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Reaction of 3/2-formylindoles with TOSMIC: formation of indolyloxazoles and stable indolyl primary enamines

Manas Chakrabarty,[a,*] Ramkrishna Basak,[a] Yoshihiro Harigaya[b] and Hiroaki Takayanagi[b]

[a]*Department of Chemistry, Bose Institute, 93/1, A.P.C. Road, Kolkata 700009, India*
[b]*School of Pharmaceutical Sciences, Kitasato University, Minato-ku, Tokyo 108, Japan*

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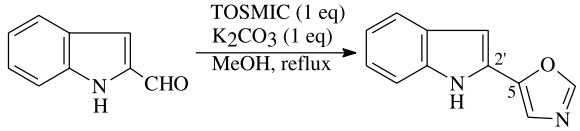
Abstract—3-Formylindole and its 1-substituted and 1,5-disubstituted derivatives react with TOSMIC in presence of potassium carbonate in methanol under reflux to furnish 5-(3′-indolyl)oxazoles, new stable *E*-2-(3′-indolyl)-2-tosylethenamines and two diastereomers of *N*-[2-(3′-indolyl)-1,2-dimethoxy]ethylformamides. In contrast, 2-formylskatole furnishes *N*-(1-tosyl-2-skatolyl)ethenylformamide.

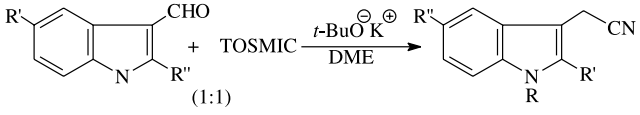
1. Introduction

1,3-Azoles are important heterocycles,[1a–c] of which only oxazoles do not participate in normal biochemical processes. Yet, bioactive secondary metabolites containing the oxazole ring are known, specially from marine organisms.[2] Our continued interest in the synthesis[3] and reactions[4] of condensed nitrogen heterocycles drew our attention to a small group of several 2-alkyl-5-(3′-indolyl)oxazoles of microbial origin. These are pimprinine[5a,b] or WS-30581c,[5c,d] pimprinethine,[5c,6] pimprinaphine,[5c] WS-30581a and b[5d] and labradorins 1 and 2,[7] which display a broad spectrum of biological activities including anticancer properties.[7–9] Some of these metabolites have already been synthesised by three different routes, viz. the cyclisation of 3-acylaminoacetylindoles,[5b,c,10] the oxidative cyclisation of *N*-acetyl/benzoyltryptamine[11a,b] and the cycloaddition of appropriate in situ-derived rhodium carbenoids, with nitriles.[12] A number of analogues have also been synthesised by the base-catalysed reaction of 3-formylindoles with *N*-tosylmethylimino synthons[13] and also by a tandem aza-Wittig/heterocumulene-mediated annulation involving iminophosphoranes.[14] However, all these methods were multi-step syntheses and the overall yields of the indolyloxazoles were as low as 10% in quite a few cases. This motivated us to try to develop an efficient, one-step synthesis of 5-(3′-indolyl)oxazoles. Towards this end, we intended to employ van Leusen's oxazole synthesis,[15a–c] which involves the base-catalysed reaction of tosylmethylisocyanide (TOSMIC) with aldehydes. This method was later applied to several heteroaryl[16a] and azole carbaldehydes,[16b] mostly leading to the corresponding 5-heteroaryl and 5-azolyloxazoles, including 5-(2′-indolyl)-oxazole from 2-formylindole (Scheme 1), which is of relevance to our objective.



Scheme 1.

In this backdrop, our modified objective was to extend this protocol to 3-formylindoles. Such an attempt also appeared to have been undertaken,[17] in which potassium *tert*-butoxide in 1,2-dimethoxyethane (DME) was used as the base. Surprisingly, indole-3-acetonitriles were formed instead of the expected indolyloxazoles (Scheme 2).



R=H, Me, Bn; R'=H, OMe

Scheme 2.

In our view, the use of the strong base, potassium *tert*-butoxide, was responsible for this unexpected outcome, and the use of a milder base, viz. potassium carbonate would

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* Corresponding author. Tel.: +91 33 23506619; fax: +91 33 23506790; e-mail: chakmanas@yahoo.co.in

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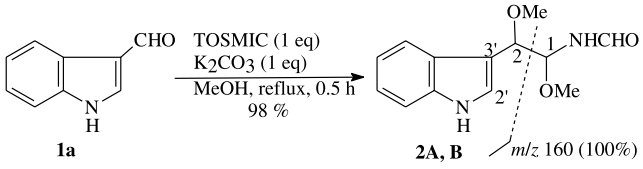
have led these reactions to the desired course. Accordingly, we carried out the reaction of a number of 3-formylindoles with TOSMIC using potassium carbonate in refluxing methanol. As a result, although the target molecules were formed in certain cases, several new structurally interesting and mechanistically significant products, including one type of stable indolyl primary enamines, were formed. The identification of these products, the possible mechanism of their formation, their synthetic potential and the significance of some of their spectral data are presented in this paper.

2. Results and discussion

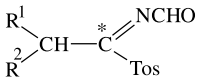
When 3-formylindole (**1a**) was allowed to react with 1 equiv of TOSMIC in the presence of potassium carbonate in methanol under reflux, two products were formed in nearly quantitative overall yield. Each of these products were analysed for $C_{13}H_{16}N_2O_3$, corroborated by mass spectral data (M^+ 248), and showed (^{1}H NMR spectroscopy) the presence of one 3-indolyl moiety, two methoxy groups, one formamido group and two separate aliphatic methine protons—one (δ 4.67–4.80) as a doublet (J=2.5–4 Hz) and the other (δ 4.62–5.52) as a doublet of doublet (J=2.5–4, ~10 Hz). All these data could only be accommodated in the gross structure of *N*-[2-(3′-indolyl)-1,2-dimethoxy]-ethylformamide (**2**), the two products being the diastereomers **2A** and **2B** (Scheme 3). Each of **2A** and **2B** recorded in its EI-MS the base peak at *m/z* 160, formed by cleavage of the *N*-(methoxymethyl)formamide moiety, thus lending additional support to the gross structures of **2A** and **2B**.



Scheme 3.

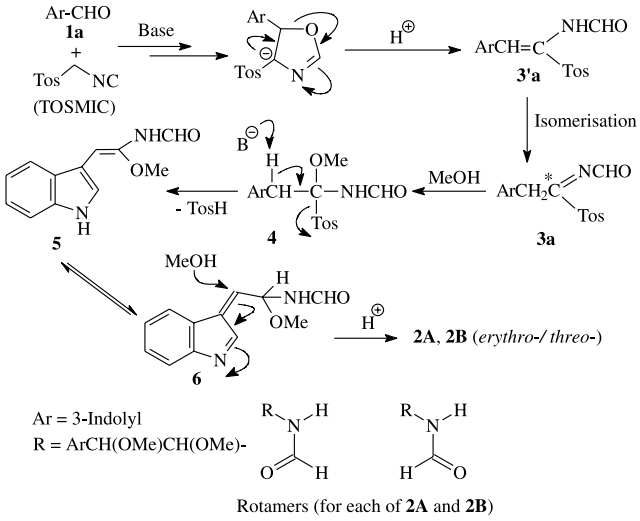
The mechanism of formation of these two products was somewhat intriguing and their NMR spectral behaviour was indeed revealing. As regards the latter, each diastereoisomer recorded two sets of signals with 2:1 ratio. It suggested the presence of each diastereoisomer as an equilibrium mixture (2:1) of two rotamers, resulting from the restricted rotation around the *N*-formyl group. Further, in each of the two diastereoisomers, the ^{1}H NMR signal for the aldehydic proton of the formamido group appeared as a singlet in the major rotamer and as a doublet (J=11.7/11.9 Hz) in the minor rotamer. Clearly, this observation was a reflection of the dihedral angle between the NH and the CHO protons, which must be 90° in the major rotamer and nearly 180° in the minor rotamer.

As to the formation of **2A** and **2B**, the intermediacy of **3a** (cf. a similar species **3b**, postulated as an intermediate in the van Leusen's base-catalysed one-step synthesis of nitriles from ketones and TOSMIC)[18] must be assumed.



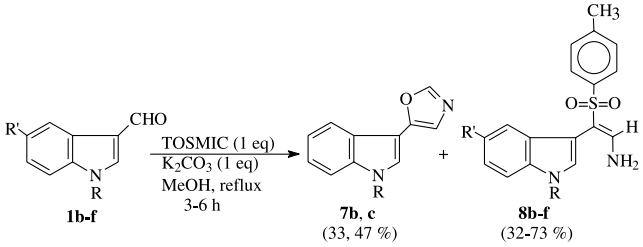
3a : R^1=H; R^2=3-Indolyl
3b : R^1, R^2=Alkyl

This intermediate possesses a carbon center, marked with asterisk, that might well be more electrophilic than the carbonyl carbon.[19] Consequently, a nucleophilic attack at this center by methanol, followed by a base-induced β-elimination of *p*-toluenesulphinic acid from the resulting molecule (**4**), may lead to the formation of the formamido olefin **5**. Thereafter, a Michael-type addition of weakly nucleophilic methanol to the benzylic carbon of the indolenine tautomer (**6**) of **5**, followed by protonation, may result in the formation of the diastereoisomers, **2A** and **2B** (*erythro*- and *threo*-), as shown in Scheme 4.



Scheme 4.

Since the outcome of the reaction with 3-formylindole (**1a**) was different from that with 2-formylindole,[16b] the present protocol was extended to the 3-formyl derivatives of *N*-methyl, *N*-ethyl, 5-methoxy-*N*-methyl, 5-methoxy-*N*-ethyl and 5-methoxy-*N*-isopropylindoles (**1b–f**, respectively). Different results were obtained from **1b** and **1c** on one hand and from **1d–f** on the other hand. Thus, each of **1b** and **1c** furnished two products, viz. **7b** and **8b** from **1b**, and **7c** and **8c** from **1c** in 79% and 75% overall yields, respectively. In contrast, each of **1d–f** furnished only one type of products, **8d–f** in (62–73)% yields (Scheme 5, Table 1).



Scheme 5.

Table 1. Reaction of 3-formylindoles (**1b–f**; 1 mmol) with TOSMIC (1.1 mmol) in presence of potassium carbonate (1.1 mmol) in methanol under reflux

3-Formylindoles (**1**)			Time (h)	Yield[a] (%)		
SM	R	R′		**7**	**8**	Overall
1b	Me	H	6	47	32	79
1c	Et	H	4	33	42	75
1d	Me	OMe	4	—	62	62
1e	Et	OMe	3	—	68	68
1f	^{i}Pr	OMe	3	—	73	73

[a] Refers to isolated pure products.

The less polar products from **1b** and **1c**, that is **7b** and **7c** were identified as the expected 5-(1′-methyl/ethyl-3′-indolyl)oxazoles from their diagnostic ^{1}H (H-2: ∼δ 7.87, s; H-4: δ 7.38/7.46, s; H-2′: δ 7.24, s) and ^{13}C (CH-2: δ 149.1; CH-4: ∼δ 123.0; C-5: δ 148.4) NMR spectral data, typical of 5-substituted oxazolyl moieties, in addition to those expected for the *N*-alkyl-3-indolyl moieties (see Section 4).

The more polar products from **1b** and **1c**, that is **8b** and **8c** and the only products from **1d–1f**, that is **8d–f** recorded similar NMR spectral data. Thus, each of these products showed the presence of a β,β-disubstituted primary enamine moiety (>C=C*H*–NH_2: δ 7.77/7.78, 1H, t, J=10/10.5 Hz and δ 4.31–4.34, 2H, d, J=10/10.5 Hz, D_2O-exchangeable; CH_α: δ 142.6/142.9; C_β: ∼δ 105), a tosyl group (MS: base peaks at M^+-155 m.u.) and a 2-unsubstituted (H-2: δ 7.09–7.23, 1H, s; *C*H-2: δ 129.7–131.4) 3-indolyl residue (see Section 4). The products **8b–f** thus turned out to be the novel stable 2-[3′-(substituted) indolyl]-2-tosylethenamines.

The formation of these primary enamines could not be explained by any straightforward mechanism. Although primary enamines were first implicated as reactive intermediates as early as 1914,[20] the first stable primary enamine was prepared nearly half a century later.[21a,b] Therefore, before discussing the stability of **8b–f** in the light of the available information on primary enamines and their equilibrium with tautomeric imines, most of which is due to the pioneering work of Albrecht et al.,[22a–c] it became all the more desirable to settle the structures of **8b–f** beyond doubt. This was accomplished by analysing the HMQC and HMBC spectra of **8b** (as a representative compound), which established the structure assigned to it. The observed HMBC correlations of **8b** are shown in Figure 1.

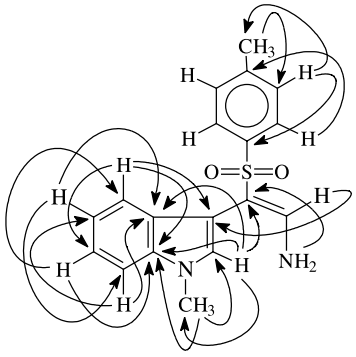


Figure 1. HMBC correlations of **8b**.

Since all the critical ^{1}H and ^{13}C NMR spectroscopic data of **8c–f** paralleled those of **8b** (see Section 4), the correctness of the structures assigned to the former group of compounds was thus established as well.

Two aspects of **8b–f** now needed to be considered—their stability and their mechanism of formation. As regards the former, Albrecht's studies revealed that, inter alia, both an electron-withdrawing group (e.g., tosyl group in **8b–f**) and a π-conjugating hydrocarbyl group (e.g., indolyl moiety in **8b–f**) at the β-carbon of a primary enamine stabilise the enamine structure in preference to its aldimine tautomer. The stability of **8b–f** is thus accounted for. Nevertheless, the structure of **8d**, again as a representative, was finally confirmed by single crystal X-ray crystallographic analysis.[23] The ORTEP diagram of **8d** is shown in Figure 2.

Although the X-ray crystallographic analysis of a few 1,6-diaryl-1,3,5-trienyl-1,6-diamines has previously been documented,[24a–c] this is, to the best of our knowledge, the first X-ray crystallographic analysis of an indolylethenamine. Also, the formation of **8b–f** constitutes the first report of indolylethenamines, although a number of indolic[25] and bisindolic[26] enamides have previously been reported as natural products.

As to the mechanism of the formation of **8b–f**, the *N*-(2-aryl-1-tosylethenyl)formamides (**A**; cf. **3′a** in Scheme 4) are likely to be the crucial intermediates. Compounds of type **A** were also independently suggested by Schöllkopf et al.[27a,b] as intermediates in the formation of carboxylic acids via nitriles from the reaction of aldehydes and ketones with TOSMIC. The lone pair of electrons on the indolic nitrogen of **A** then triggers the protonation (from methanol) of the enamidic double bond, resulting in the indoleninium species **9**. Subsequently, a 1,2-shift of the tosyl group with simultaneous neutralisation of the indoleninium cation, followed by the loss of a proton, gives rise to the intermidiate **10**. Finally, a nucleophilic attack by methanol to the *N*-formyl carbon of **10**, followed by the loss of a molecule of methyl formate and subsequent protonation, gives rise to the enamines **8b–f** (Scheme 6).

The formation of the indoleninium species **9** through the participation of the indole ring seems to be crucial to the formation of the enamines. This explains why increasing electron density at the indolic C-3 either by the presence of an alkyl group at indolic *N*(1) or by the additional presence of an electron-donating methoxyl at C-5 of the indole ring gives rise to the enamines **8b–f** in increasing yields in going from **1b** to **1f** (see Table 1). Indeed, the three

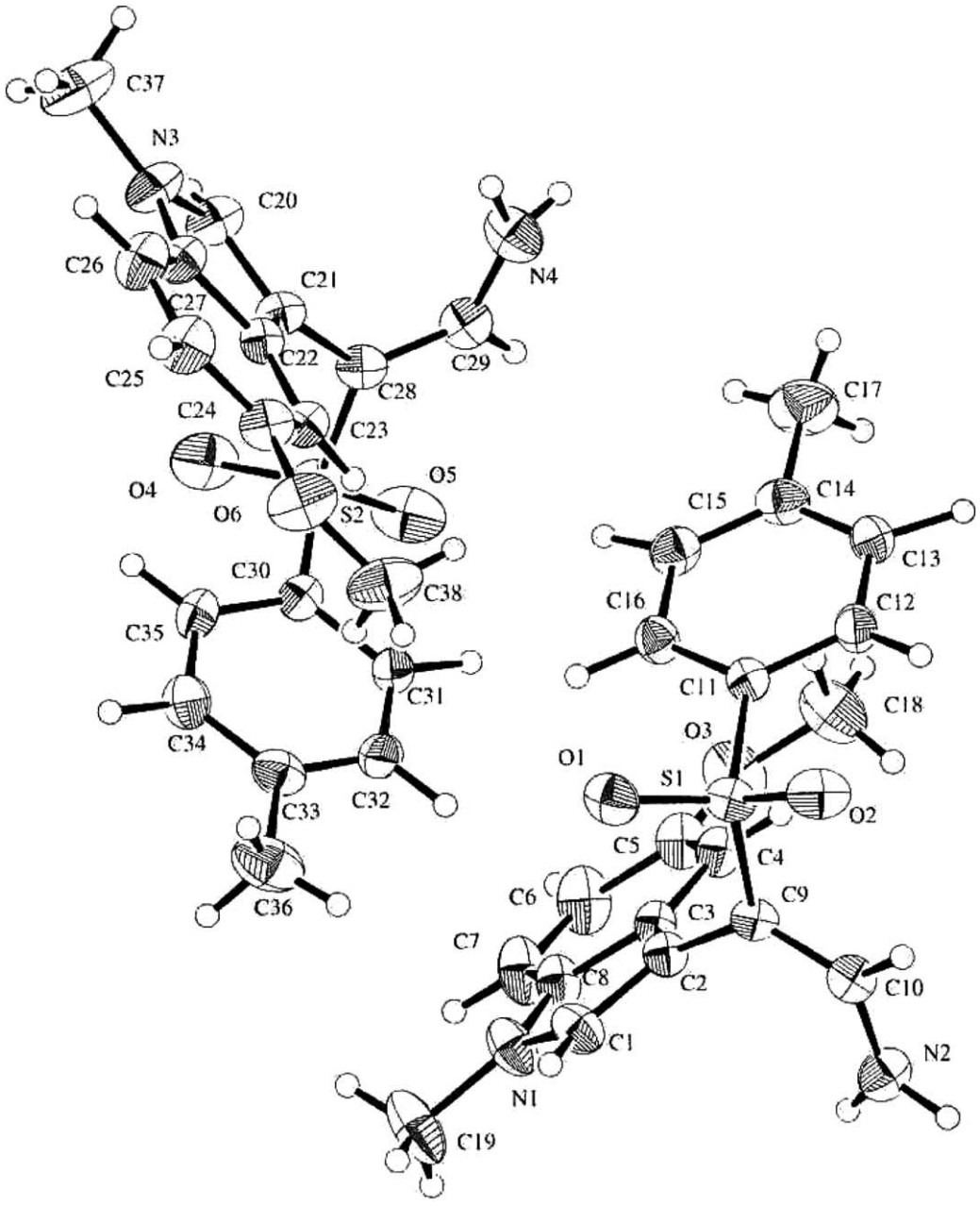
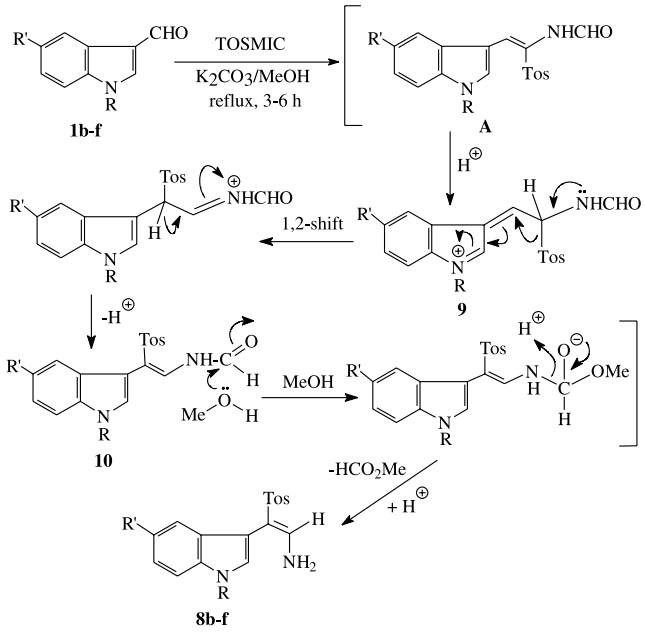


Figure 2. ORTEP diagram of **8d**.

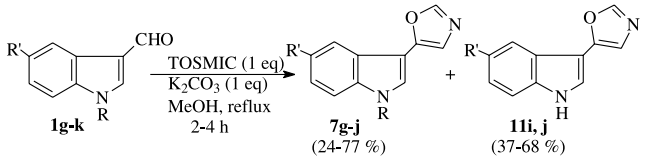
5-methoxyindoles **1d–f** furnished the enamines (**8d–f**) as the only products.

With *N*-benzyl-3-formylindole (**1g**) and 5-bromo-*N*-methyl-3-formylindole (**1h**), only the respective 5-(3′-indolyl)-oxazoles (**7g**,**h**) were formed. But with *N*-tosyl-3-formyl-indole (**1i**) and its 5-methoxy derivative (**1j**), the respective 5-(3′-indolyl)oxazoles (**7i**,**j**) along with their *N*-deprotected analogues (**11i**,**j**) were formed in excellent overall yields. In the case of these two substrates (**1i**,**j**), that the formation of the indolyloxazoles and their *N*-deprotection were taking place simultaneously was evident from a comparison of the relative yields of **7i** and **11i** with those of **7j** and **11j** as against the respective time periods for the completion of the reactions. Thus, the reaction with **1i**, which was complete in 2 h, furnished **7i** and **11i** in nearly 7:5 relative yields. Whereas, the reaction with **1j**, which took twice the time for completion, provided **7j** and **11j** in ca. 5:14 relative yields. When *N*-boc-3-formylindole (**1k**) was used as the substrate, the deprotected indolyloxazole (**11i**) was the only product. Strangely, when *N*-ethoxycarbonyl-3-formylindole (**1l**) was treated with TOSMIC under similar conditions, a mixture of **2A** and **2B** in nearly quantitative yield was obtained as the only products. This observation along with the lack of formation of similar products from **1i–k** pointed out that the cyclisation preceded *N*-deprotection in the case of reactions with **1i–k**, whereas *N*-deprotection preceded subsequent reaction with TOSMIC in the case of reaction with **1l**. The reactions with **1g–k** are shown in Scheme 7 and the results (including that from **1l**) in Table 2.

In this connection, the contrasting behaviour of

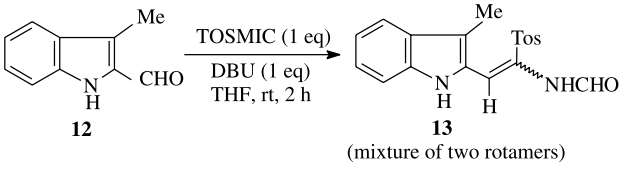


Scheme 6.



Scheme 7.

2-formylindole and 2-formylimidazole towards their base-induced reaction with TOSMIC, referred to earlier, drew our attention. While the former, using potassium carbonate in methanol as the base, furnished 5-(2′-indolyl)oxazole,[16b] the latter, using 1,3-diazabicyclo[5.4.0]undec-7-ene (DBU) in tetrahydrofuran (THF) as the base, afforded 3-tosyl-imidazo[1,2-*c*]pyrimidine, albeit in low yield (14%). These workers similarly tried to convert 2-formylindole to indolopyrimidine by treatment with TOSMIC using DBU in THF, but only a tarry mass was reported to have been formed.[16b] We felt that this objective could be accomplished by blocking C-3 of 2-formylindole and carrying out the reaction using DBU in THF. Accordingly, 2-formylskatole (**12**) was treated with equimolar amounts of TOSMIC and DBU in THF at room temperature. The reaction was complete in 2 h, but it furnished, contrary to expectation, the *N*-(indolylethenyl)formamide **13** (62%) (Scheme 8), identified spectroscopically.



Scheme 8.

Like **2A** and **2B**, **13** also showed two sets of ^{1}H and ^{13}C NMR signals, thereby demonstrating the presence of two rotamers in nearly 3:2 ratio.

3. Conclusions

The present work demonstrates the versatility of TOSMIC in bringing about a wide variety of unpredictable reactions particularly with indole-3-carbaldehydes. Besides the formation of the expected 5-(3′-indolyl)oxazoles (**7b**,**c**,**g–j**, **11i**,**j**), the formation of the novel, rearranged stable indolyl primary enamines (**8b–f**), the mechanistically conspicuous dimethoxy-*N*′-formyltryptamines (**2A**,**B**) and *N*-(1-tosyl-2-skatolyl)ethenylformamide (**13**) and the interesting spectroscopic behaviour (presence of rotamers) of **2A**, **2B** and **13** highlight the importance of our work. The present work also provides us with a suitable substrate, **13**, for preparing indolo[1,2-*c*]pyrimidines, which is open to exploitation. More importantly, on acylation/aroylation, followed by proteodetosylation, these enamines opens up a new and practicable synthetic route to the analogues of the naturally occurring indolic[25] and bisindolic enamides.[26]

4. Experimental

4.1. General

Solvents were dried and purified using standard techniques. Melting points were determined on a Toshniwal apparatus and are uncorrected. IR spectra were recorded on Nicolet Impact 410 and Magnus 750 Series II spectrophotometers, LR EI-MS in a AEI MS 30 and LR EI-MS as well as HR MS, both EI and FAB (*m*-nitrobenzyl alcohol as liquid matrix) on JEOL JMS-AX505HA and JEOL JMS-700 MStation mass spectrometers and ^{1}H (500 MHz) and ^{13}C

Table 2. Reaction of 3-formylindoles (**1g–l**; 1 mmol) with TOSMIC (1.1 mmol) in presence of potassium carbonate (1.1 mmol) in methanol under reflux

3-Formylindoles (**1**)			Time (h)	Yield[a] (%)		
SM	R	R′		**7**	**11**	Overall
1g	Bn	H	4	72	—	72
1h	Me	Br	3	77	—	77
1i	Tos	H	2	53	37	90
1j	Tos	OMe	4	24	68	92
1k	Boc	H	3	—	38[b]	38
1l[c]	CO_2Et	H	—	—	—	98

[a] Refers to isolated pure products.
[b] This product is the same (**11i**) as that obtained from **1i**.
[c] Furnished **2A**, **2B** as the only products.

(125 MHz) NMR spectra, both 1D and 2D including DEPT-135, on a Bruker DRX 500 NMR spectrometer. Individual ^{1}H and ^{13}C NMR assignments, wherever made, were based on HMQC and HMBC spectral analyses. Silica gel G (Merck, India) was used for TLCs, both analytical and preparative, and silica gel (60–120 mesh; Qualigens, India) was used for column chromatography (CC). Elemental analyses were performed in a Dr. Hans Hoesli Analyser. The 3-formylindoles **1b**,[28] **1c**,[29] **1g**,[30] **1i**,[31] **1j**,[32] **1k**[33] and 2-formylskatole (**12**)[34] were prepared following the literature procedures. For **2A**, **2B** and **13**, the designatory letters mj and mn, used in presenting NMR data, stand for the major and the minor rotamer, respectively.

4.2. General procedure for the preparation of 3-formylindoles (1d–f,h,l)

To a solution of the 3-formylindole (5 mmol) in dry DMSO (5 mL) was added NaH (0.22 g, 5.5 mmol, 60% dispersion in mineral oil) and stirred at room temperature for 30 min. The respective alkyl iodide (MeI for **1d**, **1h**; EtI for **1e**; ^{i}PrBr for **1f**; $ClCO_2Et$ for **1l**) (0.34 mL for MeI, 0.45 mL for EtI and 0.52 mL for ^{i}PrBr, 5.5 mmol in each case) was then added to this suspension, which was then stirred for another 30 min. The reaction mixture was poured into crushed ice and extracted with EtOAc (3×25 mL). The pooled extracts were washed with water, dried (Na_2SO_4), solvent distilled off and the resulting residue crystallised from pet. ether–CH_2Cl_2 to furnish the 3-formylindoles (**1d–f**,**h**,**l**).

4.2.1. 3-Formyl-5-methoxy-1-methylindole (1d). Brown crystals; yield: 0.94 g (100%); mp 128–130 °C; ν_{max} (nujol): 3105, 1645, 1614, 1536, 1265, 1034, 783 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 3.88 and 3.89 (3H, s each), 6.97 (1H, dd, J=9, 2.5 Hz), 7.22 (1H, d, J=9 Hz), 7.59 (1H, s), 7.78 (1H, d, J=2.5 Hz), 9.92 (1H, s). Anal. calcd for $C_{11}H_{11}NO_2$: C, 69.84; H, 5.82; N, 7.40. Found C, 69.78; H, 5.83; N, 7.42.

4.2.2. 1-Ethyl-3-formyl-5-methoxyindole (1e). Reddish brown flakes; yield: 1.0 g (99%); mp 98 °C; ν_{max} (nujol): 1650, 1533, 1255, 1215, 724 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 1.54 (3H, t, J=7 Hz), 3.89 (3H, s), 4.19 (2H, q, J=7 Hz), 6.97 (1H, d, J=8 Hz), 7.26 (1H, d, J=8 Hz), 7.68, 7.8 and 9.95 (1H, s each). Anal. calcd for $C_{12}H_{13}NO_2$: C, 70.93; H, 6.40; N, 6.89. Found C, 70.98; H, 6.38; N, 6.87.

4.2.3. 3-Formyl-1-isopropyl-5-methoxyindole (1f). Yellow solid; yield: 1.06 g (98%); mp 108–110 °C; ν_{max} (nujol): 1659, 1619, 1261, 1089, 731 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 1.58 (6H, d, J=6.5 Hz), 3.89 (3H, s), 4.64 (1H, septet, J=6.5 Hz), 6.96 (1H, dd, J=9, 2 Hz), 7.29 (1H, d, J=9 Hz), 7.77 (1H, s), 7.80 (1H, d, J=2 Hz), 9.96 (1H, s). Anal. calcd for $C_{13}H_{15}NO_2$: C, 71.89; H, 6.91; N, 6.45. Found C, 71.80; H, 6.93; N, 6.43.

4.2.4. 5-Bromo-3-formyl-1-methylindole (1h). Pale yellow solid; yield: 1.19 g (100%); mp 122–124 °C; ν_{max} (nujol): 1660, 1649, 1535, 1084, 731 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 3.86 (3H, s), 7.22 (1H, d, J=8.5 Hz), 7.44 (1H, dd, J=8.5, 1.5 Hz), 7.66, 8.46 and 9.9 (1H, s each). Anal. calcd for $C_{10}H_8NOBr$: C, 50.42; H, 3.36.; N, 5.88. Found C, 50.46; H, 3.35; N, 5.86.

4.2.5. 1-Ethoxycarbonyl-3-formylindole (1l).[35] Yellow crystals; yield: 1.04 g (96%); mp 74 °C; ^{1}H NMR ($CDCl_3$): δ 1.51 (3H, t, J=7 Hz), 4.57 (2H, q, J=7.5 Hz), 7.38 and 7.43 (1H, t each, J=7.5 Hz), 8.18 (1H, d, J=7.5 Hz), 8.26 (1H, s), 8.29 (1H, d, J=7.5 Hz), 10.10 (1H, s). Anal. calcd for $C_{12}H_{11}NO_3$: C, 66.36; H, 5.07; N, 6.45. Found C, 66.28; H, 5.05; N, 6.43.

4.3. General procedure for the reaction of 3-formylindoles (1a–l) with TOSMIC

A solution of the 3-formylindole (**1a–l**, 1 mmol) and TOSMIC (0.22 g, 1.1 mmol) in dry MeOH (10 mL) containing anhydrous K_2CO_3 (0.16 g, 1.1 mmol) was refluxed until the 3-formylindole was consumed completely (see Tables 1 and 2). The solution was then poured into water and extracted with EtOAc (3×25 mL). The pooled extracts were washed with water until free from of alkali, dried (Na_2SO_4), solvent distilled off and the resulting residue purified by prep. TLC [35% EtOAc/pet. ether (double development) for **2**; 35% EtOAc/pet. ether for **7b**,**c**,**j**, **8b**,**c**,**e**,**f**, **11j**; 25% EtOAc/pet. ether for **7g**,**i**, **11i**; EtOAc: pet. ether:benzene (2:4:4) for **8d**] to furnish the products, as shown in Tables 1 and 2.

4.3.1. *N*-[2-(3′-Indolyl)-1,2-dimethoxy]ethylformamide (2A and 2B). Overall yield (**2A**+**2B**) 0.24 g (98%).

2A (*mixture of two rotamers*). Cream yellow solid; mp 144–146 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3327, 3267, 1692, 1665, 732 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 3.36 and 3.37 (3H, s each, mn), 3.40 and 3.43 (3H, s each, mj), 4.62 (1H, dd, J=10, 2.5 Hz, mn), 4.76 (1H, d, J=2.5 Hz, mj), 4.80 (1H, d, J=2.5 Hz, mn), 5.52 (1H, dd, J=10, 2.5 Hz, mj), 6.29 (1H, dd, J=10, 11.9 Hz, mn), 6.33 (1H, d, J=10 Hz, mj), 7.14 and 7.15 (1H, t each, J=7.5 Hz, mj, mn), 7.15 (1H, s, mn), 7.19 (1H, s, mj), 7.20 (mj) and 7.22 (mn) (1H, t each, J=7.5 Hz), 7.36 (mj) and 7.38 (mn) (1H, d each, J=7.5 Hz), 7.65 (mn) and 7.69 (mj) (1H, d each, J=7.5 Hz), 7.95 (1H, d, J=11.9 Hz, mn), 8.26 (1H, s, mj), 8.44 (mj) and 8.50 (mn) (1H, br s each); ^{13}C NMR: δ 55.5 (mn), 56.8 (mj), 57.6 (mn), 57.8 (mj), 78.3 (mj), 78.8 (mn), 81.4 (mj), 87.4 (mn), 111.8 (mj), 111.9 (mn), 119.2 (mn), 119.5 (mj), 120.50 (mj), 120.54 (mn), 122.8 (mj), 122.9 (mn), 123.8 (mj), 124.1 (mn), 162.0 (mj), 164.2 (mn) (all CH), 111.5 (mn), 111.7 (mj), 127.1 (2×; mj+mn), 136.5 (2×; mj+mn) (all C); EI-MS: *m*/*z* (%) 248 (M^+, 7), 216 (61), 214 (25), 184 (22), 160 (100), 156 (50), 144 (38), 130 (60), 129 (29), 117 (18). HR FAB-MS: M^+, Anal. calcd for $C_{13}H_{16}N_2O_3$ 248.1161. Found 248.1173.

2B (*mixture of two rotamers*). White solid; mp 72–74 °C (pet. ether–CH_2Cl_2); ν_{max} ($CHCl_3$): 3473, 3414, 1691, 1491, 1081 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 3.32 (3H, s, mn), 3.34 (3H mj +3H mn, s), 3.37 (3H, s, mj), 4.67 (1H, d, J=3.5 Hz, mj), 4.68 (1H, d, J=4 Hz, mn), 4.76 (1H, dd, J=10, 4 Hz, mn), 5.51 (1H, dd, J=10, 3.5 Hz, mj), 6.03 (1H, dd, J=10, 11.7 Hz, mn), 6.29 (1H, d, J=10 Hz, mj), 7.14 (1H mj +1H mn, t, J=7.5 Hz), 7.20 (1H, s, mn), 7.21 (1H mj +1H mn, t, J=7.5 Hz), 7.27 (1H, d, J=2 Hz, mj), 7.38 (mn) and 7.38 (mj) (1H, d each, J=8 Hz), 7.71 (mn) and 7.74 (mj) (1H, d each, J=8 Hz), 8.11 (1H, d, J=11.7 Hz, mn), 8.29 (1H, s, mj), 8.42 (mj) and 8.46 (mn) (1H, br s each); ^{13}C NMR: δ

55.6 (mn), 57.0 (mj), 57.3 (mn), 57.5 (mj), 78.8 (mj), 79.2 (mn), 81.0 (mj), 86.9 (mn), 111.7 (mj), 111.8 (mn), 120.2 (2×; mj+mn), 120.4 (mj), 120.6 (mn), 122.7 (mj), 122.9 (mn), 124.4 (mj), 124.7 (mn), 161.8 (mj), 163.9 (mn) (all CH), 111.0 (2×; mj+mn), 126.8 (mn), 127.2 (mj), 136.6 (mj), 136.8 (mn) (all C); EI-MS: *m/z* (%) 248 (M^+, 11), 216 (50), 214 (19), 184 (14), 160 (100), 156 (40), 144 (30), 130 (51), 129 (22), 117 (17). HR FAB-MS: M^+, Anal. calcd for $C_{13}H_{16}N_2O_3$ 248.1160. Found 248.1152.

4.3.2. 5-(1′-Methyl-3′-indolyl)oxazole (7b). Waxy; yield: 0.091 g (46%); ν_{max} (nujol): 3128, 1632, 1527, 1332, 1089, 970, 741 cm^{-1}; ^1H NMR ($CDCl_3$): δ 3.81 (3H, s), 7.24 (1H, s), 7.24 (1H, dt, J=7.5, 1 Hz), 7.30 (1H, dt, J=7.5, 1 Hz), 7.35 (1H, d, J=8 Hz), 7.39 (1H, s), 7.83 (1H, d, J=8 Hz), 7.87 (1H, s); ^{13}C NMR: δ 33.4 (N-CH_3), 110.1, 119.5, 120.4, 121.0, 123.0, 127.0, 149.1 (all CH), 104.3, 125.0, 137.5, 148.4 (all C); EI-MS: *m/z* (%) 198 (M^+, 100), 169 (19), 158 (14), 143 (55), 128 (12), 115 (14). Anal. calcd for $C_{12}H_{10}N_2O$: C, 72.72; H, 5.05; N, 14.14. Found C, 72.78; H, 5.03; N, 14.10.

4.3.3. 5-(1′-Ethyl-3′-indolyl)oxazole (7c). Waxy; yield: 0.07 g (33%); ν_{max} (film): 3127, 1631, 1608, 1525, 1208, 1089, 977, 741 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.50 (3H, t, J=7.5 Hz), 4.20 (2H, q, J=7.5 Hz), 7.23 (1H, dt, J=7.5, 1 Hz), 7.24 (1H, s), 7.29 (1H, dt, J=7.5, 1 Hz), 7.38 (1H, d, J=8 Hz), 7.47 (1H, s), 7.84 (1H, d, J=8 Hz), 7.87 (1H, s); ^{13}C NMR: δ 15.7 (CH_3), 41.6 (N-CH_2), 110.2, 119.5, 120.5, 121.0, 122.9, 125.28, 149.1 (all CH), 104.4, 125.22, 136.5, 148.4 (all C); EI-MS: *m/z* (%) 212 (M^+, 100), 197 (52). Anal. calcd for $C_{13}H_{12}N_2O$: C, 73.58; H, 5.66; N, 13.20. Found C, 73.43; H, 5.63; N, 13.25.

4.3.4. 5-(1′-Benzyl-3′-indolyl)oxazole (7g). Orange crystals; yield: 0.195 g (71%); mp 106–108 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 1633, 1527, 1182, 970, 751 cm^{-1}; ^1H NMR ($CDCl_3$): δ 5.32 (2H, s), 7.14 (2H, d, J=7 Hz), 7.25 (2H, t, J=7 Hz), 7.26 (1H, s), 7.2–7.27 (1H, m), 7.29 (1H, d, J=7.5 Hz), 7.27–7.35 (2H, m), 7.45 (1H, s), 7.85 (1H, s), 7.86 (1H, d, J=7.5 Hz); ^{13}C NMR: δ 50.7 (N-CH_2), 110.7, 119.9, 120.5, 121.3, 123.3, 126.3, 127.3 (2×), 128.3, 129.3 (2×), 148.2/149.2 (all CH), 105.1, 125.3, 137.0, 137.1, 149.2/148.2 (all C); EI-MS: *m/z* (%) 274 (M^+, 100), 234 (13), 183 (11), 120 (7), 91 (40). Anal. calcd for $C_{18}H_{14}N_2O$: C, 78.83; H, 5.10; N, 10.21. Found C, 78.91; H, 5.11; N, 10.18.

4.3.5. 5-(5′-Bromo-1′-methyl-3′-indolyl)oxazole (7h). Orange solid; yield: 0.214 g (77%); mp 88–90 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 1639, 1527, 1109, 903, 777 cm^{-1}; ^1H NMR ($CDCl_3$): δ 3.80 (3H, s), 7.20 (1H, s), 7.20 (1H, d, J=8.5 Hz), 7.36 (1H, s), 7.37 (1H, dd, J=8.5, 1.5 Hz), 7.88 (1H, s), 7.96 (1H, d, J=1.5 Hz); ^{13}C NMR: δ 33.6 (N-CH_3), 111.6, 119.8, 123.0, 125.9, 127.9, 149.3 (all CH), 104.0, 114.4, 126.6, 136.1, 147.6 (all C); EI-MS: *m/z* (%) 278 (M^+, 100), 276 (100), 197 (21). Anal. calcd for $C_{12}H_9N_2OBr$: C, 51.98; H, 3.24; N, 10.10. Found C, 51.90; H, 3.22; N, 10.14.

4.3.6. 5-(1′-Tosyl-3′-indolyl)oxazole (7i). Pale yellow solid; yield: 0.18 g (53%); mp 144 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3145, 3118, 1633, 1593, 1176, 1113, 961, 751 cm^{-1}; ^1H NMR (d_6-DMSO): δ 2.27 (3H, s), 7.35 (2H, d, J=8 Hz), 7.36 (1H, t, J=7.5 Hz), 7.43 (1H, t, J=7.5 Hz), 7.75 (1H, s), 7.91 (2H, d, J=8 Hz), 7.93 (1H, d, J=8 Hz), 7.99 (1H, d, J=8 Hz), 8.21 (1H, s), 8.48 (1H, s); ^{13}C NMR: δ 21.8 (CH_3), 114.3, 121.7, 123.6, 124.1, 125.1, 126.6, 127.8 (2×), 131.2 (2×), 145.3/146.7 (all CH), 111.4, 127.1, 134.5, 135.1, 146.7/145.3, 152.2 (all C); EI-MS: *m/z* (%) 338 (M^+, 29), 183 (100), 155 (13), 127 (24), 91 (16). Anal. calcd for $C_{18}H_{14}N_2O_3S$: C, 63.90; H, 4.14; N, 8.28. Found C, 63.95; H, 4.12; N, 8.24.

4.3.7. 5-(5′-Methoxy-1′-tosyl-3′-indolyl)oxazole (7j). White amorphous solid; yield: 0.09 g (24%); mp 160–162 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3130, 1631, 1595, 1230, 1141, 970, 799 cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.34 (3H, s), 3.86 (3H, s), 7.0 (1H, dd, J=9, 2 Hz), 7.18 (1H, d, J=2 Hz), 7.23 (2H, d, J=8 Hz), 7.34 (1H, s), 7.78 (2H, d, J=8 Hz), 7.86 (1H, s), 7.93 (1H, d, J=9 Hz), 7.95 (1H, s); ^{13}C NMR: δ 21.9 (CH_3), 56.1 (OCH_3), 103.5, 114.8, 115.1, 122.4, 124.2, 127.2 (2×), 130.4 (2×), 145.7/146.1 (all CH), 111.2, 128.3, 130.2, 135.2, 146.1/145.7, 150.3, 157.3 (all C); EI-MS: *m/z* (%) 368 (M^+, 26), 213 (100), 199 (9), 115 (18). Anal. calcd for $C_{19}H_{16}N_2O_4S$: C, 61.95; H, 4.34; N, 7.60. Found C, 61.90; H, 4.35; N, 7.57.

4.3.8. (*E*)-2-(1′-Methyl-3′-indolyl)-2-tosylethenamine (8b). Reddish brown solid; yield: 0.104 g (32%); mp 92–94 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3463, 3354, 1641, 1536, 1275, 1145, 743 cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.31 (3H, s, CH_3), 3.77 (3H, s, N-CH_3), 4.35 (2H, d, J=10.5 Hz; D_2O-exchangeable; NH_2), 6.99 (1H, t, J=7.5 Hz, H-5′), 7.06 (2H, d, J=8 Hz, H-3″, 5″), 7.08 (1H, d, J=7.5 Hz, H-4′), 7.17 (1H, t, J=7.5 Hz, H-6′), 7.18 (1H, s, H-2′), 7.29 (1H, d, J=7.5 Hz, H-7′), 7.55 (2H, d, J=8 Hz, H-2″, 6″), 7.78 (1H, t, J=10.5 Hz, =C*H*NH_2; collapsed to a singlet on addition of D_2O); ^{13}C NMR: δ 21.7 (CH_3), 33.4 (N-CH_3), 102.3 (C-3′), 104.9 [Ar*C*(Tos)=], 110.0 (CH-7′), 119.94 and 119.98 (CH-4′, 5′), 122.1 (CH-6′), 126.7 (C-3′a), 127.3 (2×; CH-2″, 6″), 129.4 (2×; CH-3″, 5″), 131.4 (CH-2′), 137.1 (C-7′a), 140.1 (C-1″), 142.6 (C-4″), 142.9 (=*C*HNH_2); EI-MS: *m/z* (%) 326 (M^+, 56), 171 (100), 156 (11), 144 (21), 130 (10), 91 (11). HR FAB-MS: M^+, Anal. calcd for $C_{18}H_{18}N_2O_2S$ 326.1089. Found 326.1091.

4.3.9. (*E*)-2-(1′-Ethyl-3′-indolyl)-2-tosylethenamine (8c). Brown solid; yield: 0.14 g (41%); mp 70–72 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3471, 3355, 1639, 1271, 1142, 1080, 741 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.44 (3H, t, J=6.5 Hz), 2.28 (3H, s), 4.15 (2H, q, J=6.5 Hz), 4.33 (2H, d, J=10 Hz, D_2O-exchangeable; NH_2), 6.98 (1H, t, J=7.5 Hz), 7.05 (2H, d, J=7 Hz), 7.10 (1H, d, J=7.5 Hz), 7.16 (1H, t, J=7.5 Hz), 7.23 (1H, s), 7.31 (1H, d, J=7.5 Hz), 7.54 (2H, d, J=7 Hz), 7.78 (1H, t, J=10 Hz, =C*H*NH_2; collapsed to a singlet on addition of D_2O); ^{13}C NMR: δ 15.8, 21.7 (both CH_3), 41.5 (CH_2), 110.0, 119.9, 120.0, 121.9, 127.4 (2×), 129.4 (2×), 129.7 (all CH), 142.6 (2×; CH+C), 102.4, 105.2, 126.9, 136.2, 140.0 (all C); FAB-MS: *m/z* (%) 340 (M^+, 85), 313 (10), 186 (39), 185 (100), 172 (23), 158 (49), 130 (13). Anal. calcd for $C_{19}H_{20}N_2O_2S$: C, 67.05; H, 5.88; N, 8.23. Found C, 67.11; H, 5.87; N, 8.26.

4.3.10. (*E*)-2-(5′-Methoxy-1′-methyl-3′-indolyl)-2-tosylethenamine (8d). Colourless prisms; yield: 0.22 g (62%);

mp 180–182 °C (pet. ether–EtOAc); ν_{max} (nujol): 3461, 3347, 1639, 1533, 1269, 1215, 1134, 1082, 671 cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.29 (3H, s), 3.67 (3H, s), 3.73 (3H, s), 4.32 (2H, d, J=10 Hz), 6.42 (1H, s), 6.81 (1H, d, J=8.5 Hz), 7.08 (2H, d, J=8 Hz), 7.09 (1H, s), 7.16 (1H, d, J=8.5 Hz), 7.55 (2H, d, J=8 Hz), 7.77 (1H, t, J=10 Hz); ^{13}C NMR: δ 21.7, 33.5, 56.0 (all CH_3), 101.4, 110.7, 112.4, 127.5 (2×), 129.4 (2×), 131.8, 142.9 (all CH), 101.7, 105.2, 127.5, 132.5, 140.2, 142.6, 154.6 (all C); EI-MS: *m/z* (%) 356 (M^+, 58), 202 (16), 201 (100), 186 (10), 185 (10), 174 (11). Anal. calcd for $C_{19}H_{20}N_2O_3S$: C, 64.04; H, 5.61; N, 7.86. Found C, 64.15; H, 5.60; N, 7.89.

4.3.11. (*E*)-2-(1′-Ethyl-5′-methoxy-3′-indolyl)-2-tosylethenamine (8e). Reddish brown solid; yield: 0.25 g (68%); mp 142–144 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3502, 3376, 1633, 1533, 1268, 1215, 1129, 1076, 671 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.42 (3H, t, J=7.5 Hz), 2.29 and 3.68 (3H, s each), 4.10 (2H, q, J=7.5 Hz), 4.31 (2H, d, J=10.5 Hz), 6.46 (1H, d, J=2 Hz), 6.80 (1H, dd, J=9, 2 Hz), 7.07 (2H, d, J=8 Hz), 7.14 (1H, s), 7.19 (1H, d, J=9 Hz), 7.55 (2H, d, J=8 Hz), 7.77 (1H, t, J=10.5 Hz); ^{13}C NMR: δ 15.8, 21.7 (both CH_3), 56.1 (OCH_3), 41.6 (N-CH_2), 101.6, 110.7, 112.2, 127.5 (2×), 129.4 (2×), 130.1 (all CH), 142.6 (2×; CH+C), 101.9, 105.5, 127.6, 131.5, 140.1, 154.5 (all C); EI-MS: *m/z* (%) 370 (M^+, 93), 216 (41), 215 (100), 188 (32), 185 (18), 160 (15), 91 (20). Anal. calcd for $C_{20}H_{22}N_2O_3S$: C, 64.86; H, 5.94; N, 7.56. Found C, 64.90; H, 5.95; N, 7.52.

4.3.12. (*E*)-2-(1′-Isopropyl-5′-methoxy-3′-indolyl)-2-tosylethenamine (8f). Ochre yellow solid; yield: 0.28 g (73%); mp 54–56 °C (pet. ether–CH_2Cl_2); ν_{max} (KBr): 3479, 3375, 1637, 1483, 1276, 1218, 1147, 673 cm^{-1}; ^1H NMR ($CDCl_3$): (1.47 (6H, d, J=6.5 Hz), 2.29 and 3.69 (3H, s each), 4.32 (2H, d, J=10.5 Hz), 4.57 (1H, septet, J=6.5 Hz), 6.49 (1H, d, J=2 Hz), 6.80 (1H, dd, J=9, 2 Hz), 7.07 (2H, d, J=8 Hz), 7.17 (1H, s), 7.22 (1H, d, J=9 Hz), 7.54 (2H, d, J=8 Hz), 7.77 (1H, t, J=10.5 Hz); ^{13}C NMR: δ 21.7, 23.1 (2×) (all CH_3), 56.1 (OCH_3), 47.9, 101.5, 110.9, 112.1, 126.9, 127.6 (2×), 129.3 (2×), 142.4/142.6 (all CH), 102.0, 105.6, 127.6, 131.2, 139.9, 142.4/142.6, 154.4 (all C); EI-MS: *m/z* (%) 384 (M^+, 50), 229 (100), 202 (21), 187 (12), 174 (9), 160 (16), 156 (12), 91 (27); Anal. calcd for $C_{21}H_{24}N_2O_3S$: C, 65.62; H, 6.25; N, 7.29. Found C, 65.73; H, 6.27; N, 7.32.

4.3.13. 5-(3′-Indolyl)oxazole (11i). Pale yellow solid; yield: 0.068 g (37%); mp 170–172 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3170, 3143, 1630, 1614, 1089, 979, 738 cm^{-1}; ^1H NMR (d_6-DMSO): δ 7.12 and 7.17 (1H, t each, J=7.5 Hz), 7.41 (1H, s), 7.45 (1H, d, J=7.5 Hz), 7.77 (1H, s), 7.82 (1H, d, J=7.5 Hz), 8.29 (1H, s), 11.68 (1H, br s); ^{13}C NMR ($CDCl_3$): δ 112.0, 119.9, 120.3, 121.4, 122.5, 123.5, 149.3 (all CH), 106.0, 124.5, 136.6, 148.3 (all C); EI-MS: *m/z* (%) 184 (M^+, 100), 157 (10), 141 (18), 130 (35). Anal. calcd for $C_{11}H_8N_2O$: C, 71.73; H, 4.34; N, 15.21. Found C, 71.83; H, 4.35; N, 15.19.

4.3.14. 5-(5′-Methoxy-3′-indolyl)oxazole (11j). White solid; yield: 0.146 g (68%); mp 154–156 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3159, 1639, 1633, 1252, 1090, 797 cm^{-1}; ^1H NMR ($CDCl_3$): δ 3.90 (3H, s), 6.94 (1H, dd, J=9, 2 Hz), 7.25 (1H, s), 7.29 (1H, d, J=2 Hz), 7.32 (1H, d, J=9 Hz), 7.52 (1H, d, J=2 Hz), 7.91 (1H, s), 8.72 (1H, br s); ^{13}C NMR: δ 56.3 (OCH_3), 102.1, 112.8, 113.6, 119.6, 123.2, 149.2 (all CH), 105.6, 125.0, 131.7, 148.5, 155.4 (all C); EI-MS: *m/z* (%) 214 (M^+, 100), 199 (33), 171 (28). Anal. calcd for $C_{12}H_{10}N_2O_2S$: C, 67.28; H, 4.67; N, 13.08. Found C, 67.35; H, 4.66; N, 13.06.

4.4. Reaction of 2-formyskatole (12) with TOSMIC

To a solution of 2-formylskatole (0.16 g, 1 mmol) in THF (2 mL) was added TOSMIC (0.22 g, 1.1 mmol) and DBU (0.17 mL, 1.1 mmol), the mixture stirred at room temperature for 2 h and then neutralised with acetic acid. The solution was poured into water and extracted with EtOAc (3×20 mL). The pooled extracts were washed with water, dried (Na_2SO_4), solvent distilled off and the resulting residue purified by prep. TLC using 20% EtOAc/pet. ether as the developing system to furnish **13**.

4.4.1. *N*-[1-Tosyl-2-(3′-methyl-2′-indolyl)]ethenylformamide (13; 3:2 mixture of two rotamers). Yellow solid, yield: 0.22 g (62%); mp 74–76 °C (pet. ether–CH_2Cl_2); ν_{max} (nujol): 3362, 1712, 1639, 1225, 1137, 1076, 671 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.70 (mj) and 1.72 (mn) (3H, s each), 2.34 (3H mj +3H mn, s), 7.11 and 7.12 (2H, d each, J=7 Hz, mj, mn), 7.10 (1H, d, J=8 Hz) and 7.14 (1H, d, J=8 Hz) (mj, mn), 7.25 (1H mj+1H mn, t, J=8 Hz), 7.39 (1H mj +1H mn, t, J=8 Hz), 7.44 (mn) and 7.43 (mj) (2H, d each, J=8 Hz), 7.47 (1H mj+1H mn, d, J=8 Hz), ~7.46 (1H, s, mn), 7.65 (1H, d, J=12 Hz, mj), 7.95 (1H, d, J=11 Hz, mn), 8.19 (1H, s, mj), 8.39 (1H, d, J=12 Hz, mj), 8.51 (1H, d, J=8 Hz, mn), 8.67 (mn) and 8.77 (mj) (1H, br s each); ^{13}C NMR: δ 9.0 (mj), 14.5 (mn), 21.9 (mj), 23.0 (mn), 111.8 (mj), 111.9 (mn), 119.5 (mj), 119.6 (mn), 120.1 (2×; mj+mn), 124.1 (mj), 124.2 (mn), 127.7 (2×; mn), 127.8 (2×; mj), 130.0 (2×; mj), 130.1 (2×; mn), 131.4 (mj), 135.0 (mn), 158.8 (mj), 162.8 (mn) (all CH), 114.1 (mj), 114.2 (mn), 116.2 (mn), 117.6 (mj), 120.4 (mn), 121.1 (mj), 128.1 (2×; mj+mn), 136.6 (mn), 136.8 (mj), 137.2 (mn), 137.3 (mj), 144.6 (mj), 144.8 (mn) (all C); EI-MS: *m/z* (%) 354 (M^+, 88), 200 (17), 199 (100), 171 (31), 158 (29), 144 (13), 130 (13). HR FAB-MS: M^+, Anal. calcd for $C_{19}H_{18}N_2O_3S$ 354.1038. Found 354.1059.

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23. Crystal data: crystals from petroleum ether–EtOAc, $C_{19}H_{20}N_2O_3S$, $M=356.44$, monoclinic, $a=18.019(2)$ Å, $b=10.485(1)$ Å, $c=19.661(3)$ Å, $\beta=101.98(1)^\circ$, $V=3633.6(8)$ Å^3, $T=296.2$ K, space group $P2_1/n$, $Z=8$, $D_c=1.303$ g cm^{-3}, μ(Cu-Kα)$=17.51$ cm^{-1}, $F(000)=1504.00$, crystal dimensions: $0.40\times0.40\times0.40$ mm, Rigaku AFC5R diffractometer (rotating anode), Cu-Kα radiation, $\lambda=1.54178$ Å, $\theta_{max}=70.12^\circ$; 7220 reflections measured, 6682 unique ($R_{int}=0.082$), 5092 with $I>2.00\,\sigma(I)$, $2\theta<140.24^\circ$, $wR(F^2)=0.1810$ (all data). Two crystallographically independent molecules exist in an asymmetric unit and are represented by the carbon number C1–C19 and C20–C38. CCDC-244416 contains the supplementary crystallographic data for this paper. These data can be obtained via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033; e-mail: deposit@ccdc.cam.ac.uk).
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