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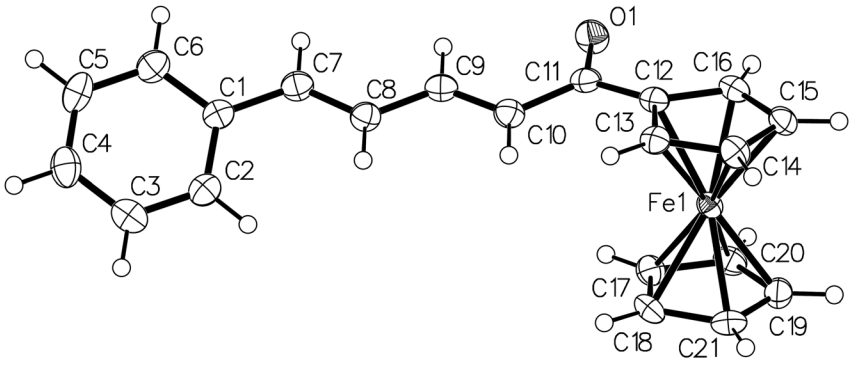
The crystal structure of (2*E*,4*E*)-1-ferrocenyl-5-phenylpenta-2,4-dien-1-one, $C_{21}H_{18}FeO$



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Abstract

$C_{21}H_{18}FeO$, monoclinic, $P2_1/c$ (no. 14), a = 5.8577(3) Å, b = 11.2160(5) Å, c = 24.1507(11) Å, β = 92.803(2)°, V = 1584.80(13) Å^3, Z = 4, $R_{gt}(F)$ = 0.0383, $wR_{ref}(F^2)$ = 0.0755, T = 170 K.

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The molecular structure is shown in the figure. Table 1 contains crystallographic data and Table 2 contains the list of the atoms including atomic coordinates and displacement parameters.

Table 1: Data collection and handling.

Crystal:	Colorless block
Size:	0.15 × 0.08 × 0.05 mm
Wavelength:	Mo *K*α radiation (0.71073 Å)
μ:	0.95 mm^{-1}
Diffractometer, scan mode:	Bruker APEX-II, φ and ω
θ_{max}, completeness:	26.4°, 98%
$N(hkl)_{measured}$, $N(hkl)_{unique}$, R_{int}:	13,035, 3155, 0.057
Criterion for I_{obs}, $N(hkl)_{gt}$:	$I_{obs} > 2\ \sigma(I_{obs})$, 2442
$N(param)_{refined}$:	208
Programs:	Bruker [1], Olex2 [2], SHELX [3, 4]

Source of material

First, 10 mmol cinnamaldehyde and 10 mmol acetylferrocene were mixed and put into a round-bottomed flask. Fifty milliliters ethanol was added to mixture, and stirred to dissolve the solid at room temperature. Subsequently, 10 mL KOH (20%) was added. After all staring material had vanished (monitored by thin layer chromatography), the reactants were poured into 50 mL water, and then separate out the solids. The solid product was treated through vacuum filtering, and washed by water and 30% ethanol aqueous solution respectively. The single crystal of the title molecule was acquired by recrystallization at the room temperature for one week.

Experimental details

All H atoms from C atoms were placed in idealized geometry and treated as riding on their parent C atoms, with d(C–H) = 0.95 Å, and U_{iso}(H) = 1.2 U_{eq}(C).

Comment

Cinnamaldehyde derivatives are feature the cinnamoyl moiety, which serve as electrophiles to react with some enzymes and receptors [5]. With the highly reactive α, β-unsaturated carbonyl pharmacophore, these derivatives exhibit excellent biological activities [6], like antifungal [5],

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Table 2: Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2).

Atom	*x*	*y*	*z*	U_{iso}*/U_{eq}
C1	0.6092 (5)	0.6450 (2)	0.45378 (11)	0.0250 (6)
C2	0.3890 (5)	0.6563 (2)	0.42937 (11)	0.0286 (7)
H2	0.333735	0.598064	0.403471	0.034*
C3	0.2509 (5)	0.7509 (2)	0.44242 (12)	0.0327 (7)
H3	0.101505	0.757029	0.425504	0.039*
C4	0.3283 (6)	0.8369 (3)	0.47996 (13)	0.0371 (8)
H4	0.232148	0.901581	0.488960	0.045*
C5	0.5456 (5)	0.8280 (3)	0.50419 (13)	0.0373 (8)
H5	0.599545	0.886808	0.529961	0.045*
C6	0.6858 (5)	0.7336 (2)	0.49103 (12)	0.0307 (7)
H6	0.836035	0.728935	0.507564	0.037*
C7	0.7622 (5)	0.5475 (2)	0.43969 (11)	0.0282 (6)
H7	0.920384	0.558360	0.448883	0.034*
C8	0.7011 (5)	0.4443 (2)	0.41511 (11)	0.0263 (6)
H8	0.543198	0.430383	0.406796	0.032*
C9	0.8609 (5)	0.3537 (2)	0.40062 (11)	0.0264 (6)
H9	1.019145	0.370907	0.406179	0.032*
C10	0.8029 (5)	0.2470 (2)	0.37992 (11)	0.0270 (6)
H10	0.645524	0.229196	0.373107	0.032*
C11	0.9738 (5)	0.1558 (2)	0.36722 (11)	0.0245 (6)
C12	0.8907 (4)	0.0331 (2)	0.35751 (11)	0.0233 (6)
C13	0.6656 (4)	−0.0129 (2)	0.36558 (10)	0.0247 (6)
H13	0.543226	0.029005	0.381142	0.030*
C14	0.6592 (5)	−0.1318 (2)	0.34619 (11)	0.0272 (6)
H14	0.531747	−0.184131	0.346898	0.033*
C15	0.8753 (5)	−0.1599 (2)	0.32549 (11)	0.0271 (6)
H15	0.916686	−0.234024	0.309825	0.033*
C16	1.0185 (5)	−0.0591 (2)	0.33209 (11)	0.0254 (6)
H16	1.172299	−0.053496	0.321543	0.031*
C17	0.7128 (5)	0.1310 (2)	0.23405 (11)	0.0272 (6)
H17	0.768398	0.208418	0.243295	0.033*
C18	0.4905 (5)	0.0871 (2)	0.24370 (12)	0.0290 (7)
H18	0.371710	0.129506	0.260508	0.035*
C19	0.6922 (5)	−0.0610 (2)	0.20186 (11)	0.0278 (6)
H19	0.731279	−0.135130	0.185808	0.033*
C20	0.8372 (5)	0.0399 (2)	0.20834 (11)	0.0279 (6)
H20	0.990438	0.045424	0.197386	0.034*
C21	0.4790 (5)	−0.0317 (2)	0.22356 (11)	0.0281 (6)
H21	0.350085	−0.082952	0.224483	0.034*
Fe1	0.73454 (6)	−0.01599 (3)	0.28395 (2)	0.02055 (11)
O1	1.1785 (3)	0.17972 (16)	0.36518 (8)	0.0331 (5)

anti-bacterial [7], anti-tubercular, anti-oxidant [8], insecticidal, anti-cancer, anti-inflammatory [9], anti-microbial [10], anti-angiogenic [11], and immunomodulatory properties [12]. Therefore, cinnamaldehyde derivatives attracted significant interest to design and synthesize more effective therapeutic agents [13, 14]. It is worth noting that the stable sandwich-like structure of ferrocene significantly changes the properties of its derivatives [15]. The incorporation of a ferrocenyl group in an existing bioactive compound is an effective strategy to develop novel therapeutic agent with innovative bioactive activity [16, 17].

The asymmetric unit comprises one molecule of the title compound (see the figure). The structure of cinnamaldehyde has an aliphatic aldoxyl unit, which leads to undesirable functionality because of its high reactivity [18–21]. The introduction of ferrocene framework makes the compound more stable than cinnamaldehyde. For the title compound, the stability of crystal mainly depends on the different intermolecular and intramolecular C–H···O interactions relating to the O atom of the aldehyde group. The two cyclopenta-1,3-dien rings of ferrocene scaffold make dihedral angles of 13.18° and 13.42° respectively with the phenyl group. All bond lengths are in the expected ranges.

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Conflict of interest statement: The authors declare no conflicts of interest regarding this article.

References

1. Bruker. SMART APEX-II CCD; Bruker AXS Inc.: Madison, WI, USA, 2006.
2. Dolomanov O. V., Bourhis L. J., Gildea R. J., Howard J. A. K., Puschmann H. OLEX2: a complete structure solution, refinement and analysis program. *J. Appl. Crystallogr.* 2009, *42*, 339–341.
3. Sheldrick G. M. Crystal structure refinement with SHELXL. *Acta Crystallogr.* 2015, *C71*, 3–8.
4. Sheldrick G. M. *SHELXTL* – integrated space-group and crystal-structure determination. *Acta Crystallogr.* 2015, *A71*, 3–8.
5. Shreaz S., Wani W. A., Behbehani J. M., Raja V., Irshad M., Karched M., Ali I., Siddiqi W. A., Hun L. T. Cinnamaldehyde and its derivatives, a novel class of antifungal agents. *Fitoterapia* 2016, *112*, 116–131.
6. Chen B. J., Fu C. S., Li G. H., Wang X. N., Lou H. X., Ren D. M., Shen T. Cinnamaldehyde analogues as potential therapeutic agents. *Mini Rev. Med. Chem.* 2017, *17*, 33–43.
7. Doyle A. A., Stephens J. C. A review of cinnamaldehyde and its derivatives as antibacterial agents. *Fitoterapia* 2019, *139*, 104405.
8. Suryanti V., Wibowo F., Khotijah S., Andalucki N. Antioxidant activities of cinnamaldehyde derivatives. *IOP Conf. Ser. Mater. Sci. Eng.* 2018, *333*, 012077.

9. Ahn S., Kim E., Lee K., Lee D.-C. Cinnamaldehyde derivatives inhibit degranulation and inflammatory mediator production in rat basophilic leukemia cells. *Int. Immunopharm.* 2016, *38*, 342–348.
10. Ravishankar S., Zhu L., Reyna-Granados J., Law B., Joens L., Friedman M. Carvacrol and cinnamaldehyde inactivate antibiotic-resistant Salmonella enterica in buffer and on celery and oysters. *J. Food Protect.* 2010, *73*, 234–240.
11. Kwon B.-M., Lee S.-H., Cho Y.-K., Bok S.-H., So S.-H., Youn M.-R., Chang S.-I. Synthesis and biological activity of cinnamaldehydes as angiogenesis inhibitors. *Bioorg. Med. Chem. Lett* 1997, *7*, 2473–2476.
12. Koh W. S., Yoon S. Y., Kwon B. M., Jeong T. C., Nam K. S., Han M. Y. Cinnamaldehyde inhibits lymphocyte proliferation and modulates T-cell differentiation. *Int. J. Immunopharm*. 1998, *20*, 643–660.
13. Li X., Sheng J., Huang G., Ma R., Yin F., Song D., Zhao C., Ma S. Design, synthesis and antibacterial activity of cinnamaldehyde derivatives as inhibitors of the bacterial cell division protein FtsZ. *Eur. J. Med. Chem.* 2015, *97*, 32–41.
14. Gan Z., Huang J., Chen J., Nisar M. F., Qi W. Synthesis and antifungal activities of cinnamaldehyde derivatives against *Penicillium digitatum* causing citrus green mold. *J. Food Qual.* 2020, *2020*, 8898692.
15. Ludwig B. S., Correia J. D. G., Kühn F. E. Ferrocene derivatives as anti-infective agents. *Coord. Chem. Rev.* 2019, *396*, 22–48.
16. Paul A., Borrelli R., Bouyanfif H., Gottis S., Sauvage F. Tunable redox potential, optical properties, and enhanced stability of modified ferrocene-based complexes. *ACS Omega* 2019, *4*, 14780–14789.
17. Patra M., Gasser G. The medicinal chemistry of ferrocene and its derivatives. *Nat. Rev. Chem.* 2017, *1*, 0066.
18. LoPachin R. M., Gavin T. Molecular mechanisms of aldehyde toxicity: a chemical perspective. *Chem. Res. Toxicol.* 2014, *27*, 1081–1091.
19. Polaquini C. R., Torrezan G. S., Santos V. R., Nazaré A. C., Campos D. L., Almeida L. A., Silva I. C., Ferreira H., Pavan F. R., Duque C., Regasini L. O. Antibacterial and antitubercular activities of cinnamylideneacetophenones. *Molecules* 2017, *22*, 1685.
20. Yathirajan H. S., Bindya S., Mithun A., Narayana B., Bolte M. 5-Phenyl-1-(2-thienyl)penta-2,4-dien-1-one. *Acta Crystallogr.* 2007, *E63*, o61–o62.
21. Maynadie J., Delavaux-Nicot B., Lavabre D., Donnadieu B., Daran J.-C., Sournia-Saquet A. From calcium interaction to calcium electrochemical detection by $[(C_5H_5)Fe(C_5H_4COCH$ db $CHC_6H_4NEt_2)]$ and its two novel structurally characterized derivatives. *Inorg. Chem.* 2004, *43*, 2064–2077.