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Synthesis of Coniferyl and Dihydroconiferyl Derivatives Using Radical Bromination with *N*-Bromosuccinimide as the Key Step

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Coniferyl and dihydroconiferyl derivatives have been synthesized by reacting bromides, obtained from allylic and benzylic brominations using *N*-bromosuccinimide (NBS), with appropriate nucleophiles. For instance, NBS bromination of eugenol acetate, followed by replacement of bromine by an acetoxy group and subsequent reduction with lithium aluminium hydride, afforded coniferyl alcohol in 65 % overall yield. Due to the availability of the starting materials (eugenol and isoeugenol) and the good overall yields obtained, these synthetic routes compete well with other methods of preparation.

Coniferyl alcohol, together with other *p*-hydroxycinnamyl alcohols and related compounds, constitutes an important substrate for enzymatic dehydrogenation which ultimately results in the formation of lignins.[1] Some years ago, it was also shown that coniferyl alcohol was an intermediate in technical delignification processes, *e.g.* in sulfate pulping,[2,3] where it undergoes sulfidation, condensation and fragmentation reactions.[4] Many attempts have, therefore, been made to find a convenient method of synthesis for this compound and its derivatives.

In the past the synthetic route most frequently used for the preparation of coniferyl alcohol entailed a Knoevenagel condensation between vanillin and ethyl hydrogen malonate followed by a lithium aluminium hydride reduction of the ethyl ferulate thus formed.[5] The latter step has been improved by using sodium dihydro-bis(2-methoxyethyl)aluminate as reductant.[6] Some years ago, a new route was reported[7] (*cf.* also Ref. 8) initiating from isoeugenol. The isoeugenol methoxymethyl ether was allylically oxidized to the coniferaldehyde derivative. Removal of the protecting methoxymethyl group and sodium borohydride reduction of the coniferaldehyde afforded coniferyl alcohol. The overall yield from isoeugenol methoxymethyl ether was 64 %.[7]

The present work deals primarily with a new method for the synthesis of coniferyl type compounds based on allylic (radical) bromination of the acetates of eugenol (*1a*) (or isoeugenol, *2a*) by *N*-bromosuccinimide (NBS),[9] followed by displacement of bromine with an appropriate nucleophile. Coniferyl alcohol diacetate, for instance, was conveniently obtained from coniferyl bromide acetate by replacement of bromine by an acetoxy group. An analogous pathway was followed in the preparation of dihydroconiferyl alcohol derivatives substituted in the benzylic position (*cf.* also Ref. 10).

RESULTS AND DISCUSSION

Allylic and benzylic brominations. Isoeugenol reacted very rapidly with NBS but bromination took place mainly at the aromatic nucleus (^{1}H NMR). The corresponding acetate reacted mainly in the side chain.

Eugenol acetate (*1a*) reacted about 7 times faster than isoeugenol acetate (*2a*). This is consistent with the generally accepted mechanism[11,12] for radical bromination with NBS, in which the abstraction of a hydrogen atom by a bromine radical is the rate-determining step. Methylene hydrogens, as in *1a*, are more easily abstracted than methyl hydrogens as in *2a*. However, *1a* and *2a* afforded the same yield of *trans*-coniferyl bromide acetate (*3a*), which is thermodynamically favoured over the allylic isomer

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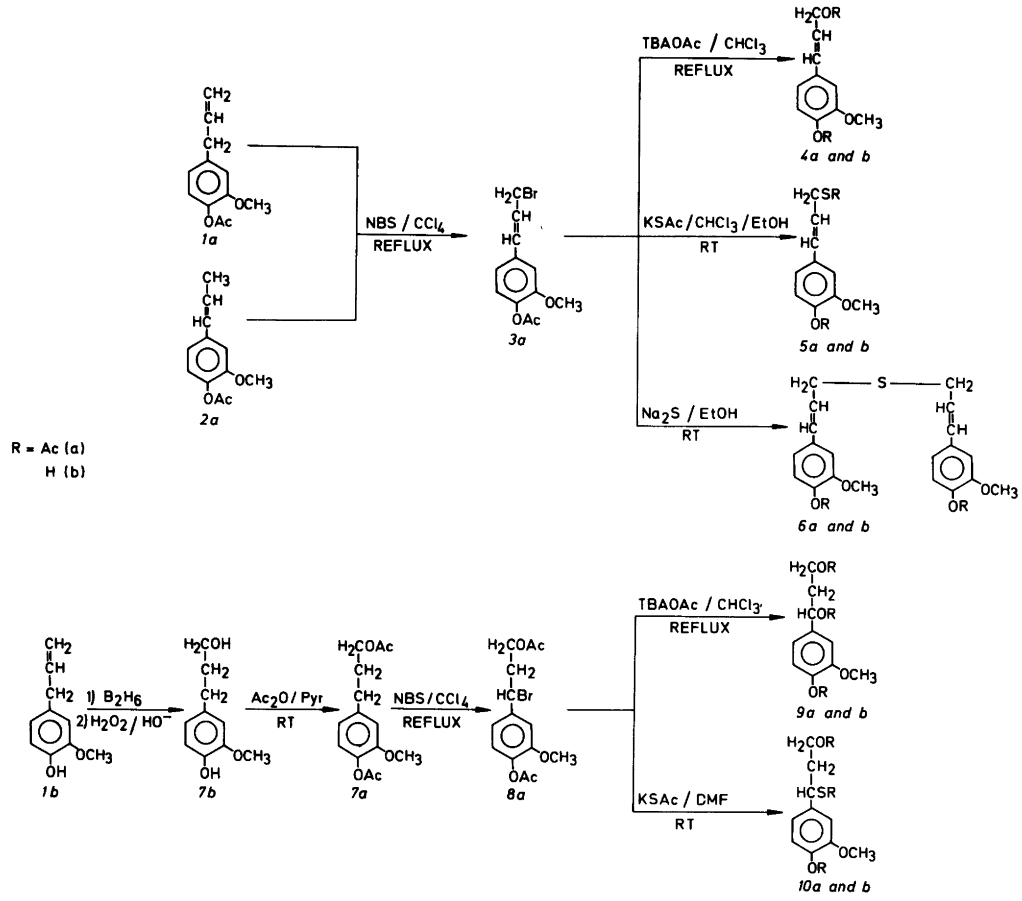

[3-(4-acetoxy-3-methoxyphenyl)-3-bromo-1-propene] (*cf.* Ref. 13).

The acetate of *trans*-coniferyl bromide (*3a*) was obtained in a yield of 68 %. Separation of the components of the reaction mixture from bromination of *2a* by column chromatography (CC) on silica gel showed that the reaction gave 1,2-dibromo-1-(4-acetoxy-3-methoxyphenyl)-propane (about 7 %) and the *cis*-isomer of *3a* (about 1 %) as by-products (^{1}H NMR, MS).

Benzylic bromination by the action of NBS on the diacetate of dihydroconiferyl alcohol (*7a*) gave the benzyl bromide *8a* in quantitative yield.

Compound *7a* was prepared from eugenol [14] by a modified [15] hydroboration-oxidation reaction followed by acetylation. The yield of *7b* obtained was slightly lower than that reported in the literature [14] but can probably be improved by applying more rigorously controlled anhydrous conditions. An attempt to isomerize the alkyl borane by increasing the reflux time [16] (2 h instead of 30 min) did not change the ratio (82:18) of the primary to the secondary alcohol.

Preparation of allylic and benzylic acetates, thioacetates and sulfides from the corresponding bromides. Attempts to replace the bromine in *trans*-coniferyl bromide acetate (*3a*) with the acetoxy group using potassium acetate in ethanol were not successful, due to competing solvolytic reactions. The main products were *trans*-3-(4-acetoxy-3-methoxyphenyl)-1-ethoxy-2-propene and 3-(4-acetoxy-3-methoxyphenyl)-3-ethoxy-1-propene and only minor amounts of the acetate *4a* were obtained (CC, ^{1}H and ^{13}C NMR, MS).

The acetate *4a* was finally obtained in quantitative yield by refluxing a chloroform solution of the allylic bromide *3a* and tetrabutylammonium acetate. [17] Substitution of the thioacetoxy group for

bromine was carried out using potassium thioacetate in anhydrous ethanol at room temperature affording the thioacetate *5a* in a 68 % yield. When treated with sodium sulfide using the same solvent and temperature, *3a* gave a quantitative yield of the diacetate of diconiferyl sulfide (*6a*).

The benzylic bromide (*8a*) afforded a 50 % yield of the benzylic acetate *9a* when treated with tetrabutylammonium acetate in chloroform. This low yield (compared to the yield of *4a*) was due in part to incomplete conversion (CC, ^{1}H NMR).

For the conversion of *8a* to the benzylic thioacetate *10a*, the former was treated with potassium thioacetate in dimethylformamide. The yield was quantitative.

In the preparation of the aforementioned coniferyl and dihydroconiferyl derivatives from the corresponding bromides, it was preferable to use the crude bromination products due to the instability of the purified bromides *3a* and *8a* on storage. Moreover, the derivatives so prepared could easily be obtained in a pure state by column chromatography on silica gel and/or recrystallization.

Compounds *4a*, *5a*, *6a*, *9a* and *10a* can be easily deacetylated by treatment with lithium aluminium hydride in anhydrous tetrahydrofurane to give the corresponding phenolic alcohols, thiols and sulfides. The yields were found to range between 92 and 100 %.

CONCLUSIONS

Allylic bromination of the acetates of eugenol and isoeugenol with *N*-bromosuccinimide, followed by displacement of the bromine with the appropriate nucleophile and deacetylation, provides a convenient synthetic route to coniferyl alcohol and other important coniferyl derivatives. The method is competitive with other methods of preparation, due to the easy availability of the starting materials and the good overall yields obtained. An analogous procedure for the preparation of dihydroconiferyl alcohol derivatives substituted at the benzylic carbon offers similar advantages.

EXPERIMENTAL

All melting points are uncorrected. Elemental analyses were performed at the laboratories of Dr. Alfred Bernhardt, Elbach über Engelskirchen, West Germany. Mass spectra were run on a Finnigan 3200 F quadrupole instrument with data system 6000 using either the direct inlet system or a GC equipped with an SE-30 glass capillary column. Spectra were taken at 40 or 70 eV. ^{1}H NMR spectra were run on a Perkin-Elmer R-12 60 MHz-instrument. *trans* configurations were assigned to compounds *3*–*6* from the observed coupling constants; these compounds exhibited ABX_2 type of spectra. ^{13}C NMR spectra were run on a Varian CFT-20 spectrometer. For assignment of signals, *cf.* Refs. 18 and 19. Shift values marked by an asterisk (*) denote that the corresponding assignments may be reversed. Column chromatography (CC) was performed on a Merck Lobar size B (310 mm × 25 mm i.d.) silica gel column using the solvent system ethyl acetate-light petroleum 60–71 °C.[4] Analytical HPLC and GC were carried out as previously described.[4]

In all the preparation steps described other than the deacetylation, crude reaction mixtures from the previous step were used. When the yield of a step was determined in a separate experiment using the purified starting compound, this is denoted by (HPLC), (GC) and/or (^{1}H NMR) following the yield figure. As internal standards, benzophenone for HPLC, benzophenone or anthracene for GC and dioxane for ^{1}H NMR were used. Peak areas in HPLC and GC were obtained using a Philips computing integrator DP 88. All solvents were freshly distilled. Evaporations were carried out under reduced pressure at a water bath temperature below 50 °C.

trans-*3-(4-Acetoxy-3-methoxyphenyl)-2-propenyl bromide (*3a*).* Eugenol acetate (*1a*, 20.6 g, 0.100 mol) was dissolved in carbon tetrachloride (200 ml). *N*-Bromosuccinimide (NBS, 20.4 g, 0.115 mol, purified according to Ref. 20) and a spatula tip of benzoyl peroxide (stabilized with 30 % of water) were added. The mixture was refluxed with magnetic stirring untill all the NBS had reacted, which took about 3 h. The reaction mixture was cooled in ice-water and filtered through a Büchner funnel. To an aliquot was added a few drops of TMS and yield (68 %) was determined by ^{1}H NMR from the ratio of the methylene doublet to the acetoxy or methoxy singlet.

A similar procedure was used for isoeugenol (*2a*), but the reflux time was increased to 20 h.

The crude reaction mixture was stable when stored in a refrigerator. When purified by CC on silica gel, pure *3a* was easily obtained. Pure *3a* was not stable (darkened) when stored in the refrigerator. Anal. $C_{12}H_{13}O_3Br$: C, H, O, Br. Amorphous. MS *m/e* (rel. int.): 286 (M, 0.4, ^{81}Br), 284 (M, 0.4, ^{79}Br), 244 (M−42, 2.0, ^{81}Br), 242 (M−42, 2.0, ^{79}Br), 163 (66), 131 (100), 119 (11), 103 (48). ^{1}H NMR δ 2.20 [s, 3 H, ϕOAc], 3.71 [s, 3 H, OCH_3], 4.04 [d, 2 H, $J_{1,2}$ 7 Hz], 6.24 [dt, H, ol, $J_{2,3}$ 15 Hz $J_{1,2}$ 7 Hz],

6.49 [d, H, ol, $J_{2,3}$ 15 Hz], 6.87 [s, 3 H, ar]. ^{13}C NMR δ 20.5 (CH_3 in acetate), 33.1 (C 1), 55.8 (OCH_3), 110.4 (C 2'), 119.5 (C 6'), 122.9 (C 5'), 125.5 (C 2), 133.8 (C 3), 134.9 (C 1'), 140.0 (C 4'), 151.3 (C 3'), 168.7 (C=O in acetate).

trans-*3-(4-Acetoxy-3-methoxyphenyl)-2-propenyl acetate (4a)*. Compound *3a* (2.85 g, 10 mmol) in chloroform (25 ml) was refluxed with tetrabutylammonium acetate[17] (8.79 g, 30 mmol) for 6 h with magnetic stirring. (The reaction was followed by evaporating an aliquot of the reaction mixture, dissolving the residue in deuteriochloroform and measuring the relative intensities of the appropriate doublet methylene signals in the ^1H NMR spectrum.) The chloroform was evaporated and the residual oil extracted (magnetic stirring) with ether (2 × 100 ml). The ether was carefully decanted and the combined extracts were washed with water (2 × 75 ml), dried over Na_2SO_4 and the solvent evaporated. ^1H NMR and HPLC showed that the yield was quantitative. MS, ^1H NMR and ^{13}C NMR spectra were in agreement with structure *4a*.

trans-*3-(4-Hydroxy-3-methoxyphenyl)-2-propenol (4b)*. A solution of 2.64 g (10 mmol) of *4a* in dry (distilled from lithium aluminium hydride, LAH) tetrahydrofuran (THF) (10 ml) was added dropwise in a nitrogen atmosphere to a magnetically stirred suspension of LAH (0.76 g, 20 mmol) in dry THF (10 ml). The temperature was kept below −10 °C during the addition and for an additional 30 min. The excess of LAH was destroyed with ethyl acetate (5 ml) and a mixture of THF (10 ml) and water (1.5 ml) was added cautiously. Water (40 ml) and dichloromethane (25 ml) were added and the water phase was neutralized with 10 % phosphoric acid. The dichloromethane layer was separated and the extraction was repeated (2 × 25 ml). The combined organic layers were dried over Na_2SO_4 and the solvents were evaporated. Yield of almost pure (^1H NMR) *4b* was 95 %. The product was crystallized from toluene to yield pure *4b*.

trans-*3-(4-Acetoxy-3-methoxyphenyl)-2-propenyl thioacetate (5a)*. To 2.85 g (10 mmol) of *3a* in chloroform (40 ml) was added dropwise with magnetic stirring a solution of potassium hydroxide (1.12 g, 20 mmol) and thioacetic acid (1.43 ml, 20 mmol) in ethanol (10 ml). Potassium bromide precipitated immediately. The reaction mixture was stirred at room temperature for 30 min after addition of the ethanol solution was completed. The reaction mixture was washed with water (3 × 50 ml), dried over Na_2SO_4 and the solvents were evaporated. Separation by CC and crystallization from dichloromethane – light petroleum (60 – 71 °C) yielded pure *5a*. Yield: 68 % (GC). Anal. $C_{14}H_{16}O_4S$: C, H, O, S, M.p. 71 °C. MS *m/e* (rel. int.): 280 (M, 1.6), 238 (M − 42, 16), 163 (61), 131 (100), 103 (25). ^1H NMR δ 2.26 [s, 3 H, ϕOAc], 2.31 [s, 3 H, RSAc], 3.66 [d, 2 H, $J_{1,2}$ 7 Hz], 3.79 [s, 3 H, OCH_3], 6.07 [dt, H, ol, $J_{2,3}$ 15 Hz], 6.48 [d, H, ol, $J_{2,3}$ 15 Hz], 6.88 [s, 3 H, ar]. ^{13}C NMR δ 20.5 (CH_3 in phenolic acetate), 30.4 (CH_3 in thioacetate), 31.6 (C 1), 55.8 (OCH_3), 110.1 (C 2'), 119.1 (C 6'), 122.8 (C 5'), 124.8 (C 2), 132.5 (C 3), 135.7 (C 1'), 139.7 (C 4'), 151.2 (C 3'), 168.8 (C=O in phenolic acetate), 194.8 (C=O in thioacetate).

trans-*3-(4-Hydroxy-3-methoxyphenyl)-2 -propenylthiol (5b)*. Compound *5a* (2.80 g, 10 mmol) was deacetylated according to the procedure described for the preparation of *4b*. Crude yield: 97 %. Anal. $C_{10}H_{12}O_2S$: C, H, O, S. Amorphous. MS *m/e* (rel. int.): 196 (M, 13), 163 (41), 149 (5), 135 (5), 131 (100), 119 (7), 103 (59). ^1H NMR δ 1.49 [t, H, RSH, $J_{1,SH}$ 7 Hz], 2.93 – 3.58 [m, 2 H, $J_{1,2}$ 6 Hz, $J_{1,SH}$ 7 Hz], 3.83 [s, 3 H, OCH_3], 4.93 [broad s, H, ϕOH], 6.10 [dt, H, ol, $J_{2,3}$ 15 Hz, $J_{1,2}$ 6 Hz], 6.34 [d, H, ol, $J_{2,3}$ 15 Hz], 6.80 [s, 3 H, ar]. ^{13}C NMR δ 27.3 (C 1), 55.9 (OCH_3), 108.5 (C 2'), 114.6 (C 5'), 120.2 (C 6'), 126.5 (C 2), 129.4 (C 1') 130.8 (C 3), 145.7* (C 3'), 146.8* (C 4').

trans,trans-*Bis[3-(4-acetoxy-3-methoxyphenyl)-2-propenyl] sulfide (6a)*. A solution of 5.70 g (20 mmol) of *3a* in absolute ethanol (40 ml) was added dropwise to a magnetically stirred solution of 2.64 g (11 mmol) of $Na_2S.9H_2O$ in absolute ethanol (150 ml). The temperature was kept below +5 °C (ice bath). After addition was completed the solution was stirred for 30 min. Water (200 ml) was added and the solution was extracted with ether (3 × 50 ml). The combined ethereal extracts were dried over sodium sulfate and the solvent was evaporated. The crude product was acetylated with acetic anhydride/pyridine (10 + 10 ml) at room temperature overnight. The solvents of the acetylation mixture were evaporated azeotropically with toluene (2 × 50 ml). The residue was crystallized from ethanol to yield 2.6 g (60 %) of *6a*. Yield determined by HPLC was 100 %. Anal. $C_{24}H_{26}O_6S$: C, H, O, S. M.p. 89 – 90 °C. MS *m/e* (rel. int.): 442 (M, 0.1), 400 (M − 42, 3), 358 (M − 84, 5), 195 (24), 163 (81), 131 (100), 103 (27). ^1H NMR δ 2.26 [s, 6 H, ϕOAc], 3.26 [d, 4 H, $J_{1,2}$ 6 Hz], 3.78 [s, 6 H, OCH_3], 6.07 [dt, 2 H, ol, $J_{2,3}$ 15 Hz, $J_{1,2}$ 6 Hz], 6.34 [d, 2 H, ol, $J_{2,3}$ 15 Hz], 6.90 [s, 6 H, ar]. ^{13}C NMR δ 20.5 (CH_3 in acetate), 33.3 (C 1), 55.8 (OCH_3), 110.0 (C 2'), 119.0 (C 6'), 122.8 (C 5'), 126.3 (C 2), 131.8 (C 3), 135.8 (C 1'), 139.4 (C 4'), 151.2 (C 3'), 168.8 (C=O in acetate).

trans,trans-*Bis[3-(4-hydroxy-3-methoxyphenyl)-2-propenyl] sulfide (6b)*. Compound *6a* (4.42 g, 10 mmol) was deacetylated according to the procedure described for the preparation of *4b*. The crude product (yield 100 %) was crystallized from dichloromethane – light petroleum (60 – 71 °C). First crop: 69 % yield. Anal. $C_{20}H_{22}O_4S$: C, H, O, S. M.p. 114.0 – 114.5 °C. MS *m/e* (rel. int.): 358 (M, 5), 195

(7), 163 (49), 135 (10), 131 (100), 119 (8), 103 (50). ^{1}H NMR δ 3.26 [d, 4 H, $J_{1,2}$ 6 Hz], 3.82 [s, 6 H, OCH_3], 5.99 [dt, 2 H, ol, $J_{2,3}$ 15 Hz, $J_{1,2}$ 6 Hz], 6.33 [d, 2 H, ol, $J_{2,3}$ 15 Hz], 6.78 [s, 6 H, ar], 6.88 [broad s, 2 H, ϕOH]. ^{13}C NMR δ 33.6 (C 1), 55.9 (OCH_3), 108.3 (C 2), 114.6 (C 5), 120.2 (C 6'), 123.8 (C 2), 129.4 (C 1'), 132.3 (C 3), 145.7* (C 3'), 146.9* (C 4').

*3-(4-Hydroxy-3-methoxyphenyl)-1-propanol (*7b*) and 3-(4-acetoxy-3-methoxyphenyl)-1-propyl acetate (*7a*).* Eugenol (*1b*, 16.4 g, 0.10 mol) and tetrabutylammonium boranate[15] (25.7 g, 0.10 mol) were dissolved in 400 ml of dichloromethane in a dry, three-necked 1 l flask equipped with a pressure-equalizing dropping funnel, a reflux condenser and a motor-driven stirrer. Methyl iodide (9.4 ml, 0.15 mol), dissolved in 25 ml of dichloromethane, was slowly added during stirring. After addition was complete the solution was refluxed for 30 min. The mixture was cooled and water (10 ml) was added dropwise followed by 2 M sodium hydroxide (75 ml, 0.15 mol NaOH). The, 30 % H_2O_2 (24 ml) was added dropwise with vigourous stirring and the stirring was continued for 1.5 h.

The phases were separated, the aqueous layer was extracted with methylene chloride (2 × 50 ml) and the combined dichloromethane layers were dried over Na_2SO_4, filtered and evaporated. The resulting syrup was added dropwise to ether (400 ml) with vigourous stirring. The tetrabutylammonium iodide (TBAI) precipitate was filtered off using a Büchner funnel and the ether was evaporated to yield 5.5 g of a viscous syrup. The water phase from above was saturated with sodium chloride, neutralized with 2 M HCl and extracted with ether (3 × 100 ml). The combined ethereal extracts were dried over Na_2SO_4, filtered and evaporated to yield 11.9 g of a viscous syrup. The syrups were added to give a crude yield of 17.4 g (96 %) of a mixture of *7b* and 1-(4-hydroxy-3-methoxyphenyl)-2-propanol (ratio 82:18), slightly contaminated from TBAI. The crude product mixture was acetylated with acetic anhydride/pyridine (20+20 ml) at 50 °C for 1 h. The acetylation mixture was poured into ice water, acidified with 2 M HCl and extracted with ether (4 × 100 ml). The combined organic layers were dried over Na_2SO_4, filtered and the solvents were evaporated to yield 20.8 g (81 %) of a mixture of *7a* and its isomer. Pure *7a* was obtained by CC on silica gel. NMR and MS were consistent with the given structures for all compounds.

*3-(4-Acetoxy-3-methoxyphenyl)-3-bromo-1-propyl acetate (*8a*).* A mixture (10 g, 38 mmol) of *7a* and its acetylated isomer (ratio 82:18) in carbon tetrachloride (130 ml) together with NBS (7.7 g, 43 mmol) and a spatula tip of benzoyl peroxide, stabilized with 30 % water, were refluxed with magnetic stirring for 30 min. The reaction mixture was cooled and filtered. A portion (850 mg) of the residue after evaporation was separated by CC to afford pure *8a* (256 mg) together with other reaction products, all characterized by ^{1}H NMR. Thus, it was found that in the ^{1}H NMR spectrum of the crude reaction mixture, signals due to compounds other than *8a* overlapped with the methine signals used for estimation of the yield of *8a*. In a separate experiment using pure *7a* the yield of *8a* was found to be quantitative (^{1}H NMR). The crude reaction mixture was stable when stored in the refrigerator, while pure *8a* was unstable and darkened during storage. Anal. calculated for $C_{14}H_{15}O_5Br$: C 49.00, H 4.41, O 23.31, Br 23.28. Found: C 48.66, H 4.91, O 23.31, Br 23.12. M.p. 84.5–85.5 °C. MS *m/e* (rel. int.) 346 (M, 0.9, ^{81}Br), 344 (M, 1.0, ^{79}Br), 304 (M−42, 1.4, ^{81}Br), 302 (M−42, 2.0, ^{79}Br), 286 (0.8, ^{81}Br), 284 (0.8, ^{79}Br), 223 (5), 205 (14), 179 (8), 163 (56), 150 (25), 135 (11), 131 (100). ^{1}H NMR δ 1.98 [s, 3 H, ROAc], 2.23 [s, 3 H, ϕOAc], 2.43 [dt, 2 H, $J_{1,2}$ 6 Hz, $J_{2,3}$ 7 Hz], 3.77 [s, 3 H, OCH_3], 4.13 [t, 2 H, $J_{1,2}$ 6 Hz], 5.03 [t, H, $J_{2,3}$ 7 Hz], 6.93 [s, 3 H, ar]. ^{13}C NMR δ 20.6 (CH_3 in phenolic acetate), 20.8 (CH_3 in aliphatic acetate), 38.9 (C 2), 50.8 (C 3), 56.0 (OCH_3), 62.3 (C 1), 111.6 (C 2'), 119.5 (C 6'), 123.0 (C 5'), 140.0 (C 4'), 140.2 (C 1'), 151.4 (C 3'), 168.7 (C=O in phenolic acetate), 170.7 (C=O in aliphatic acetate).

*3-Acetoxy-3-(4-acetoxy-3-methoxyphenyl)-1-propyl acetate (*9a*).* Compound *8a* (2.42 g, 7.0 mmol) and tetrabutylammonium acetate[17] (6.15 g, 21 mmol) in chloroform (10 ml) were refluxed for 6 h. Work-up was as described for the synthesis of *4a*. Yield 50 % (^{1}H NMR). The components of a portion (1.54 g) of the crude reaction mixture were separated by CC on silica gel to yield pure *9a* (855 mg) which crystallized on evaporation of the solvents. Recrystallization was performed from dichloromethane–light petroleum (60–71 °C). M.p. 77–79 °C; the compound has been obtained previously[21] in an amorphous state. MS *m/e* (rel. int.): 324 (M, 1.4), 282 (M−42, 10), 222 (24), 180 (27), 179 (58), 163 (23), 153 (96), 151 (100), 149 (44), 131 (48), 125 (15). ^{1}H NMR δ 1.96 [s, 3 H, ROAc], 2.01 [s, 3 H, ROAc], 2.21 [s, 3 H, ϕOAc], 1.87–2.40 [m, 2 H], 3.76 [s, 3 H, OCH_3], 3.84–4.29 [m, 2 H], 5.80 [t, H, $J_{2,3}$ 6 Hz], 6.91 [s, 3 H, ar]. ^{13}C NMR δ 20.6 (CH_3 in phenolic acetate), 20.8 and 21.1 (CH_3 in aliphatic acetates), 35.3 (C 2), 56.0 (OCH_3), 60.6 (C 1), 72.5 (C 3), 110.9 (C 2'), 118.8 (C 6'), 122.9 (C 5'), 138.8 (C 1'), 139.7 (C 4'), 151.3 (C 3'), 168.8 (C=O in phenolic acetate), 170.0 and 170.9 (C=O in aliphatic acetates).

*3-Hydroxy-3-(4-hydroxy-3-methoxyphenyl)-1-propanol (*9b*).* Compound *9a* (324 mg, 1.0 mmol) was deacetylated with LAH (228 mg, 6 mmol) as described for *4b*, except for the work-up procedure. The excess of LAH was destroyed with ethyl acetate

(2 ml) and THF (10 ml) was added. The solution was carefully neutralized with 10 % phosphoric acid and filtered through a Büchner funnel. The solid material was washed with acetone, the acetone was combined with the THF solution and the solvents evaporated to yield pure (^{1}H NMR) *9a*, which was dried *in vacuo* over P_2O_5/KOH. Yield: 193 mg (92 %). Amorphous. MS *m/e* (rel. int.): 198 (M, 17), 153 (100), 125 (39). ^{1}H NMR [$(CD_3)_2$ CO] δ 1.67–2.11 [dt, 2 H, $J_{1,2}=J_{2,3}$ 6 Hz], 3.69 [t, 2 H, $J_{1,2}$ 6 Hz], 3.79 [s, 3 H, OCH_3], 4.80 [t, H, $J_{2,3}$ 6 Hz], 6.78–6.98 [m, 3 H, ar], 7.6 [broad, H, ϕOH], ROH broad. ^{13}C NMR [$(CD_3)_2$ CO], 42.8 (C 2), 56.2 (OCH_3), 60.5 (C 1), 72.6 (C 3), 110.3 (C 2'), 115.3 (C 5'), 119.2 (C 6'), 138.3 (C 1'), 146.3* (C 3'), 148.1* (C 4').

*3-(4-Acetoxy-3-methoxyphenyl)-3-thioacetoxy-1-propyl acetate (*10a*).* Compound *8a* (5.2 g, 15 mmol) and potassium thioacetate (4.2 g, 36 mmol) in DMF (50 ml) were stirred at room temperature for 4.0 h. Water (400 ml) was added and the solution was extracted with dichloromethane (4 × 50 ml). The combined organic layers were washed with water (10 × 100 ml) to remove DMF, dried over Na_2SO_4, filtered and the solvent was evaporated. Yield 100 % (GC; ^{1}H NMR). Pure *10a* was obtained from separation by CC on silica gel. Amorphous. MS *m/e* (rel. int.): 340 (M, 0.8), 298 (M–42, 4), 223 (5), 195 (6), 163 (100), 131 (95). ^{1}H NMR δ 1.98 [s, 3 H, ROAc], 2.23 [s, 3 H, ϕOAc], 2.28 [s, 3 H, RSAc], 1.87–2.44 [m, 2 H], 3.78 [s, 3 H, OCH_3], 3.83–4.28 [m, 2 H], 4.67 [t, H, $J_{2,3}$ 7 Hz], 6.92 [s, 3 H, ar]. ^{13}C NMR δ 20.6 (CH_3 in phenolic acetate), 20.8 (CH_3 in aliphatic acetate), 30.4 (CH_3 in thioacetate), 35.0 (C 2), 44.6 (C 3), 55.9 (OCH_3), 61.8 (C 1), 112.0 (C 2'), 119.7 (C 6'), 122.9 (C 5'), 139.2 (C 4'), 139.9 (C 1'), 151.2 (C 3'), 168.7 (C=O in phenolic acetate), 170.8 (C=O in aliphatic acetate), 194.0 (C=O in thioacetate).

*3-(4-Hydroxy-3-methoxyphenyl)-3-mercapto-1-propanol (*10b*).* Compound *10a* (340 mg, 1.0 mmol) was deacetylated with LAH (228 mg, 6.0 mmol) as described for *9b*. Yield: 207 mg (97 %). Anal. $C_{10}H_{14}O_3S$: C, H, O, S. Amorphous. MS *m/e* (rel. int.): 214 (M, 21), 181 (99), 169 (9), 163 (5), 151 (80), 137 (100), 124 (15), 119 (62). ^{1}H NMR δ 1.82–2.29 [dt, 2 H, $J_{1,2}$ 6 Hz, $J_{2,3}$ 7 Hz], 3.59 [t, 2 H, $J_{1,2}$ 6 Hz], 3.77 [s, 3 H, OCH_3], 6.16 [t, H, $J_{2,3}$ 7 Hz], 6.73 [broad, 3 H, ar]. ^{13}C NMR δ 40.6 (C 3), 42.4 (C 2), 56.0 (OCH_3), 60.5 (C 1), 109.8 (C 2'), 114.7 (C 5'), 119.7 (C 6'), 136.3 (C 1'), 145.0* (C 3'), 146.9* (C 4').

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REFERENCES

1. Freudenberg, K. and Neish, A. C. *Constitution and Biosynthesis of Lignin*, Springer, Berlin 1968.
2. Brunow, G. and Miksche, G. E. *Acta Chem. Scand. 26* (1972) 1123 and preceding communications.
3. Gierer, J., Pettersson, I., Smedman, L. Å. and Wennberg, I. *Acta Chem. Scand. 27* (1973) 2083.
4. Gierer, J. and Lindeberg, O. *Acta Chem. Scand. B 32* (1978) 577.
5. Freudenberg, K. and Hübner, H. H. *Chem. Ber. 85* (1952) 1181.
6. Minami, K., Lakai, H. and Fukuzumi, T. *J. Jpn. Wood Res. Soc. 20* (1974) 42.
7. Niakamuri, Y. and Higuchi, T. *Wood Res. 59/60* (1976) 101.
8. Sadler, I. H. and Stewart, J. A. G. *Chem. Commun.* (1968) 1930.
9. For a review of the properties and reactions of *N*-bromosuccinimide, see Pizey, J. S. *Synthetic Reagents 2*, Wiley, Chichester 1974, p. 1; Sosnovsky, G. *Free Radical Reactions in Preparative Organic Chemistry*, Mc Millan, New York 1964, p. 337.
10. Yamaguchi, A., Hiroi, T. and Miyazaki, M. *J. Jpn. Wood Res. 15* (1969) 256.
11. Day, J. C., Lindström, M. J. and Skell, P. S. *J. Am. Chem. Soc. 96* (1974) 5616.
12. Thaler, A. W. In Huyser, E. S., Ed., *Methods in Free Radical Chemistry*, Vol. 2, Dekker, New York 1969, p. 198.
13. Horner, L. and Winkelmann, E. H. In Foerst, W. *Neuere Methoden der präparativen organischen Chemie*, Bd. III, Verlag Chemie, Weinheim/Bergstrasse 1960, p. 110.
14. Pepper, J. M., Lundaram, G. S. and Dyson, G. *Can. J. Chem. 49* (1971) 3394.
15. Brändström, A., Junggren, U. and Lamm, B. *Tetrahedron Lett.* (1972) 3173.
16. Brown, H. C. *Hydroboration*, W. A. Benjamin, New York 1962, p. 136.
17. Brändström, A. *Preparative Ion Pair Extraction*, Swedish Academy of Pharmaceutical Sciences, Stockholm 1974, p. 146.
18. von Masow, F. and Smith, M. A. R. *J. Chem. Soc. Perkin Trans. 2* (1976) 977.
19. Erasmuson, A. F., Ferrier, R. J., Franca, N. C., Gottlieb, H. E. and Wenkert, E. *J. Chem. Soc. Perkin Trans. 1* (1977) 492.
20. Pearson, R. E. and Martin, J. C. *J. Am. Chem. Soc. 85* (1963) 3142.
21. Kratzl, K. and Miksche, G. E. *Monatsh. Chem. 94* (1963) 530.

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