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Short Communications

Synthesis of the 3-Butenylglucosinolate Ion

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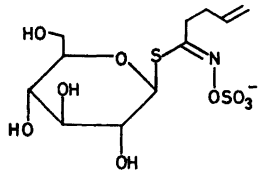
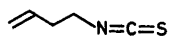
3-Butenylglucosinolate ion * (I), the accepted natural progenitor of 3-butenyl



(I)

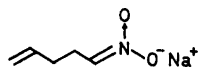


(II)

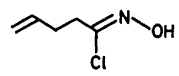
isothiocyanate (II), is rather widely distributed in species of Cruciferae,[2] notably within the important genus *Brassica* (*cf.* Ref. 3, and literature cited therein). We here report a chemical synthesis of the ion (I).

The employed procedure followed closely that described by Benn and Ettlinger for synthesis of the lower homologue, the allylglucosinolate ion, isolated, combined with potassium ion, as the classical glucoside sinigrin.[4]

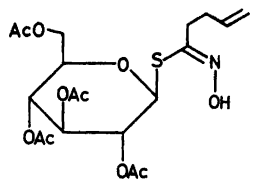
5-Bromo-1-pentene,[5] on treatment with sodium nitrite and urea in dimethyl sulphoxide,[6] afforded 5-nitro-1-pentene, the sodium salt of which, (III), was converted, by hydrochloric acid and lithium chloride,[4] into 4-pentenohydroxamoyl chloride (IV). Without purification, the latter was condensed with tetra-*O*-acetyl-1-thio-β-D-glucopyranose, following Benn's directions,[7] to give the crystalline *S*-(tetra-*O*-acetyl-β-D-glucopyranosyl-4-pentenothiohydroximic acid (V).



(III)



(IV)



(V)

Sulphonation of (V), with pyridine-sulphur trioxide complex in pyridine,[8] followed by treatment with potassium bicarbonate,[7] gave the crystalline potassium

* Frequently referred to as 'gluconapin', an ambiguous designation which should be abandoned, *cf.* Ref. 1.

O-tetraacetyl-3-butenylglucosinolate.* Finally, deacetylation with ammonia in methanol afforded the amorphous, hygroscopic potassium 3-butenylglucosinolate. Attempts to produce crystalline salts by cation exchange have thus far been unsuccessful.

On enzymatic hydrolysis with myrosin, the synthetic glucosinolate was readily cleaved to, *inter alia*, 3-butenyl isothiocyanate (II), identified by comparison of its ammonia addition product with authentic 1-(3-butenyl)-thiourea.[9]

*Experimental.*** *5-Nitro-1-pentene.* 5-Bromo-1-pentene [5] (70 g) was added to a solution of sodium nitrite (60.5 g) and urea (60 g) in dimethyl sulphoxide (600 g). The mildly exothermic process was controlled by slight cooling, and the solution was stirred for 6 h at room temperature. The orange-brown solution was then poured into water (1.5 l). The nitropentene was extracted with petroleum ether (b.p. 40–60°), the extract was dried over sodium sulphate, and the solvent was removed. Fractional distillation afforded the colourless 5-nitro-1-pentene (18.1 g), b.p. 82°/32 mm, n_D^{25} 1.4358, which proved homogeneous on VPC. The NMR-spectrum displayed the expected signals. (Found: C 52.14; H 7.81; N 11.92. Calc. for $C_5H_9NO_2$: C 52.16; H 7.88; N 12.17).

S-(*Tetra*-O-*acetyl-β*-D-*glucopyranosyl*)-*4-pentenothiohydroximic acid (V).* 5-Nitro-1-pentene (8.6 g, 75 mmoles) was dissolved in methanol (75 ml), containing sodium methoxide (70 mmoles). After 5 min, anhydrous ether (600 ml) was added, resulting in precipitation of the sodium salt (III).

The dried, finely ground salt (8.4 g) was stirred into a cooled solution (5–7°) of lithium chloride (20 g) in conc. hydrochloric acid (75 ml) in the course of 10 min. After stirring for an additional 10 min, the solution was poured into ice-cold water (1 l). The reaction mixture was extracted with methylene chloride, the extract was dried, and the solvent removed *in vacuo*.

The oily 4-pentenohydroxamoyl chloride (IV) (5.7 g) was dissolved in dry ether (500 ml), in which tetra-*O*-acetyl-1-thio-*β*-D-glucopyranose (9.2 g) was suspended. Addition of anhydrous triethylamine (6 g), dissolved in dry ether (50 ml), resulted in precipitation of triethylammonium chloride. After stirring for 30 min, the reaction mixture was poured into ice-cold 1 N sulphuric acid (300 ml). The ethereal phase was separated and combined with two further ether extracts. After drying, the ether was removed *in vacuo*. The residue, mainly consisting of crystals, was freed of some oily material by decanting, followed by two quick washes with small quantities of ethanol. After recrystallization from absolute ethanol, the thiohydroximic acid (V) (3.35 g), m.p. 150–152°, was obtained as fluffy, colourless needles. An analytical specimen, m.p. 155°, was produced by two additional recrystallizations from ethanol, $[\alpha]_D^{27}$ −14.2° (*c* 1.0, $CHCl_3$). (Found: C 49.50; H 5.94; N 2.87; S 6.98. Calc. for $C_{19}H_{27}NO_{10}S$: C 49.44; H 5.90; N 3.04; S 6.95). The NMR-spectrum was in agreement with the proposed structure.

Potassium O-*tetraacetyl-3-butenylglucosinolate.* The thiohydroximic acid (V) (2.3 g) was sulphonated with SO_3-pyridine complex (2.5 g) in dry pyridine (25 ml) by stirring overnight. Neutralization with potassium hydrogen carbonate (4 g) in water (20 ml) was followed by several extractions with ether, causing the acetylated potassium glucosinolate (1.45 g) to separate from the aqueous phase. Additional material was obtained by concentration of the aqueous phase in vacuum at 50°. The combined fractions were recrystallized from 95 % ethanol to give a colourless, crystalline product (2.3 g), m.p. 189° (decomp., after sintering from 165°). Two additional recrystallizations from 95 % ethanol afforded an analytical specimen, m.p. 189° (decomp., sintering from 165°), $[\alpha]_D^{27}$ −17.1° (*c* 1.3, H_2O). (Found C 38.90; H 4.50; N 2.35; S 11.02. Calc. for $C_{19}H_{26}NO_{13}S_2K$: C 39.37; H 4.52; N 2.42; S 11.06). The complex NMR-spectrum displayed the expected signals.

Potassium 3-butenylglucosinolate. A solution of the above tetraacetate (1.0 g) in methanol (50 ml), saturated with ammonia, was left overnight in the refrigerator. After evaporation, the residue was triturated with two 20 ml portions of ether which were discarded. Attempted crystallizations from 95 % ethanol were unsuccessful. A sample was triturated with anhydrous ethanol and subjected to prolonged drying at room temperature over P_2O_5 in vacuum to give a highly hygroscopic, amorphous solid, m.p. 125° (closed capillary, sintering from 100°), $[\alpha]_D^{25}$ −23.5° (*c* 1.8, H_2O) (Found: C 31.61; H 4.67; N 3.27; S 14.95. Calc.

* A new compound in literature. However, a potassium glucosinolate tetraacetate, isolated from seeds of *Brassica campestris* L. var. sarson Prain by Mr. H. M. Tsay, while working in the laboratory of Professor F. W. Hougen, University of Manitoba, Canada, has been established here as acetylated potassium 3-butenylglucosinolate on critical comparison with the synthetic specimen.

** Melting points are uncorrected and determined in an electrically heated oil bath.

for $C_{11}H_{18}NO_9S_2K$: C 32.11; H 4.41; N 3.40; S 15.59).

Enzymatic hydrolysis. The synthetic potassium 3-butenylglucosinolate (136 mg), dissolved in a citrate buffer (pH 6.4) (3 ml), was subjected to enzymatic hydrolysis by adding a myrosinase solution (0.5 ml). Next day, the solution was extracted with ether. Ammonia-saturated methanol (0.5 ml) was added to the dried ether extract. After standing overnight, the solvents were removed, and the oily residue was purified by silica gel chromatography, with ethyl acetate as the eluting solvent. The thiourea-containing fractions were combined and concentrated to dryness. Upon recrystallization from water, colourless needles (6 mg) separated, m.p. 65°. They were identified as 1-(3-butenyl)-thiourea by comparison with an authentic specimen [9] (undepressed mixed melting point and coinciding IR-spectra).

The authors are indebted to Professor F. W. Hougen for a sample of potassium *O*-tetra-acetyl-3-butenylglucosinolate of natural origin.

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A Note Concerning the NMR-Spectra of *cis*- and *trans*-1-Benzylsulfinyl-1-phenyl-1-propen-2,3-dicarboxylic Acid

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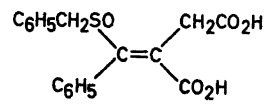
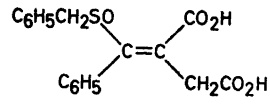
During the last few years much interest has been devoted to the study of proton magnetic non-equivalence originating from an adjacent asymmetric atom [1,2] and it has been possible to demonstrate, by means of NMR-technique, a kinetic non-equivalence of diastereotopic methylene protons upon hydrogen exchange and to get information about the stereochemistry of transient asymmetric carbanions.[3–6] Rather few examples of magnetically non-equivalent methylene protons located a great distance from the asymmetric atom can be found,[7] however, and we will therefore make a contribution to this field by briefly reporting the synthesis and NMR-spectra of *cis*- and *trans*-II.



cis-II



trans-II

The acids were prepared according to the synthetic route on p. 3327.

In Table 1 the NMR-signals and their assignments to the various protons in IIa and IIb are given. It is found for each compound that both methylene groups appear as AB-quartets. We believe this is the first example of a long-range effect of a sulfoxide group giving rise to magnetic non-equivalence of methylene protons at such a great distance. Previously, how-