{11}N_3O_3S$ (325·4) calculated: 59·07% C, 3·41% H, 12·92% N; found: 58·88% C, 3·53% H, 13·02% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 680, ν(C=C) 1 695 cm^{-1}, 1 650, ν(C=N) 1 495. ^{1}H NMR spectrum: 7·75 (m, C_6H_5) 8·00 (s, —CH=).

2-(3-*Methylphenyl*)-5-*benzylidenethiazolin*-4-*one* (IIh). Yield 30%, m.p. 170—172°C (methanol–water). For $C_{17}H_{14}N_2OS$ (294·4) calculated: 69·37% C, 4·79% H, 9·52% N; found: 68·91% C, 4·66% H, 9·18% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 700, ν(C=C) 1 645, ν(C=N) 1 595. ^{1}H NMR spectrum: 2·40 (s, CH_3), 7·25 (m, C_6H_5), 7·75 (s, —CH=).

2-(3-*Bromophenyl*)-5-*benzylidenethiazolin*-4-*one* (IIi). Yield 22%, m.p. 172—174°C (methanol–water). For $C_{16}H_{11}BrN_2OS$ (359·2) calculated: 53·49% C, 3·09% H, 7·80% N; found: 53·19% C, 3·26% H, 7·60% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 675, ν(C=C) 1 625, ν(C=N) 1 510. ^{1}H NMR spectrum: 7·80 (m, C_6H_5), 8·00 (s, —CH=).

2-(3-*Nitrophenyl*)-5-*benzylidenethiazolin*-4-*one* (III). Yield 48%, m.p. 275°C (methanol–water). For $C_{16}H_{11}N_3O_3S$ (325·4) calculated: 59·07% C, 3·41% H, 12·92% N; found: 59·24% C, 3·63% H, 12·73% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 660, ν(C=C) 1 625, ν(C=N) 1 500. ^1H NMR spectrum: 7·75 (m, C_6H_5), 7·95 (s, —CH=).

5-Substituted 2-(3-Phenylpropenoylimino)benzo[*d*]thiazoles *IIg*, *IIj*, *IIk*

Bromine (2 mmol) was added to a stirred solution of the respective thiourea *Ig*, *Ij*, *Ik* (2 mmol) in chloroform (30—70 ml). During a 1 h stirring a precipitate separated, which was filtered off, dried and crystallized from methanol to afford the respective thiazole.

5-*Methoxy*-2-(3-*phenylpropenoylimino*)*benzo*[d]*thiazole* (IIg). Yield 65%, m.p. 206—208°C (methanol). For $C_{17}H_{14}N_2O_2S$ (310·4) calculated: 65·79% C, 4·55% H, 9·03% N; found: 66·10% C, 4·32% H, 8·90% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 660, ν(C=C) 1 615, ν(C=N) 1 530, γ(CH=CH) 965. ^1H NMR spectrum: 3·72 (s, CH_3), 6·90 and 7·90 (dd, —CH=CH—, J_{AB} = = 16 Hz), 7·40 (m, C_6H_5). ^{13}C NMR spectrum) δ, ppm, Scheme 2), 55·47 (q, $C_{(1)}$), 104·07 (d, $C_{(2)}$), 112·95 (dd, $C_{(4)}$), 119·22 (dd, $C_{(10)}$), 121·69 (dd, $C_{(5)}$), 124·15 (s, $C_{(6)}$), 128·26 (d, $C_{(13)}$), 128·85 (d, $C_{(14)}$), 139·35 (d, $C_{(15)}$), 134·38 (s, $C_{(12)}$), 144·01 (dd, $C_{(11)}$), 149·98 (s, $C_{(7)}$), 159·01 (s, $C_{(3)}$), 160·28 (s, $C_{(8)}$), 164·46 (s, $C_{(9)}$).

5-*Hydroxy*-2-(3-*phenylpropenoylimino*)*benzo*[d]*thiazole* (IIj). Yield 51%, m.p. 262°C (methanol). For $C_{16}H_{12}N_2O_2S$ (296·1) calculated: 64·86% C, 4·05% H, 9·46% N; found: 64·94% C, 4·06% H, 9·12% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 660, ν(C=C) 1 620, ν(C=N) 1 540, γ(CH=CH) 980. ^1H NMR spectrum: 7·25 and 8·00 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·70 (m, C_6H_5).

5-*Amino*-2-(3-*phenylpropenoylimino*)*benzo*[d]*thiazole* (IIk). Yield 53%, m.p. 215°C (methanol). For $C_{16}H_{11}N_3O_3S$ (295·6) calculated: 65·08% C, 4·41% H, 14·24% N; found: 65·29% C, 4·16% H, 14·45% N. IR spectrum, cm^{-1} (KBr): ν(C=O) 1 675, ν(C=C) 1 620, ν(C=N) 1 535, γ(CH=CH) 980. ^1H NMR spectrum: 7·12 and 8·15 (dd, —CH=CH—, J_{AB} = 16 Hz), 7·75 (m, C_6H_5).

Spectral Measurements

Infrared absorption spectra were measured with a Specord IR 75 (Zeiss, Jena) spectrophotometer, the ^1H NMR spectra with a Tesla BS 487A apparatus operating at 80 MHz, and the ^{13}C NMR spectra with a Tesla BS 567 instrument operating at 25·15 MHz in deuteriochloroform–hexadeuteriodimethyl sulfoxide, tetramethylsilane being the internal reference for both ^1H NMR and ^{13}C NMR. The multiplicity of signals was ascribed by the ^1H-off-resonance technique.

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