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CRYSTAL STRUCTURES OF COUMARIN-3-CARBAMATE DERIVATIVES WITH HERBICIDAL ACTIVITIES†

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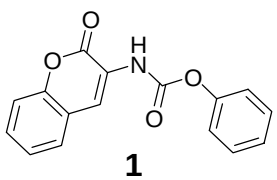
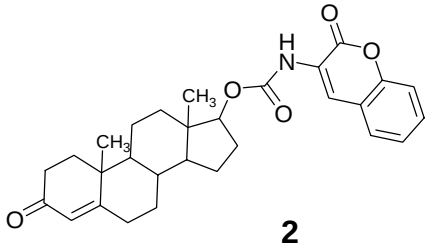
Abstract – Coumarin-3-carbamate derivatives were prepared by the reaction of alcohols with coumarin-3-carbonyl azide. The testosterone derivative has herbicidal activities, but the benzene derivative does not have the activities. The crystal structures of two coumarin-3-carbamate derivatives were analyzed by X-ray crystallography. The crystals of the testosterone derivative had intermolecular N—H···O, C—H···O, and C—H···π interactions.

The discovery and development of new herbicides is a long and difficult endeavor.[1] A large number of herbicides are currently available to assist in controlling weeds in a variety of crops. Herbicides can be classified into families based on their chemical structures and modes of action.[2] For examples, the carbamate herbicides inhibit protein biosynthesis and are effective in a gramineous weed. Coumarin is a chemical compound found in many plants, notably in high concentration in the Tonka bean woodruff and bison grass. The coumarin derivatives are an useful component for developing new materials such as fluorescence materials and laser dyes, nonlinear optical materials and reagents, photorefractive materials, photo resists, intermediates for drug synthesis, luminescence materials, and analytical reagents etc.[3,4]



1



2

Recently we have reported the synthesis and biological activities of

†Dedicated to Professor Yoshito Kishi on the occasion of his 70th birthday.

coumarin-3-carbamate derivatives (**1**, **2**) as a new herbicide.[5] The testosterone derivative (**2**) found to be particularly effective herbicide against wild amaranth (*Amaranthus blitum L.*) and foxtail grass (*Setaria viridis Beauv.*), but the benzene derivative (**1**) did not have the herbicidal activities for these weeds. Numerous studies have been dedicated to determining their structural investigation, in an effort to acertain the mechanism of action of herbicides.[6] Crystal structure analyses provide us with important information about intermolecular interaction.[7] We now report the structures of the two coumarin-3-carbamate derivatives with the aim of contributing to a deeper understanding of the biological mechanism of action of the carbamate herbicides.

Coumarin-3-carbamate derivatives (**1**, **2**) were prepared by the reaction of the corresponding alcohols such as phenol and testosterone with coumarin-3-carbonyl azide as reported by the previous paper.[5] The single crystals of **1** and **2** were obtained from the mixtures of methanol and $CHCl_3$ solution of **1**. The molecular structure of **1**[8] is shown in Figure 1.

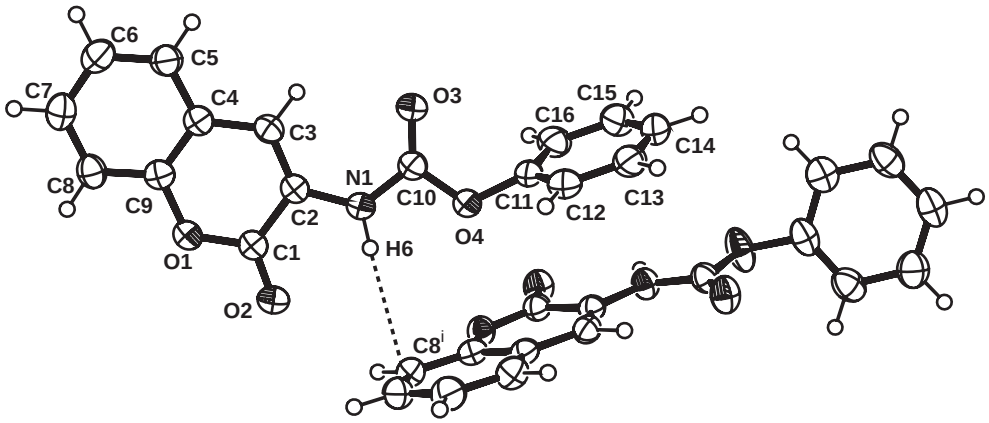


Figure 1. Intermolecular N—H···π interaction of **1**. Symmetry code: (i) 1/2-x, y-1/2, z.

Table 1. Hydrogen-bond geometry (Å, °) of **1**

D—H···A	D—H	H···A	D···A	D—H···A
N1—H6···C8^{i}	0.89	2.688	3.557(2)	172
C7—H4···O2^{ii}	0.95	2.629	3.348(1)	133
C8—H5···O2^{iii}	0.95	2.663	3.202(1)	117
C13—H8···O2^{iv}	0.95	2.612	3.247(1)	125

Symmetry codes: (i) 1/2-x, y-1/2, z ; (ii) 1/2+x, 5/2-y, 1-z ; (iii) 1/2-x, 1/2+y, z ; (iv) x, 3/2-y, z-1/2.

The carbamate plane (refined by N1/C10/O3/O4) makes angles of 5.21(3)° and 105.96(4)° with the coumarin ring systems (refined by C1—C9/O1/O2) and the phenyl least-squares plane (refined by C10—C16), respectively. The molecular length of the compound is 12.1 Å for the C7···C14 distance. Intermolecular N—H···π interaction is observed in the crystal structure of **1**. The N1···C8^{i} and H6···C8^{i} distance [3.557(2) and 2.688 Å] (symmetry code: (i) 1/2-x, y-1/2, z) is close to the intermolecular N—H···π distance [N···C: 3.59 Å, H···C: 2.77 Å] of 2-amino-5-metoxycarbonyltropone.[9] Intermolecular π—π interactions occur in **1** between the coumarin and the unfused benzene ring. The C···C distance is within the range associated with π—π interactions [3.3—3.8 Å].[4,7,10,11] There are some C—H···O hydrogen bonds in **1**. The C—H···O distances are similar to those of

7-diethylamino-3-dimethylaminocoumarin,[4] 7,16-bis(1-pyrenylmethyl)-1,4,10,13-tetraoxa-7,16-diaza-cyclooctadecane[12] and 4,4'-dimethoxy-2,2'-dihydroxybenzalazine.[7]

The molecular structure of herbicide (**2**)[13] is shown in Figure 2. The carbamate plane (refined by N1/C10/O3/O4) makes angles of 7.7(1)˚ and 85.6(1)˚ with the coumarin ring systems (refined by C1—C9/O1/O2) and the cyclopentane ring (refined by C23—C27) of testosterone backbone, respectively. The molecular length of **2** is 17.2 Å for the O5···C7 distance. There is an intermolecular N—H···O

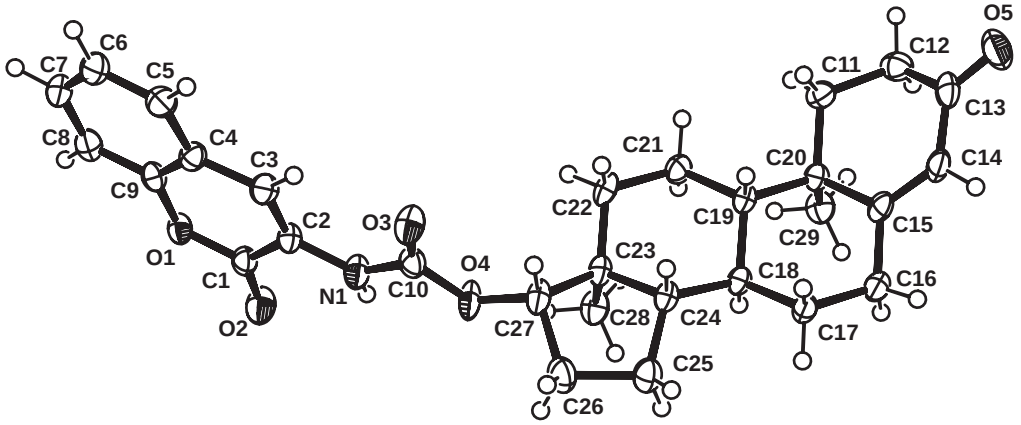


Figure 2. An ORTEP drawing of **2** showing 50% probability displacement ellipsoids.

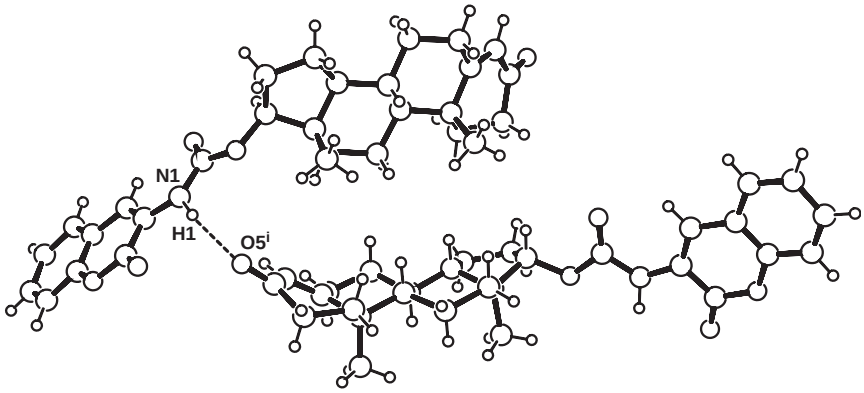


Figure 3. Intermolecular N—H···O interaction of **2**. Symmetry code: (i) 1/2+x, 1/2-y, 1-z.

hydrogen bond of carbamate unit (Fig. 3 & Table 2). The N—H···O distance is close to the intermolecular N—H···O distance [N···O^{i} 2.877 (4) Å] of 2-amino-5-hexyloxytropone.[14]

Table 2. Hydroge-bond geometry (Å, ˚) of **2**

D—H···A	D—H	H···A	D···A	D—H···A
N1—H1···O5^{i}	0.99(5)	2.16(5)	3.062(3)	164
C5—H3···O1^{ii}	0.95	2.398	3.321(3)	150
C11—H7···O1^{iii}	0.95	2.563	3.407(3)	148
C12—H10···C8^{iii}	0.95	2.814	3.581(3)	138
C25—H23···C4^{iv}	0.95	2.878	3.796(3)	163
C28—H29···C5^{iv}	0.95	2.799	3.695(4)	157
C29—H31···O2^{v}	0.95	2.582	3.246(4)	127

Symmetry codes: (i) 1/2+x, 1/2-y, 1-z ; (ii) x-1/2, 1/2-y, -z; (iii) 2-x, 1/2+y, 1/2-z ; (iv) 2-x, y-1/2, 1/2-z ; (v) 5/2-x, -y, 1/2+z.

The NH group of carbamate participates in the N—H···O intermolecular hydrogen bond. Intermolecular C—H···π and C—H···O interacions are observed in the

crystal structure of **2** (Table 2), with distances typical for these types of interactions (C—H···π: 2.8—3.1 Å, C—H···O: 2.5—2.7 Å).[9,11,12,15] The combination of intermolecular N—H···O, C—H···π, and C—H···O interactions in **2** builds up a three-dimensional network. These interactions of **2** should play an important role in the inhibition of protein biosynthesis. Thus, the crystal structure of herbicides would afford much useful information about intermolecular interaction in the biological mechanism of action of herbicides

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