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RAPID COMMUNICATIONS

Improved Preparation of Coniferyl and Sinapyl Alcohols

Keywords: *Coniferyl alcohol; sinapyl alcohol; lignin; lignin monomer; sodium borohydride*

INTRODUCTION

Variable-scale syntheses of coniferyl and sinapyl alcohols **2a**,**b** have become increasingly important in recent years due to the usefulness of these lignin monomers in preparing synthetic lignins and lignin model compounds (Sarkanen and Ludwig, 1971; Adler, 1977; Landucci, 1995; Landucci *et al.*, 1981; Helm and Ralph, 1992; Ralph *et al.*, 1992a,b). In the past, reduction of ethyl ferulate and ethyl sinapate with lithium aluminum hydride (Allen and Byers, 1949; Freudenberg and Hübner, 1952; Freudenberg and Swaleh, 1969), sodium bis(2-methoxyethyl)aluminum hydride (Minami *et al.*, 1974; Kirk and Brunow, 1988), or diisobutyl aluminum hydride (DIBAL-H) (Newman *et al.*, 1986; Quideau and Ralph, 1992) was the method of choice. The problems associated with these methods are the moderate yields, the necessity of handling air-sensitive reagents under protective gases, and the varying amounts of undesired double-bond-reduction byproducts, the so-called 1,4-reduction products **3**. The tolerably low amount of 1,4-reduction products was the strength of a DIBAL-based method (Quideau and Ralph, 1992). Nonreductive synthetic methods (Nakamura and Higuchi, 1976; Steglich and Zechlin, 1978; Zanarotti, 1982; Rothen and Schlosser, 1991) leading to *p*-hydroxycinnamyl alcohols also have the disadvantages of requiring several steps, requiring nonambient conditions, or producing poor to moderate overall yields.

Sodium borohydride is a versatile reducing agent that is particularly attractive for general use by nonchemists because of its ease of handling. However, reduction of conjugated aldehydes and ketones is generally complicated by competing 1,4- and 1,2-processes (Kropf, 1981). For example, borohydride reduction of cyclopenten-2-one produces cyclopentanol quantitatively (Chaiken and Brown, 1949). Presumably for this reason, and because of the previous unavailability of the aldehydes, borohydride approaches have not appeared in the literature, with one exception; sodium borohydride reduction of the protected aldehydes using a buffer system under argon at 0 °C has been reported but does not address the 1,4-reduction products (Daubresse *et al.*, 1994).

This paper describes a quick, efficient, and clean synthesis of milligram to decagram quantities of the substituted cinnamyl alcohols **2a**,**b** using sodium borohydride reduction of coniferyl and sinapyl aldehydes **1a**,**b** which are now commercially available.

RESULTS AND DISCUSSION

Coniferyl and sinapyl alcohols **2a**,**b** were prepared cleanly from their corresponding aldehydes **1a**,**b** by sodium borohydride reduction in ethyl acetate at room temperature (Figure 1). The yields were 99% and 94% for **2a** and **2b**, respectively, as described under the Experimental Methods. Large-scale preparation of **2a** yielded 76% crystalline (first crop) material. Unlike prior methods, the synthesis presented offers a very efficient and easy to handle method for preparing variable amounts of coniferyl and sinapyl alcohols **2a**,**b**. The advantages are that the yields of the desired compounds are high, the reaction products may be used directly in following reactions, there is no need to protect the phenolic hydroxy group as in some of the other preparation methods, and under 1% of the troublesome double-bond-reduced compound **3** is produced. The simplicity allows access to high-quality coniferyl and sinapyl alcohols; even without purification by crystallization, the purity is notably superior to that which can be obtained commercially.

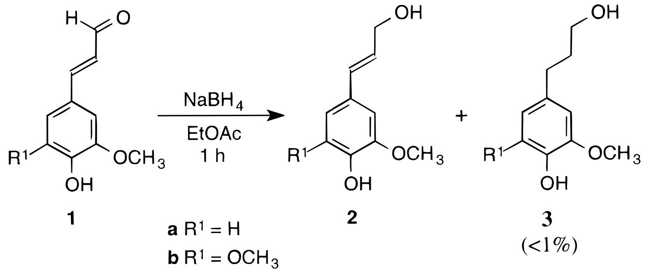

Figure 1. $NaBH_4$ reduction of coniferyl (**1a**) and sinapyl (**1b**) aldehydes.

EXPERIMENTAL METHODS

Melting points are uncorrected. ^1H and ^{13}C NMR spectra (with assignments made using the usual complement of 2D spectra) were identical to those reported previously (Quideau and Ralph, 1992) and reported in three solvents in the lignin model database (compounds 2001 and 2002) (Ralph *et al.*, 1996). Petroleum ether was the 30−60 °C fraction, usually distilled. Ethyl acetate was distilled. Coniferaldehyde and sinapylaldehyde were obtained from Aldrich Chemical Co., Milwaukee, WI. Products **2a**,**b** were identical with those fully characterized previously (Quideau and Ralph, 1992).

Coniferyl Alcohol 2a. Coniferaldehyde **1a** (50 mg, 0.28 mmol) was dissolved in ethyl acetate (10 mL). Sodium borohydride (21 mg, 0.56 mmol, 2 equiv) was added and the solution stirred for 1 h at room temperature. During that time a yellow precipitate formed. The reaction mixture was poured into water (50 mL), the organic layer was separated, and the aqueous layer was extracted with ethyl acetate (2 × 50 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and evaporated to dryness under reduced pressure at 40 °C to give coniferyl alcohol **2a** as a white/pale yellow solid, or sometimes as a pale yellow oil (49.9 mg, 99%). ^1H NMR of the crude product **2a** showed $<1\%$ of the 1,4-reduction product **3a**. Recrystallization from dichloromethane/petroleum ether gave **2a** as very pale yellow plates: mp 78.2−78.6 °C [lit. (Freudenberg and Hübner, 1952) 74−76 °C; lit. (Quideau and Ralph, 1992) 77.9−78.6 °C]. For large-scale preparations (5 g) the reaction was run for 6.5 h at room temperature using TLC to monitor progress and worked up as above to yield crude **2a** (4.66 g, 92%). Crystallization from dichloromethane/petroleum ether afforded first-crop **2a** in 76% yield.

Sinapyl Alcohol 2b. Sinapyl aldehyde **1b** was reduced as described for **1a** to yield sinapyl alcohol **2b** as a yellow-orange oil in 94% yield. Crystallization was more difficult than for **2a** but could be effected from methylene chloride/petroleum ether as described previously (Quideau and Ralph, 1992).

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LITERATURE CITED

Adler, E. Lignin chemistry—past, present and future. *Wood Sci. Technol.* **1977**, *11*, 169−218.

Allen, C. F. H.; Byers, J. R. A synthesis of coniferyl alcohol and coniferyl benzoate. *J. Am. Chem. Soc.* **1949**, *71*, 2683−2684.

Chaiken, S. W.; Brown, W. G. Reduction of aldehydes, ketones and acid chlorides by sodium borohydride. *J. Am. Chem. Soc.* **1949**, *71*, 122−125.

Daubresse, N.; Francesch, C.; Mhamdi, F.; Rolando, C. A mild synthesis of coumaryl, coniferyl, sinapyl aldehydes and alcohols. *Synthesis* **1994**, 369−371.

Freudenberg, K.; Hübner, H. H. Oxyzimtalkohole und ihre Dehydrierungs-polymerisate. *Chem. Ber.* **1952**, *85*, 1181−1191.

Freudenberg, K.; Swaleh, M. Aufbau and Abbau des künstlichen Lignins aus Coniferylalkohol-[γ-14C]. *Chem. Ber.* **1969**, *102*, 1316−1319.

Helm, R. F.; Ralph, J. Lignin−hydroxycinnamyl model compounds related to forage cell wall structure. 1. Ether-linked structures. *J. Agric. Food Chem.* **1992**, *40*, 2167−2175.

Hhaos, A. Reduktion. In *Methoden der Organischen Chemie*; Kropf, H., Ed.; Georg Thieme Verlag: Stuttgart, 1981; Vol. 4/1d, p 299.

Kirk, T. K.; Brunow, G. Synthetic carbon-14-labeled lignins. *Methods Enzymol.* **1988**, *161*, 65−73.

Landucci, L. L. Reactions of *p*-hydroxycinnamyl alcohols with transition metal salts. 1. Oligolignols and polylignols (DHPs) from coniferyl alcohol. *J. Wood Chem. Technol.* **1995**, *15*, 349−368.

Landucci, L. L.; Geddes, S. A.; Kirk, T. K. Synthesis of carbon-14-labeled 3-methoxy-4-hydroxy-α-(2-methoxyphenoxy)-β-hydroxypropiophenone, a lignin model compound. *Holzforschung* **1981**, *35*, 67−70.

Minami, K.; Sakai, H.; Fukuzumi, T. Synthesis of coniferyl alcohol with a new reducing reagent from acetylferulic acid ethyl ester. *J. Jpn. Wood Res. Soc.* **1974**, *20*, 42−44.

Nakamura, Y.; Higuchi, T. New synthesis of coniferyl aldehyde and alcohol. *Wood Res.* **1976**, *59/60*, 101−105.

Newman, J.; Rej, R. N.; Just, G.; Lewis, N. G. Synthesis of (1,2-13C), (1-13C), and (3-13C) coniferyl alcohol. *Holzforschung* **1986**, *40*, 369−373.

Quideau, S.; Ralph, J. Facile large-scale synthesis of coniferyl, sinapyl, and *p*-coumaryl alcohol. *J. Agric. Food Chem.* **1992**, *40*, 1108−1110.

Ralph, J.; Helm, R. F.; Quideau, S. Lignin-feruloyl ester cross-links in grasses. Part 2. Model compound syntheses. *J. Chem. Soc., Perkin Trans. 1* **1992a**, 2971−2980.

Ralph, J.; Helm, R. F.; Quideau, S.; Hatfield, R. D. Lignin-feruloyl ester cross-links in grasses. Part 1. Incorporation of feruloyl esters into coniferyl alcohol dehydrogenation polymers. *J. Chem. Soc., Perkin Trans. 1* **1992b**, 2961−2969.

Ralph, S. A.; Ralph, J.; Landucci, L. L. NMR database of lignin and cell wall model compounds. Available at http://www.dfrc.wisc.edu/software.html, or send e-mail to jralph@facstaff.wisc.edu; 1996.

Rothen, L.; Schlosser, M. A one-pot synthesis of coumaryl, coniferyl and sinapyl alcohol. *Tetrahedron* **1991**, *32*, 2475−2476.

Sarkanen, K. V.; Ludwig, C. H. *Lignins, Occurrence, Formation, Structure and Reactions*; Wiley-Interscience: New York, 1971.

Steglich, W.; Zechlin, L. Synthese des Fomentariols. Eine neue Methode zur Darstellung von Zimtalkoholen. *Chem. Ber.* **1978**, *111*, 3939−3948.

Zanarotti, A. Preparation and reactivity of 2,6-dimethoxy-4-allylidene-2,5-cyclohexadien-1-one (vinyl quinone methide). A novel synthesis of sinapyl alcohol. *Tetrahedron Lett.* **1982**, *23*, 3815−18.

Registry No. Supplied by the Author: **1a**, 458-36-6; **1b**, 4206-58-0; **2a**, 458-35-5; **2b**, 537-33-7; $NaBH_4$, 16940-66-2.

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