



Reconsidering the feruoylation of arabinoxylan by Mitsunobu reaction with a di-arabinofuranosyl-xylotriose model

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Maintext

In our recent article (Elschner et al. 2023), we reported about the Mitsunobu esterification of arabinoxylan with ferulic acid at position 5 of the arabinose side chain. However, for low molecular weight xylan, the modification of the anomeric hydroxyl group at the reducing end has to be considered. The end group modification is not visible in the spectra of arabinoxylan ferulate recorded within our original publication. The intensities of the signals arising from end groups of xylan are naturally very low and overlapped with other resonances due to low resolution of spectra from polymers. Therefore, we show the additional findings with support of the model compound 2³,3³-di- α -L-arabinofuranosyl-xylotriose (A^{2,3}XX).

In 1967, Oyo Mitsunobu published the synthesis of phosphoric acid esters by means of diethyl azodicarboxylate and triphenylphosphine, which has been developed to a powerful tool in organic chemistry to

achieve high regio- and stereoselectivity (Mitsunobu et al. 1967; Swamy et al. 2009). The standard Mitsunobu reaction for the esterification of carboxylic acids with alcohols takes place according to a dehydrative S_N2 process enabled by reductive triphenylphosphine and diisopropyl azodicarboxylate as oxidant. Regarding the modification of polysaccharides, cellulose esters of ferulic-, p-coumaric-, and caffeic acid could be obtained under these conditions in N,N-dimethylacetamide/LiCl (Elschner et al. 2021). The reaction occurred preferably at primary hydroxyl groups (position 6) achieving DS values of up to 0.5. This procedure was found to be insensitive regarding double bonds and phenolic hydroxyl groups present in phenolic acids. Protecting group chemistry was not necessary and moreover, side products could be removed. Cellulose ferulates obtained by Mitsunobu chemistry were found to be soluble in dimethyl sulfoxide (DMSO). Thus, this synthesis path is more attractive than the Steglich procedure.

For other polysaccharides than cellulose, Mitsunobu chemistry seems to be more complicated. Benzoylation of amylose was also found to be regioselective at position 6, but for degree of substitution (DS) values above 0.5 an esterification at position 2 occurred (Cimecioglu et al. 1993). Recently, arabinoxylan was allowed to react under Mitsunobu conditions but chloride ions of the solvent system lead to Appel type products, i.e. deoxychloro moieties next to ferulate in the polymer backbone (Elschner et al. 2023).

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The novel one-step procedure for the synthesis of polysaccharide hydroxycinnamates allows the tailoring of antioxidative biomaterials as well as the design of lignocellulosic model compounds to achieve progress in biorefining. However, Mitsunobu conditions may lead to unexpected results, which are difficult to detect in polymer chemistry. Therefore, in this work an arabinoxylooligomer was used to reveal the reactivity of arabinoxylan. It turned out that not only the primary hydroxyl group (position 5) of the arabinose side chain was modified, but also the anomeric hydroxyl group of the reducing end.

In the HSQC-DEPT NMR spectrum of A^{2,3}XX (Fig. 1), all ¹H- and ¹³C NMR resonances could be assigned by evaluating HH correlations, CH long-range experiments, and coupling constants as well as literature data (Pu et al. 2016).

A^{2,3}XX was received from Megazyme and allowed to react under Mitsunobu conditions with

ferulic acid analogous to arabinoxylan (Elschner et al. 2023). As expected, the HSQC-DEPT NMR spectrum (Fig. 2) of ferulated A^{2,3}XX shows the typical cross-peaks of 5-O-feruoylated arabinose moieties at 4.3/63.5 ppm of 5(Ara-FA) and 4.1/80.7 ppm of 3(Ara-FA), known from the literature (Hatfield et al. 1991). Surprisingly, all signals arising from the reducing end (1 to 5(Xred α / β)) are not visible at its original shifts. Instead, the doublets at 6.0 ppm and 5.4 ppm reveal the formation of the α - and the β -glycoside of ferulic acid, respectively (Hanesian et al. 2003; Cheel et al. 2005). The result is in accordance with literature describing the formation of anomeric esters under Mitsunobu conditions (Hain et al. 2018). Starting the reaction with a mixture of α and β -anomers, the formation of both anomers can be assumed according to S_N2 mechanism. Moreover, the Mitsunobu conditions applied within this work may lead to the S_N1 path, too (Takeuchi

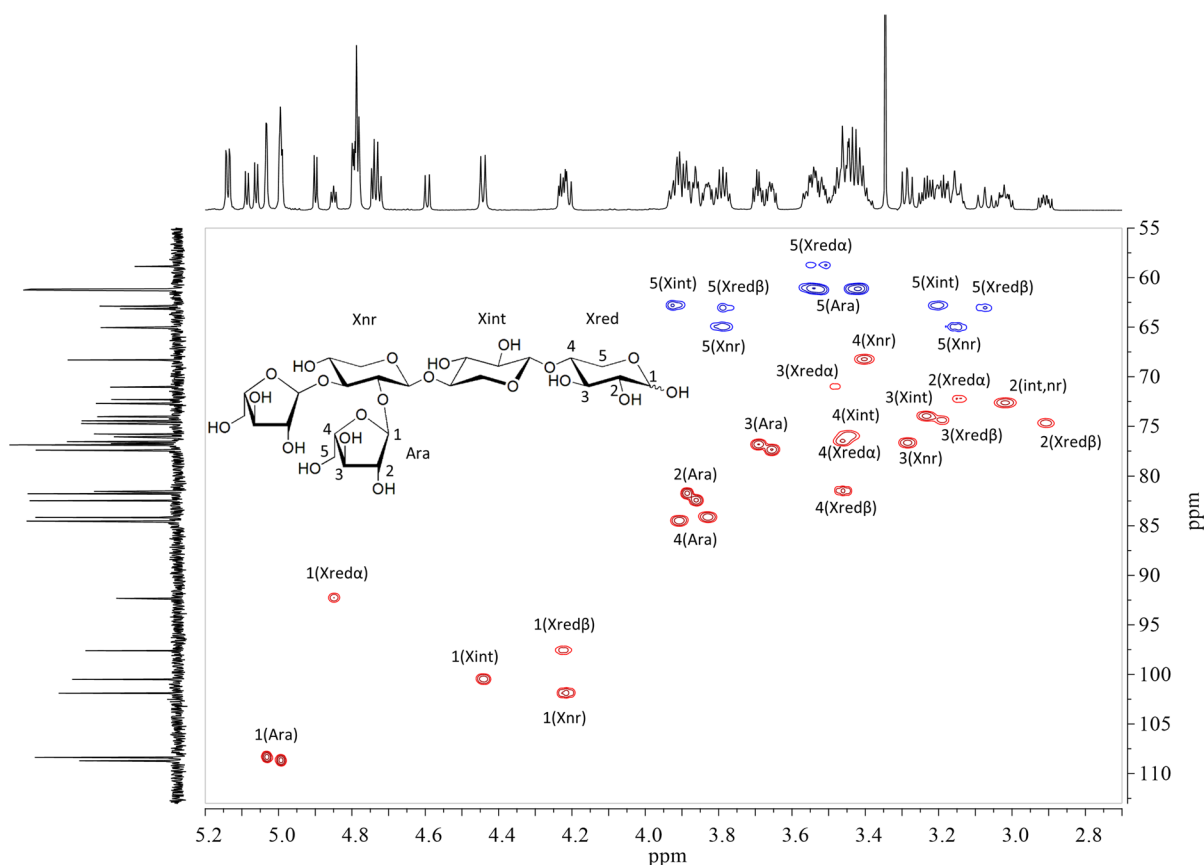


Fig. 1 HSQC-DEPT NMR spectrum (section) of 2³,3³-di- α -L-arabinofuranosyl-xylotriose (A^{2,3}XX) recorded in DMSO-d₆

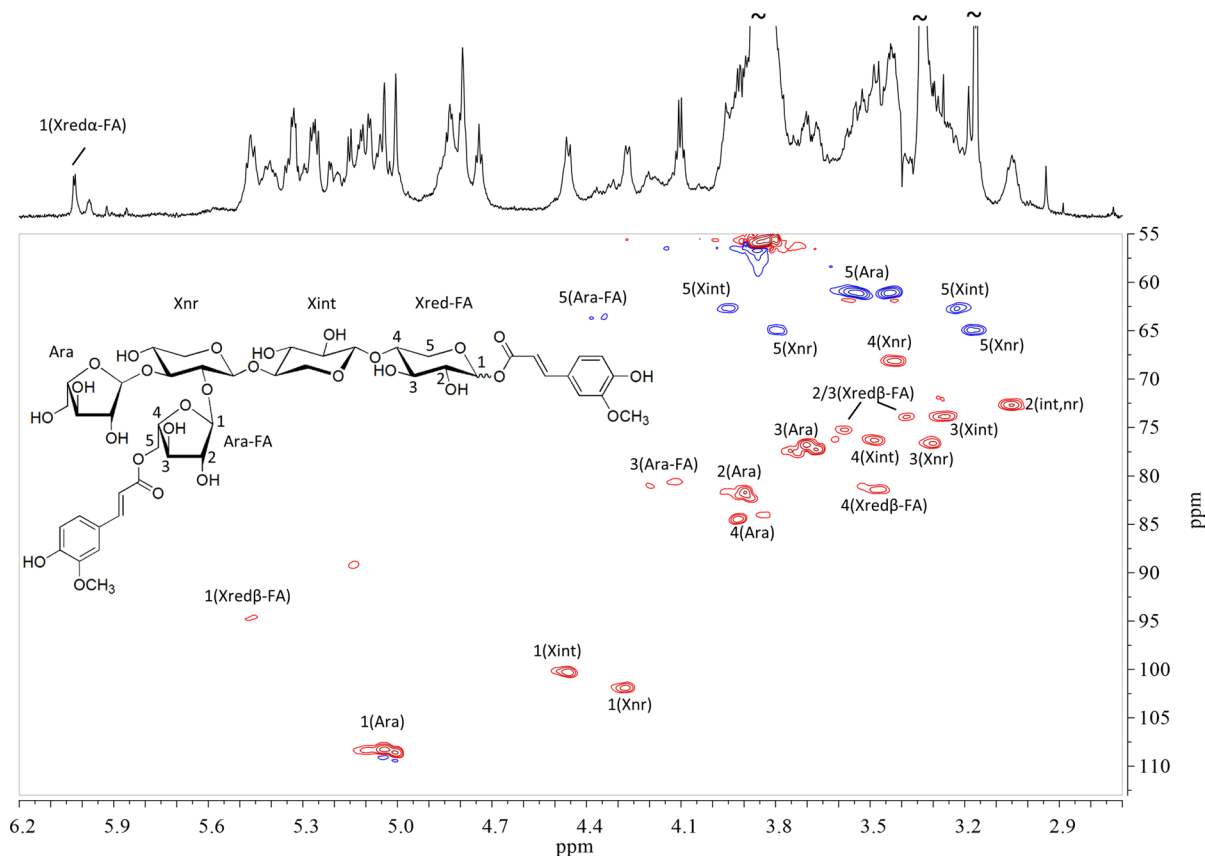


Fig. 2 HSQC-DEPT NMR spectrum (section) of feruoylated A^{2,3}XX recorded in DMSO-d₆

et al. 2020). In practice, we observed more β - than α -glycoside with a ratio of about 5:1 as determined from integral intensities of the ¹H NMR spectrum.

To conclude, a modification of the end group of low molecular weight xylan can be assumed, although it is not visible in the NMR spectra of arabinoxyxylan ferulates.

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Data availability Information or data are available on reasonable request from the corresponding author.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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