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Synthesis and structural characterisation of 6-hydroxycoumarin derivatives

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Abstract

This work involved the synthesis and structural characterisation of two O-acylated derivatives of 6-hydroxycoumarin (6-coumarinyl 4-chlorobenzoate and 6-coumarinyl 4-tert-butylbenzoate). The structure of the synthesised product was confirmed by various spectroscopic techniques, notably infrared (IR) spectroscopy, proton (^{1}H) nuclear magnetic resonance (NMR), carbon-13 (^{13}C) NMR, and mass spectrometry. The appearance of new IR vibrational bands, attributed to the new bonds formed, and the good correlation between the proton (^{1}H) NMR and carbon-13 (^{13}C) NMR results confirm this conclusion.

1. Introduction

Coumarins represent a large class of oxygen-containing heterocycles that have attracted the attention of

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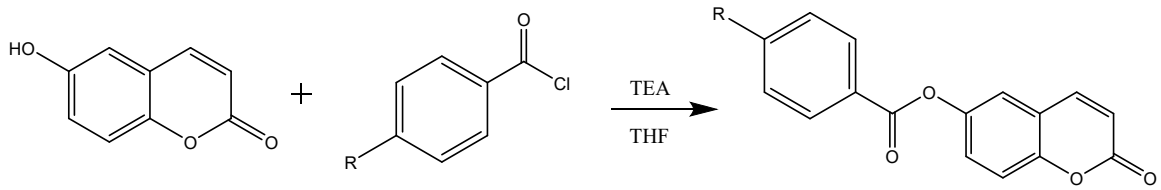
many researchers. These biologically active compounds play a major role in our society, as they form the basis of many active ingredients used in the pharmaceutical, cosmetics and perfumery industries [1-4]. Although these compounds are of natural origin, they can be obtained by total synthesis or by semisynthesis [5]. 6-Hydroxycoumarin, a hydroxylated derivative of coumarin, belongs to a family of these aromatic compounds that are widely distributed throughout the plant kingdom [6]. It is the presence of the simple coumarin ring (benzo-α-pyrone) that confers pharmacological and therapeutic interest on these compounds [7,8]. Functionalising this ring with various groups can significantly optimise its properties [9]. The aim of this work is to synthesise and determine, by spectrometry, the structures of two esters derived from 6-hydroxycoumarin.

2. Experimental Section

2.1. Synthesis

2.1.1. Summary

6-Coumarinyl benzoates were synthesised from 6-hydroxycoumarin by acylation with an acyl chlorides in the presence of triethylamine (TEA) in tetrahydrofuran (THF) [10].



6-hydroxycoumarine Chlorure de benzoyle 4-tertiobutylbenzoate de 6-coumarinyle (1)

1a: R= Cl; 1b: R = t-Bu

Scheme 1. Synthesis of 6-coumarinyl benzoates (1).

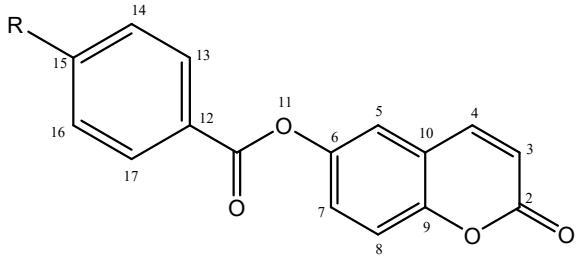
2.1.2. Procedure

In a 100 mL round-bottomed flask fitted with a condenser and containing 30 mL of THF, add one mole of benzoyl chloride and three moles of triethylamine. With stirring, add one mole of the substrate (6-hydroxycoumarin). The reaction mixture is refluxed for four (4) hours [11]. The resulting solution is poured into a separating funnel containing forty (40) mL of chloroform and then acidified with a 10% dilute hydrochloric acid solution. The organic phase is separated and washed with distilled water until the pH becomes neutral. This is then dried over $CaCl_2$. After filtration, the solvent is removed using a rotary evaporator. This yields crude 6-coumarinyl benzoate, which is subsequently recrystallised from a chloroform-hexane solvent mixture (1:3, v/v).

2.1.3. Equipment and measurements

The melting point was determined in capillary tubes using a Stuart SMP 11 apparatus. The IR spectrum was recorded on a Bruker IFS 66/S (FT-IR) spectrometer. The ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AVANCE DPX300 spectrometer operating at 300 MHz at 25 °C. The electrospray ionisation mass spectra (ESI-MS) were acquired on a Thermo Finnigan LCQ Deca XP ion trap mass spectrometer.

2.2. Characterisation



Scheme 2. Numbering of the compound's structure (1).

2.2.1. 6-coumarinyl 4-chlorobenzoate (1a)

White solid; **mp:** 95-98 °C; **Rdt:** 80%; $\mathbf{R_f}$: 0.62 (acetone/hexane: 4/6).

IR (cm^{-1}): 1750 (C=O Ester); 1710 (C=O lactone); 1450 (C=C benzene); 1250 (C-O aliphatique); 1099 (C-O lactone); 910-800 (C-H aromatique); 750 (C-Cl).

RMN ^{13}C (ppm): 167.2 (C_{11}); 162.5 (C_2); 151.5(C_6); 148.5 (C_9); 145.5 (C_4); 141 (C_{15}); 135 ($C_{13\text{-}17}$); 130 ($C_{14\text{-}16}$); 126.5 (C_{12}); 123 (C_{10}); 121.5 (C_8); 118.5 (C_7); 116.5 (C_5); 111 (C_3).

RMN ^{1}H (ppm): 8.1 (d, 2H, $H_{13\text{-}17}$); 7.85 (d, 2H, $H_{14\text{-}16}$); 7.68 (d, 1H, H_4); 7.59 (d, 1H, H_7); 7.26 (s, 1H, H_5); 7.12 (d, 1H, H_8); 6.32 (d, 1H, H_3).

2.2.2. 6-coumarinyl 4-tert-butylbenzoate (1b)

Pale yellow crystals; **mp:** 162-164 °C, **Rdt:** 84%; $\mathbf{R_f}$: 0.57 (acetone/ hexane: 4/6).

IR (cm^{-1}): 1740 (C=O, ester); 1710 (C=O, lactone); 1460 (C=C, aromatique); 1190 (C-O, ester); 1050 (C-O, lactone); 3098 and 1240 (C-H, aromatique); 2950 (C-H, CH_3).

RMN ^{13}C (ppm): 162.5 (C_{11}); 160.94 (C_2); 156.16 (C_{15}); 150.85 (C_6); 148.65 (C_9); 131.52 (C_4); 129.64 ($C_{13\text{-}17}$); 125.8 (C_{12}); 125.48 ($C_{14\text{-}16}$); 124.51 (C_{10}); 123.84 (C_8); 108.94 (C_7); 72.51 (C_5); 39.51 (C_3); 35.46 (C_{18}); 30.65 (C_{19}).

RMN ^{1}H (ppm): 8.79 (d, 2H, $H_{13\text{-}17}$); 8.18 (d, 2H, $H_{14\text{-}16}$); 7.8 (d, 1H, H_4); 7.73 (d, 1H, H_8); 7.31 (s, 1H, H_5); 7.21 (d, 1H, H_7); 6.46 (d, 1H, H_3); 1.34 (s, 9H, CH_3).

ESI-MS: m/z 323.03 $[M+H]^+$ and m/z 666.93 $[2M+Na]^+$.

2.2.3. Crystal structure determination (1b)

Chemical formula: $C_{20}H_{18}O_4$; molar mass: 322.34; crystal description: prism, colourless; melting point (K): 435–437; crystal system: monoclinic; Hall symbol: -C2yc; space group: C2/c; temperature (K): 100; diffractometer: Bruker D8 Venture; wavelength (Å): λ = 0.71073; unit cell dimensions: a = 35.908 (4) Å, b = 6.8473 (6) Å, c = 13.2661 (11) Å; β = 98.915 (4)°; Volume (Å³): 3222.3 (5); Z = 8; radiation type: MoKα; absorption coefficient (mm^{-1}): 0.09; density ($mg.m^{-3}$): 1.329; F(000): 1360; crystal size (mm): 0.20 × 0.15 ×

0.08; 4940 measured reflections; 60054 independent reflections; Rint = 0.061; (sin θ/λ)max ($Å^{-1}$) = 0.716; R[$F^2 > 2\sigma(F^2)$] = 0.044; wR(F^2) = 0.124; S = 1.11; H-atom treatment: all H-atom parameters refined; 289 parameters; Δρ max (e $Å^{-3}$) = 0.30; Δρ min (e $Å^{-3}$) = -0.27 [4].

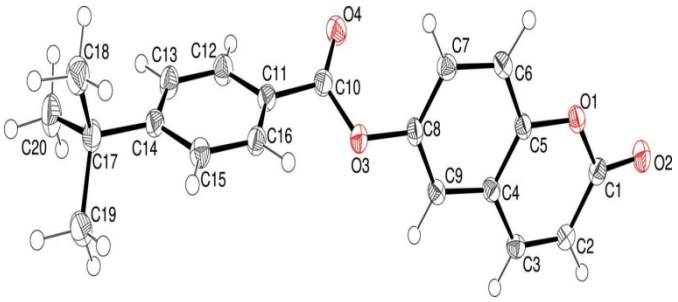


Figure 1. Crystal structure.

3. Discussion

The absorption bands of the C=O carbonyl group appear at 1750 cm^{-1} with high intensity for the ester group and at 1710 cm^{-1} for the lactone group with relatively high intensity [12,13]. The absorption bands between 910–800 cm^{-1} correspond to the vibrational bands of the aromatic C–H bonds [14]. Similarly, the stretching bands of the aliphatic C–O bond are observed at 1250 cm^{-1} with high intensity [5,15]. As for the bands appearing between 1600–1450 cm^{-1}, these correspond to the stretching vibrations of the aromatic C=C bonds [16]. We observe the presence of a characteristic mid-infrared band of the Cl substituent located in the para position of the phenyl ring (1a). This is the C–Cl band at 750 cm^{-1} [17,18]. The band observed at 2950 cm^{-1} is attributable to the stretching of the C–H bond of the tert-butyl group (1b).

The nuclear magnetic resonance spectrum shows most of the expected signals. The signals at 162 and 160 ppm correspond to carbonyls ($C_{2–11}$). The peaks between 145 and 115 ppm correspond to aromatic carbons, with multiple signals for the two benzene rings. At 126.5 ppm there is a C_{12} carbon; equivalent $C_{13–17}$ and $C_{14–16}$ carbons have chemical shifts of approximately 135 and 130 ppm, respectively. The chemical shift at 141 ppm is attributable to the carbon bearing the chlorine atom (Cl–C) (1a). The most shielded carbons (aliphatic carbons) generally appear at chemical shifts between 8.69 and 55.57 ppm [2]. In the spectrum of compound (1b), the signal observed at 30.65 ppm is attributed to the tert-butyl group, consistent with its saturated aliphatic nature. The ^1H NMR spectra of the compounds show the expected number of signals. The aliphatic protons appear at chemical shifts between 1.21 and 2.36 ppm [19]. The signal at 1.34 ppm is a 9H singlet corresponding to the tert-butyl group. The other protons are aromatic and resonate between 6 and 9 ppm, with the expected multiplicities.

Mass spectrometric analysis of the sample using positive-mode electrospray ionisation revealed the presence, in solution, of a compound with a molecular mass of 322 g/mol and the molecular formula $C_{20}H_{18}O_4$. Consequently, this could be the compound 6-coumarinyl 4-tert-butylbenzoate.

4. Conclusion

We synthesised 6-coumarinyl 4-tert-butylbenzoate and 6-coumarinyl 4-chlorobenzoate. We obtained the compounds with an average yield of 80%. We were able to confirm their structure using complementary

spectroscopic methods; the good resolution of the spectra attests to the purity of the products. The infrared spectra enabled us to identify the functional groups. Through the proton and carbon-13 NMR spectra, we highlighted the expected chemical shifts and signal multiplicities. The ESI-MS spectrum of compound 1b yielded a molecular mass of 322 g/mol, corresponding to the theoretical mass calculated from the molecular formula $C_{20}H_{18}O_4$. X-ray diffraction enabled us to determine the crystal structure of compound 1b. 6-Hydroxycoumarin derivatives present themselves as potential candidates for the development of new bioactive molecules, particularly in the pharmaceutical and cosmetic sectors. Further studies, particularly on their biological properties, as well as in vivo and mechanistic investigations, will be necessary to better understand their modes of action and confirm their therapeutic potential.

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References

[1] Murray, R. D. H., Mendez, J., & Brown, S. A. (1982). *The natural coumarins: Occurrence and biochemistry*. Wiley-Interscience.

[2] Pawar, B., Shinde, V., & Chaskar, A. (2013). n-Dodecylbenzene sulfonic acid (DBSA) as a novel Brønsted acid catalyst for the synthesis of bis(indolyl)methanes and bis(4-hydroxycoumarin-3-yl)methanes in water. *Green and Sustainable Chemistry, 3*(2), 56–60. https://doi.org/10.4236/gsc.2013.32010

[3] Fethi, R. (2017). *Coumarines à intérêt thérapeutique : Synthèse et contrôle analytique* (Doctoral dissertation, Université Abou Bekr Belkaid).

[4] Tsobnang, P. K., Ziki, E., Siaka, S., Yoda, J., Kamal, S., Bouraima, A., Hounsi, A. D., Wenger, E., Bendeif, E. E., & Lecomte, C. (2024). Synthesis, structure and Hirshfeld surface analysis of 2-oxo-2H-chromen-6-yl 4-tert-butylbenzoate: Work carried out as part of the AFRAMED project. *Acta Crystallographica Section E: Crystallographic Communications, 80*, 106–109. https://doi.org/10.1107/S2056989023011052

[5] Bakouan, Y., Sessouma, B., & Tarpaga, L. (2021). Étude phytochimique et activité antioxydante des extraits de Cassia sieberiana DC. *Journal de la Société Ouest-Africaine de Chimie, 50*, 23–29.

[6] Bruneton, J. (2009). Coumarines. In *Pharmacognosie, phytochimie, plantes médicinales* (rev. ed., pp. 263–278). Tec & Doc.

[7] Abdelhafez, O. M., Amin, K. M., Batran, R. Z., Maher, T. J., Nada, S. A., & Sethumadhavan, S. (2010). Synthesis, anticoagulant and PIVKA-II induced by new 4-hydroxycoumarin derivatives. *Bioorganic & Medicinal Chemistry, 18*, 3371–3378. https://doi.org/10.1016/j.bmc.2010.04.009

[8] Rohini, K., & Srikumar, P. S. (2014). Therapeutic role of coumarins and coumarin-related compounds. *Journal of Thermodynamics & Catalysis, 5(*2), Article 130. https://doi.org/10.4172/2157-7544.1000130

[9] Djandé, A., Cissé, L., Yoda, J., Kaboré, L., & Duvernay, F. (2019). Synthesis and fluorescence study of a series of 4-hydroxycoumarin O-acylation derivatives. *World Journal of Pharmacy and Pharmaceutical Sciences, 8*(1), 116–130.

[10] Yoda, J. (2020). Synthesis and characterization of some new coumarin derivatives by esterification of 4-hydroxycoumarin. *American Journal of Heterocyclic Chemistry, 6*(1), 6–10. https://doi.org/10.11648/j.ajhc.20200601.12

[11] Tapase, A. B., Venkat, S. S., Naranyan, D. S., & Devani, B. S. (2012). Synthesis and antimicrobial activity of some novel coumarin derivatives. *Bulletin of Environment, Pharmacology and Life Sciences, 1*(7), 30–33.

[12] Punjabi, D., Huang, Y.-C., Holzhauer, L., Tremouilhac, P., Friederich, P., Jung, N., & Bräse, S. (2024). *Infrared spectrum analysis of organic molecules with neural networks using standard reference data sets in combination with real world data*. ChemRxiv. https://doi.org/10.26434/chemrxiv-2024-7twhh

[13] Dahoo, P. R., & Lakhlifi, A. (2018). *Spectroscopie infrarouge de molécules diatomiques pour l'observation spatiale*. ISTE Éditions. https://doi.org/10.51926/ISTE.9781784053888

[14] Frost, R. L., & Kloprogge, J. T. (1999). Raman spectroscopic study of the uranyl micas. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 55*, 2195–2205. https://doi.org/10.1016/S1386-1425(99)00016-5

[15] Sosso, S. (2019). *Synthèse, caractérisation structurale et études de la fluorescence et du pouvoir reducteur d'une série de composés d'acylation de la chroman-2,3-dione* (Doctoral dissertation, Université Joseph KI-ZERBO).

[16] Yoda, J. (2015). *Synthèse et étude des propriétés physico-chimiques des carboxylates de 3-coumarinyle* (Doctoral dissertation, Université de Ouagadougou).

[17] Coates, J. (1996). Interpretation of infrared spectra, a practical approach. *Applied Spectroscopy Reviews, 31*(1–2), 179–192. https://doi.org/10.1080/05704929608000568

[18] Coates, J. (2004). Interpretation of infrared spectra, a practical approach. In R. A. Meyers (Ed.), *Encyclopedia of Analytical Chemistry* (pp. 1–23). John Wiley & Sons.

[19] Canet, D., Boubel, J.-C., & Canet-Soulas, E. (2020). *La RMN: Concepts, méthodes et applications*. HAL. ⟨hal-02995311⟩.