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Biotransformations in the Regioselective Deacetylation of Polyphenolic Peracetates in Organic Solvents[1]

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Abstract—Regioselectivity has been observed in the deacetylation of peracetates of polyphenolic aromatic ketones by lipases from porcine pancreas (PPL) and *Candida cyclindracea* (CCL) suspended in organic solvents. The deacetylation of acetoxyl groups at positions *para* and *meta* to the carbonyl (ketonic) group is favoured over the one at the *ortho* position.

Introduction

Naturally occurring chalcones having isopentenylated groups in the acyclic or cyclic (chromano and chromeno) form have been known to possess high biological activities, i.e. antibacterial,[2] antiulcer[3] and antifungal.[4] Nearly 95 such chalcones have thus far been isolated from different natural sources. A chromanochalcone, crotmadine having antifungal activity has been reported to occur in *Crotalaria madurensis* by Bhakuni and Chaturvedi,[4] who assigned the structure **1** to it. Based on our synthetic studies, we had earlier[5] revised the structure of crotmadine as **2**. The synthesis of **2** required 3-acetoxy-4-hydroxyacetophenone (**3**) or 3-hydroxy-4-acetoxy-acetophenone (**4**); attempts to synthesize these compounds by purely chemical approaches were unsuccessful.

Hydrolytic enzymes, such as lipases, esterases and proteases have been extensively used as catalytsts in the regio- and enantioselective synthesis of intermediates and target molecules.[6] Though a number of reports are available in literature on the enzyme-assisted selective reactions on diols, triols and polyols,[7] carbohydrates,[8] nucleosides,[9] epoxides,[10] phospholipids[11] and sterols,[12] such studies have rarely been carried out on polyphenols.[13] We have earlier reported the regioselective enzymatic deacetylation of peracetylated polyhyroxy acetophenones and benzopyranones.[14] It was found that the acetoxyl group *para* to the ketonic group undergoes deacetylation preferentially over the one at the *meta* position. With an aim to prepare the partially acetylated 3,4-dihydroxyacetophenone and to generalise our finding of the regioselectivity of enzyme-catalysed deacetylation, we herein present our results on the enzymatic deacetylation of different types of peracetylated polyhydroxy aromatic ketones (acetophenones, propiophenones, a butyrophenone, a benzophenone and a chalcone). This study also includes the effect of the solvent on the yields of the reactions.

Results and Discussion

The enzymatic deacetylation of 3,4-diacetoxyacetophenone (**5**)[15] with both PPL and CCL in different organic solvents gave exclusively 3,4-dihydroxyacetophenone (**13**),[15] thus the aimed partial deacetylation was not observed in this case. Lipase-catalyzed deacetylation of 2,3,4-triacetoxypropiophenone (**6**) yielded 2,3-diacetoxy-4-hydroxypropiophenone (**14**) as the only isolable product. The structure of **14** was established from its ^{1}H NMR and UV spectral data. It is known[16] that in the presence of sodium acetate, the benzenoid compounds possessing a free phenolic hydroxyl group in conjugation with a carbonyl group exhibit a significant bathochromic shift in their UV absorption maxima. The compound **14** exhibited a bathochromic shift of 14 nm in its UV absorption maxima on addition of NaOAc, thus indicating the presence of a free -OH group at the (conjugated) C-4 position. The enzymatic deacetylation of 2,4,6-triacetoxypropiophenone (**7**)[17] yielded only one compound, i.e. 2,6-diacetoxy-4-hydroxypropiophenone (**15**), the deacetylation thus taking place exclusively at the *para* position in these propiophenones. Similar observations were made during the deacetylation of 2,4-diacetoxybenzophenone (**9**)[18] and 2',4'-diacetoxy-4-methoxychalcone (**10**)[19] which yielded 2-acetoxy-4-hydroxybenzophenone (**18**) and 2'-acetoxy-4'-hydroxy-4-methoxy-chalcone (**19**), respectively in good yields. In all these cases, the acetoxyl groups at the *para* position to the carbonyl group are deacetylated exclusively.

To generalise our study further, 2,4,5-triacetoxybutyrophenone (**8**) was taken as another test case; the deacetylation took place at the *para* acetoxy function (to the carbonyl group) predominantly to yield 2,5-deacetoxy-4-hydroxybutyrophenone (**16**) in 65 % yield in THF. The structure of this compound is based on the ^{1}H NMR and mass spectral data. The position of free hydroxyl group at C-4 in **16** was established by the observed bathochromic shift of 11 nm in its UV absorption maxima in the presence of NaOAc.[16] Another compound, obtained in 20 % yield was identified as 2-acetoxy-4,5-dihdroxybutyrophenone (**17**) On the basis of its ^{1}H NMR and mass spectral data, the positions of two free hydroxyl groups in **17** were inferred by the observed bathochromic shift of 12 nm in its UV absorption maxima on addition of NaOAc and H_3BO_3. It is reported in literature[16] that a mixture of sodium acetate and boric acid induces a bathochromic shift of 12–30 nm in the UV absorption maxima of benzenoid compounds having a carbonyl group and an *ortho* dihydroxy system. the results indicate that the enzymatic deacetylation takes place preferentially at the *para* acetoxyl group over *meta* acetoxyl group, however the *ortho* acetoxyl to carbonyl group is inert to transesterification reaction. Observations in all these cases revealed that the carbonyl group directly attached to the aromatic ring plays an important role in the recognition of the *ortho*, *meta* and *para* acetoxyl groups in polyphenolic peracetates by the enzyme. The role of directly attached carbonyl group on the selectivity of the enzyme is supported by enzymatic deacetylation of resorcinol diacetate and *tert* butylhydroquinone diacetate. Both the substrates lack a directly attached ketone group on the aromatic ring. When these substrates were incubated with PPL and CCL in different organic solvents, i.e. acetone, tetrahydrofuran (THF) and diisopropylether (DIPE), resorcinol and *tert* butylhydroquinone were obtained as the exclusive products after the reaction. Further, the generalisation that the acetoxyl group *ortho* to the carbonyl is not accepted by the enzyme for deacetylation is supported by the result that no deacetylation occurred even after 68 h on 2-acetoxy-3,4,6-trimethoxyacetophenone (**11**)[20] either with PPL or CCL in any of the solvents, i.e. THF, DIFE or acetone. This was also the case with the attempted enzymatic deacetylation of 2,6-diacetoxyacetophenone (**12**).[20]

Results from the above enzymatic studies indicate that THF and DIPE act as the best solvents (Table 1). This is probably due to the high polarity of these solvents. In most of the cases, PPL worked excellently to give the products in 60–80 % yields. However, CCL-induced transesterification gave good to moderate yields. No deacetylation reaction was observed on any of these substrates by carrying out reactions on each one of them under the same conditions but without adding the lipase.

Acetophenone-, propiophenone- and butyrophenone-based compounds are building blocks for the synthesis of various types of bioactive compounds, such as chalcones, flavanones, isoflavanones and 3-alkylchromanones. Since exhaustive chemical methods of protection/deprotection during the synthesis of these types of biopolyphenolics involve a large number of steps and are accompanied by lower yields, our study of enzyme-catalyzed selective protection in moderately good yields should be of help in their efficient synthesis. In the course of these enzymatic deacetylation studies, eight new compounds have been obtained, i.e. the peracetylated substrates 2,3,4-triacetoxypropiophenone (**6**) and 2,4,5-triacetoxybutyrophenone (**8**), and the lipase-mediated reaction products **14–19** having the *ortho* hydroxyl acetylated, which otherwise are difficult to get by purely chemical reactions.

Experimental

General methods

Melting points were determined in sulphuric acid bath and are uncorrected. The UV spectra were recorded on a Beckman DU-2 spectrophotometer and IR spectra on a Shimadzu model 435 spectrophotometer. The ^{1}H NMR spectra were recorded on either a Perkin–Elmer R-32 (90 MHz) spectrometer or on Jeol JNM-FX 200 FT-NMR spectrometer with $SiMe_4$ as an internal standard and the mass spectra were recorded on a Varian Mat 311 A instrument. The TLCs were performed on precoated silica gel G plates. Solvent systems used were **A** (benzene:EtOAc. 17:3), **B** (benzene:EtOAc, 4:1) and **C** (benzene:EtOAc, 7:3). The developing agent was alcoholic $FeCl_3$ solution (3 %) or iodine vapours.

The peracetates were prepared by acetic anhydride–pyridine method. The previously known compounds were identified by comparison of their physical and spectral data with those reported in the literature, while the new compounds were unambiguously identified on the basis of their ^{1}H NMR, IR and mass spectral data. The CCL (Type VII) and PPL (Type II) were purchased from Sigma Chemical Co. (U.S.A.) and used after keeping *in vacuo* over P_2O_5 for 10 h. The organic solvents used were redistilled and dried over molecular sieves (4Å).

General procedure of enzymatic deacetylation of peracetates 5–10

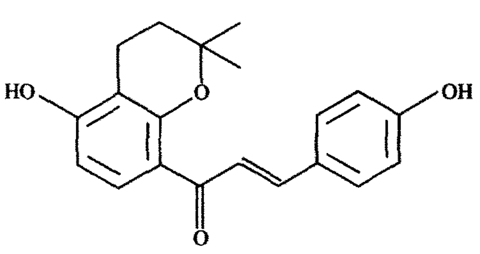
Polyhydroxy alkyl/aryl ketone peracetate (2–2.5 mmol) was taken in the organic solvent [tetrahydrofuran (THF). diisopropyl ether (DIPE) or acetone (20–25 mL)] containing *n*-butanol (5 eq.) at 42–45 °C and PPL/CCL (500–600 mg) was added. The contents were stirred for 40 h. The solvent was removed *in vacuo* and the product(s) purified by preparative thin layer or column chromatography. The results obtained with seven ketones are summarised in Table 1.

2,3,4-Triacetoxypropiophenone (6). mp 75–76 °C; R_f 0.5 (solvent **B**); MS(EI) m/z (rel. int.): 308 (1) $[M^{+\cdot}]$ ($C_{15}H_{16}O_7$), 266 (17) $[M–CH_2CO]^+$, 224 (71) $[M - 2 \times CH_2CO]^+$, 195 (8) $[M - 2 \times CH_2CO, -C_2H_5]^+$, 182 (96) $[M - 3 \times CH_2CO]^+$, 153 (93) $[M - 3 \times CH_2CO, -C_2H_5]^+$, 107 (6), 84 (14), 57 (14), 43 (100); ^{1}H NMR ($CDCl_3$) δ: 1.3 (3H, t, J = 8, CH_3CH_2), 2.4 (9H, s, 3 × $OCOC_3$), 2.9 (2H, q, J = 8, CH_3-CH_2), 7.15 (1H, d, J = 10, C-5H), 7.65 (1H, d, J = 10, C-6H); IR (Nujol): 3000, 1760, 1690, 1610, 1440, 1360, 1170, 1060, 1020, 910 and 860 cm^{-1}.

2,4,5-Triacetoxybutyrophenone (8). mp 108–110 °C; R_f 0.5 (solvent **B**); MS(EI) m/z (rel. int.): 322 (4) $[M^{+\cdot}]$ ($C_{16}H_{18}O_7$), 280 (41) $[M - CH_2CO]^+$, 253 (1), 251 (1), 238 (72) $[M - 2 \times CH_2CO]^+$, 209 (3), 204 (4), 196 (91) $[M - 3 \times CH_2CO]^+$, 195 (25), 181 (8), 179 (9), 168 (12), 153 (76); ^{1}H NMR ($CDCl_3$) δ: 0.93 (3H, t, J = 8, CH_3-CH_2-CH_2-CO-), 1.70 (2H, m, CH_3-CH_2-CH_2-CO-), 2.30 (9H, bs, 3 × -$OCOCH_3$), 2.81 (2H, t, J = 8, CH_3-CH_2-CH_2-CO), 7.09 (1H, s, C-3H) and 7.62 (1H, s, C-6H); IR (Nujol): 1760, 1682, 1610, 1495, 1458, 1360, 1300, 1270, 1175, 1150, 1085 and 915 cm^{-1}.

Table 1. Deacetylation of aromatic ketone peracetates by PPL/CCL in organic solvents

Substrate	Enzyme	Solvent	Products(s) (% yield)
3,4-Diacetoxyacetophenone (5)	PPL	DIPE	3,4-dihydroxyacetophenone (13) (80)
		THF	(60)
		Acetone	(50)
	CCL	DIPE	(40)
		THF	(40)
		Acetone	(25)
2,3,4-Triacetoxypropiophenone (6)	PPL	THF	2,3-diacetoxy-4-hydroxypropiophenone (14) (70)
		Acetone	(20)
		DIPE	(65)
	CCL	THF	(50)
		Acetone	(20)
		DIPE	(65)
2,4,6-Triacetoxypropiophenone (7)	PPL	THF	2,6-diacetoxy-4-hydroxypropiophenone (15) (60)
		DIPE	(50)
		Acetone	(35)
	CCL	THF	(35)
		DIPE	(20)
		Acetone	(30)
2,4,5-Triacetoxybutyrophenone(8)	PPL	THF	2,5-diacetoxy-4-hydroxybutyrophenone (16) (40) and 2-acetoxy-4,5-dihydroxybutyrophenone (17) (10)
		DIPE	16 (40) and 17 (15)
		Acetone	16 (30) and 17 (15)
	CCL	THF	16 (65) and 17 (20)
		DIPE	16 (50) and 17 (10)
		Acetone	16 (30) and 17 (10)
2,4-Diacetoxybenzophenone (9)	PPL	THF	2-acetoxy-4-hydroxybenzphenone (18) (75)
		DIPE	(50)
		Acetone	(50)
	CCL	DIPE	(60)
		THF	(40)
		Acetone	(30)
2',4'-Diacetoxy-4-methoxychalcone(10)	PPL	THF	2'-acetoxy-4'-hydroxy-4-methoxychalcone (19) (20)
		DIPE	(30)
		Acetone	(35)
	CCL	THF	(30)
		DIPE	(25)
		Acetone	(35)



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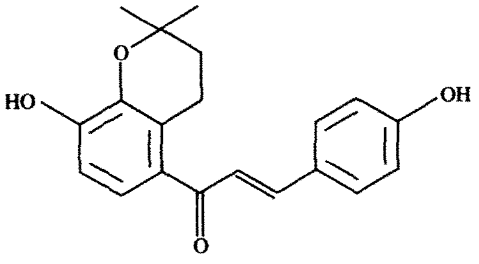

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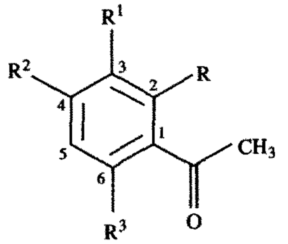
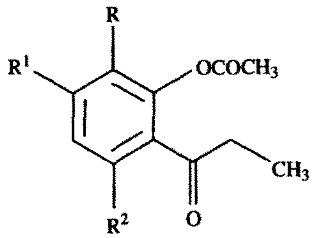
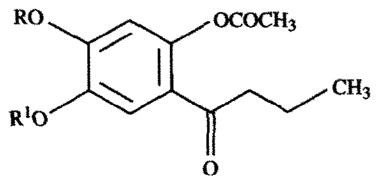


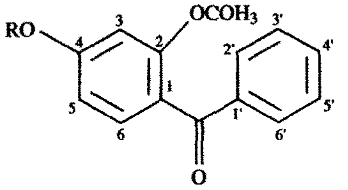
3 R=R^3=H, R^1=OCOCH$_3$, R^2=OH
4 R=R^3=H, R^1=OH, R^2=OCOCH$_3$
5 R=R^3=H, R^1=R^2=OCOCH$_3$
11 R=OCOCH$_3$, R^1=R^2=R^3=OCH$_3$
12 R=R^3=OCOCH$_3$, R^1=R^2=
13 R=R^3=H, R^1=R^2=OH



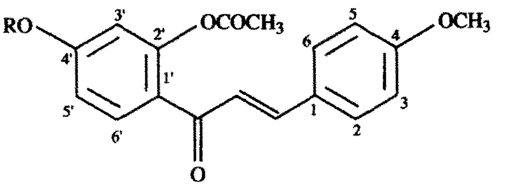
6 R=R^1=OCOCH$_3$, R^2=H
7 R=H, R^1=R^2=OCOCH$_3$
14 R=OCOCH$_3$, R^1=OH, R^2=H
15 R=H, R^1=OH, R^2=OCOCH$_3$



8 R=R^1=COCH$_3$
16 R=H, R^1=COCH$_3$
17 R=R^1=H



9 R=COCH$_3$
18 R=H



10 R=COCH$_3$
19 R=H

2-Acetoxy-3,4,6-trimethoxyacetophenone (11). Semi-solid mass; ^{1}H NMR (CDCl$_3$) δ: 2.20 (3H, s, -OCOCH$_3$), 2.40 (3H, s, -COCH$_3$), 3.20, 3.78 and 3.85 (9H, 3s, 3 × -OCH$_3$), 6.36 (1H, s, H-5), IR (Nujol): 1755, 1740, 1620, 1450, 1370, 1280, 1180, 1120, 1000 and 900 cm^{-1}.

2,6-Diacetoxyacetophenone (12). Yellow viscous oil; ^{1}H NMR (CDCl$_3$) δ: 2.35 (6H, s, 2 × -OCOCH$_3$), 2.51 (3H, s, -COCH$_3$), 7.15 (1H, d, J = 10, C-4H), 7.45–7.56 (2H, 2d, C-5H and C-3H); IR (Nujol): 1760, 1740, 1680, 1600, 1450, 1370, 1180 and 1030 cm^{-1}.

2,3-Diacetoxy-4-hydroxypropiophenone (14). mp 68–70 °C; R_f 0.4 (solvent **B**); MS(EI) m/z (rel. int.): 266 (37) [M^{+}] (C$_{13}$H$_{14}$O$_6$), 224 (92) [M – CH$_2$CO]$^+$, 195 (15) [M – CH$_2$CO, -C$_2$H$_5$]$^+$, 182 (95) [M – 3 × CH$_2$CO]$^+$, 153 (93) [M – 3 × CH$_2$CO, -C$_2$H$_5$]$^+$, 124 (5), 107 (8), 57 (12), 43 (100); ^{1}H NMR (CDCl$_3$) δ: 1.2 (3H, t, J = 8, CH_3-CH$_2$), 2.25 (6H, s, 2 × $OCOCH_3$) 2.8 (2H, q, J = 8, CH_3-CH_2), 7.1 (1H, d, J = 10, C-5H), 7.5 (1H, d, J = 10, C-6H); IR (Nujol): 3450, 2950, 1780, 1690, 1610, 1430, 1370, 1170, 1060,1020, 910 and 850 cm^{-1}; UV (MeOH): 264, 280 (sh) and 316 nm: + NaOAc: 264, 282 and 330 nm.

2,6-Diacetoxy-4-hydroxypropiophenone (15). mp 110–114 °C; R_f 0.4 (solvent **B**); MS(EI) m/z (rel. int.): 266 (1) [$M^{+\cdot}$] ($C_{13}H_{14}O_6$), 224 (23), 195 (6), 182 (44), 180 (5), 165 (3), 154 (23), 153 (99), 137 (3), 128 (3), 124(5); ^1H NMR ($CDCl_3$) δ: 1.12 (3H, t, J = 8, CH_3-CH_2-), 2.21 (6H, s, 2 × $OCOCH_3$), 2.80 (2H, q, J = 8, CH_3-CH_2-), 3.40 (lH, s, phenolic -OH), 6.0 (1H, d, J = 3, C-3H) and 6.10 (lH, d, J = 3, C-5H).

2,5-Diacetoxy-4-hydroxybutyrophenone (16). mp 142–143 °C; R_f 0.4 (solvent **C**); MS(EI) m/z (rel. int.): 238 [M – CH_2CO]$^+$ (2), 209 (3), 196 (84) [M – 2 × CH_2CO]$^+$, 181 (29), 163 (25), 153 (100) [M – 2 × CH_2CO,-C_3H_7]$^+$, 149 (3), 124 (11), 108 (5), 107 (45); ^1H NMR ($CDCl_3$ + DMF-d_7) δ: 0.98 (3H, t, J = 10, CH_3-CH_2-CH_2-), 1.68, (2H, m , CH_3-CH_2-CH_2-), 2.28 (6H, s, 2 × $OCOCH_3$), 2.80 (2H, t, J = 10, CH_3-CH_2-CH_2-), 6.55 (lH, s, C-3H) and 7.40 (lH, s, C-6H); UV (MeOH): 234, 273 and 328 nm; + NaOAc: 250, 280 (sh) and 339 nm.

2-Acetoxy-4,5-dihydroxybutyrophenone (17). mp 118–120 °C; R_f 0.3 (solvent **C**): MS(EI) m/z (rel. int.): 238 (23) [$M^{+\cdot}$] ($C_{12}H_{14}O_5$), 209 (2), 196 (91), 181 (19), 168(18), 163(12), 153(100); ^1H NMR (DMF-d_7) δ: 0.94 (3H, t, J = 10, CH_3-CH_2-CH_2-), 1.60 (2H, m, CH_3-CH_2-CH_2-), 2.24 (3H, s, $OCOCH_3$), 2.74 (2H, t, J = 10, CH_3-CH_2-CH_2), 6.50 (lH, s, C-3H), 7.40 (1H, s, C-6H), 7.74 (1H, s, -OH) and 8.04 (1H, s, -OH); IR (Nujol): 3500, 3320, 2900, 1720, 1675, 1620, 1450, 1350, 1300, 1280, 1240, 1150, 915 and 890 cm^{-1}; UV (MeOH): 271 and 309 nm; + NaOAc: 270 and 322 nm; + NaOAc + H_3BO_3 : 285 and 321 nm.

2-Acetoxy-4-hydroxybenzophenone (18). mp 130–131 °C; R_f 0.5 (solvent **B**); MS(EI) m/z (rel. int.): 256 (34) [$M^{+\cdot}$] ($C_{15}H_{12}O_4$), 229 (5), 227(5), 213 (100), 197 (14), 185 (9), 157 (10), 153 (5), 137 (81), 128 (21), 115 (2), 105(55); ^1H NMR ($CDCl_3$) δ:1.94 (3H, s, -$OCOCH_3$), 6.70 (1H, s, C-3H), 6.73 (1H, d, J = 10, C-5H), 7.44–7.65 (6H, m, C-2'H to C-6'H and phenolic -OH) and 7.80 (1H, d, J = C-6H); IR (Nujol): 3350, 1760, 1740, 1555, 1510, 1458, 1370, 1315, 1240, 1220, 1010 and 990 cm^{-1}; UV (MeOH): 239 and 287 nm; + NaOAc: 287 and 333 nm.

2'-Acetoxy-4 '-hydroxy-4-methoxychalcone (19). Yellow viscous oil; R_f 0.3 (solvent **A**); MS(EI) m/z (rel. int.): 3212 (34) [$M^{+\cdot}$] ($C_{18}H_{16}O_5$), 295 (4), 270 (26), 255 (4), 253 (6), 241 (6), 239 (3), 213 (5); ^1H NMR ($CDCl_3$) δ: 2.20 (3H, s, -$OCOCH_3$), 3.72 (3H, s, OCH_3), 6.02 (1H, s, -OH), 6.40 (1H, dd, J = 10 and 3, C-5'H), 6.70 (2H, d. J = 10, C-3H and C-5H), 6.96 (lH, d, J = 15, H-β), 7.04 (1H, d, J = 3, C-3'H), 7.16 (2H, d, J = 10, C-2H and C-6H), 7.40 (1H, d, J = 15, H-) and 7.54 (lH, d, J = 10, C-6'H); IR (Nujol): 3330, 1765, 1650, 1635, 1588, 1505, 1420, 1362, 1300, 1285, 1250, 1190, 1140, 1110 and 1005 cm^{-1}.

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References and Notes

1. This paper is dedicated to Professor J Bryan Jones on his 60th birthday.

2. De lima, O. G.; De Mello, J. F.; Coelho, J. S. D.; Lyra, F. D. D.; De Albuquerque, M. M. F.; Marini-Bettolo, G. B.; Delle Monache, G.; Delle Monache, F. *Farmaco. Ed. Sci*. **1975**, *30*, 326 (*Chem. Abstr.* **1975**, *83*, 91495).

3. Kyogoku, K.; Hatayama, K.; Yokumori, S.; Saziki, R.; Nakane, S.; Sasajima, M.; Sawada, J.; Ohzeki, M.; Tanaka, I. *Chem Pharm. Bull.* **1979**, *27*, 2943; Sasajima, M.; Nakane, S.; Saziki, R.; Saotome, H.; Hatayama, K.; Kyogoku, K.; Tanaka, I. *Nippon Yakurigaku Zasshi* **1978**, *74*, 897 (*Chem. Abstr*. **1979**, *90*, 197536).

4. Bhakuni, D. S.; Chaturvedi, R. *J. Nat. Prod*. **1984**, *47*, 585.

5. Malhotra, S.; Sharma, V. K.; Parmar, V. S. *J. Nat. Prod.* **1988**, *51*, 578.

6. Ballesteros, A.; Bernabe, M.; Cruzado, C.; Lomas, M. M.; Otero, C. *Tetrahedron* **1989**, *45*, 7077; Chenvert, R.; Desjardins, M.; Gagnon, R. M. *Chem. Lett*. **1990**, *33*; Moris, F.; Gotor, V. *Tetrahedron* **1992**, *48*, 9869; Hiroyuki, A.; Isao, U.; Masako, N.; Shinji, N. *Tetrahedron: Asymmetry* **1993**, *4*, 757; Faber, K.; Riva, S. *Synthesis* **1992**, 895; Ader, U.;Andersch, P.; Berger, M.; Georgens, U.; Seemayer, R.; Schneider, M. *Pure Appl. Chem.* **1992**, *64*, 1165; Kilbanov A. M. *Acc. Chem. Res.* **1990**, *23*, 114.

7. Santaniello, E.; Ferraboschi, P.; Griesente, P. *Tetrahedron Lett*. **1990**, *31*, 5657; Xie, Z. F.; Suemune, H.; Sakai, K. *J. Chem. Soc., Chem. Commun*. **1988**, 1638; Parmar, V. S.; Sinha, R.; Bisht, K. S.; Gupta, S.; Prasad, A. K.; Taneja, P. *Tetrahedron* **1993**, *49*, 4107; Bisht, K. S.; Parmar, V. S.; Crout, D. H. G. *Tetrahedron: Asymmetry* **1993**, *4*, 957; Johnson, C. R.; Adams, J. P.; Bis, S. J.; De Jong, R. L.; Golebiowski, A.; Medich, J. R.; Penning, T. D.; Senanayake, C. H.; Steensma, D. H.; Van Zandt, M. C. *Pure Appl. Chem.* **1992**, *64*, 1115; Bernardo, H.; Senida, C.; Anabel, M.; Serafin, V. *Tetrahedron: Asymmetry* **1993**, *4*, 845; Miyazawa, K.; Yoshida, N. *Chem. Lett*. **1993**, 1529.

8. Luigi, P.; Sara, B.; Sergio, R.; Giovanni, R. *Tetrahedron: Asymmetry* **1993**, *4*, 931; Andersch, P.; Schneider, M. P. *Tetrahedron: Asymmetry* **1993**, *4*, 2135; Chon, C.; Heisler, A.; Junot, N.; Levayer, F.; Rabiller, C. *Tetrahedron: Asymmetry* **1993**, *4*, 2441; Khan, R.; Gropen, L.; Konowincz, P. A.; Matulova, M.; Paoletti, S. *Tetrahedron Lett.* **1993**, *34*, 7767; Pulido, R.; Ortiz, F. L.; Gotor, V. *J. Chem. Soc., Perkin Trans 1* **1992**, 2891; Uemura, A.; Nozaki, K.; Yamashita, J.; Yasumoto, M. *Tetrahedron Lett.* **1989**, *30*, 3817; Kim, M. J.; Hennen, W. J.; Sweers, H. M.; Wong, C. H. *J. Am. Chem. Soc* **1988**, *110*, 6481; Drueckhammer, D. G.; Hennen, W. J.; Pederson, R. L.; Barbas, III C. F.; Gautheron, C. M.; Krach, T.; Wong, C. H. *Synthesis* **1991**, 499.

9. Garcia-Alles, L. F.; Francisco, M.; Gotor, V. *Tetrahedron Lett.* **1993**, *34*, 6337; Singh, H. K.; Cote, G. L.; Sikorski, R. S. *Tetrahedron Lett*. **1993**, *34*, 5201; Moris, F.; Gotor, V. *J. Org. Chem*. **1993**, *58*, 653; Uemura, A.; Nozaki, K.; Yamashita, J.; Yasumoto, M. *Tetrahedron Lett.* **1989**, *30*, 3819; Moris, F.; Gotor, V. *Tetrahedron* **1993**, *49*, 10089.

10. de Bont, J. A. M. *Tetrahedron: Asymmetry* **1993**, *4*, 1331.

11. Morimoto, T.; Murakami, N.; Nagatsu, A.; Sakakibara, J. *Tetrahdron Lett.* **1993**, *34*, 2487.

12. Riva, S.; Bovara, R.; Ottolina, G.; Secundo, F.; Carrea, G. *J. Org. Chem.* **1989**, *54*, 3161.

13. Nicolosi, G.; Piattelli, M.; Sanfilippo, C. *Tetrahedron* **1992**, *48*, 2477; Nicolosi, G.; Piattelli, M.; Sanfilippo, C. *Tetrahedron* **1993**, *49*, 3143.

14. Parmar, V. S.; Prasad, A. K.; Sharma, N. K.; Singh, S. K.; Pati, H. N.; Gupta, S. *Tetrahedron* **1992**, *48*, 6495; Parmar, V. S.; Prasad, A. K.; Sharma, N. K.; Vardhan, A.; Pati, H. N.; Sharma, S. K.; Bisht, K. S. *J. Chem. Soc., Chem. Commun.* **1993**, 27.

15. *Dictionary of Organic Compounds* (Name Index), D-04145, 5th Ed., Chapman and Hall; New York, 1982.

16. Mabry, T. J.; Markham, K. R.; Thomas, M. B. *The Systematic Identification of Flavonoids*, pp. 49–50, Springer-Verlag; Berlin, 1970.

17. Szell, T. *J. Chem. Soc. C.* **1967**, 2041.

18. *Dictionary of Organic Compounds* (Name Index), D-04255, 5th Ed., Chapman and Hall; New York, 1982.

19. Achenbach, H.; Stocker, M.; Constenla, M. A. *Phytochemistry* **1988**, *27*, 1835.

20. Though the compounds **11** and **12** have been reported earlier (Bargellini, G.; Zoras, S. M. *Gazz. Chem. Ital.* **1934**, *64*, 192 and Limaye, D. B.; Kelkar, G. R. *J. Indian Chem. Soc.* **1935**, *12*, 788, respectively), their spectral data has not been published thus far.

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