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AN IMPROVED METHOD FOR THE CONVERSION OF SACCHARIDES INTO FURFURAL DERIVATIVES

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An improved method for the preparation of furan compounds by dehydrating saccharides with hydrochloric acid either in a mixture containing water, organic solvent and a catalytic amount of a surface active agent or in the presence of magnesium halide is described.

The 5-substituted furfural derivatives have potential versatility as a starting material especially for agricultural chemicals$^{1)}$ and can be obtained by dehydrating saccharides with mineral or organic acids.$^{2), 3)}$ However the yields are generally low (21- 40 %) and the operations are rather troublesome by gelation and resinification (formation of condensation products such as humins). Recently reported$^{4)}$ conversion of D-(-)-fructose to 5-chloromethyl-2-furaldehyde (CFAL) is impractical because of the use of large amount of hazardous solvent and the necessity of high-speed stirring. In this communication, we describe a new and improved practical method for preparing useful furfural derivatives.

When the conversion of saccharides with hydrochloric acid into furfural derivatives is carried out in a mixture containing water, inert organic solvent (e.g., toluene, carbon tetrachloride) and a catalytic amount of a surface active agent (e.g., cationic or anionic agent may be used alone or in combination), desired furfural derivatives can be prepared in a relatively high yield and with high purity.$^{5)}$ The present method well overcome the drawbacks of so far known syntheses and undesired hydrolysis of the product was prevented by the formation of micelle-like condition during the course of reaction. Pentoses (e.g., xylose) and methylpentoses (e.g., rhamnose) can be converted to furfural and 5-methyl-2-furaldehyde (MFAL) respectively. CFAL can be prepared from ketohexoses (e.g., fructose, sorbose), aldohexoses (e.g., glucose) and disaccharides (e.g., saccharose) (Table 1).

In a typical run, D-(-)-fructose, conc. hydrochloric acid and catalytic amount of a cationic surface active agent were mixed and stirred at 20°C for 2 h ("pre-reaction solution"). The "pre-reaction solution" was added dropwise to an inert organic solvent, such as toluene, maintained at 80°C in about 30 min with stirring and the stirring was continued for 10 min at the same temperature. After the temperature of the solution was allowed to drop to room temperature under continuous stirring (1-2 h), a small amount of water and active charcoal were added and the mixture was stood under stirring. The organic layer separated after filtration was washed with saturated aqueous NaCl solution, dried over anhydrous sodium sulfate and concentrated. The purity of CFAL over 95 % was easily insured by adding small amount of active charcoal to the anhydrous organic layer, being followed by filtration through a Celite bed and concentration of the solvent.

Table 1. Conversion of saccharides into furan compounds

saccharide	acid	reaction condition	surfactant[b]	product	yield (%) (isolated)
D-(-)-fructose	35% HCl(4 equiv.)	toluene[a], 60-85°C	A or B[b]	CFAL	60-65 [c]
Saccharose	35% HCl(4 equiv.)	toluene, 50-80°C	B	CFAL	50-55
L-rhamnose	35% HCl(4 equiv.) or 70% H_2SO_4(4-6 equiv.)	carbon tetrachloride 40-70°C	A	MFAL	45-50
High Fructose Syrup (solid 75.8%, fructose 90.0%)	35% HCl(4 equiv.)	toluene, 80-85°C	B	CFAL	55-60

a) saccharide/conc.HCl/toluene=1.0/2.5/3.5 by weight ratio

b) surfactant, 0.2-0.5 wt.% of saccharide. A,$C_{12}H_{25}C_6H_4SO_3Na/C_{16}H_{33}(CH_3)_3NCl$(1/1)
B,$C_{12}H_{25}N(CH_3)_3Cl$

c) purity, 95% up/GC analysis (LAC/2R446-H_3PO_4, 2 m)

Among the additives investigated, such as inorganic or organic acid salts of alkali metal, alkaline earth metal and aluminum, magnesium halides were found to be most effective for the conversion of D-(-)-fructose to the corresponding furfural derivatives. In a typical run, a paste prepared from 18 g of D-(-)-fructose and 2.2 g of water, 20.4 g of $MgCl_2 \cdot 6H_2O$ were added to 250 ml of toluene with stirring at 75°C, being followed by stirring for 30 min. Then 31.4 g of conc. hydrochloric acid (3 mol equivalent for D-(-)-fructose) was added to this solution in 5 min and stirred for another 1 h at 75°C. After the solution cooled to room temperature under continuous stirring, the same operation as in the method with a surface active agent was followed to give 80 % yield of CFAL without any difficulty in isolation. The present method offers a new and advantageous direct synthesis of CFAL from a carbohydrate starting material compared with a method starting from furfuryl alcohol through several steps.[6] 5-Bromomethyl-2-furaldehyde can be obtained by use of conc. sulfuric acid and $MgBr_2 \cdot 6H_2O$. The yield of corresponding 5-halomethyl-2-furaldehyde was increased by 10 % in average using equimolar amount of a magnesium halide for D-(-)-fructose.

The effect of magnesium halides can be at least partly explained by the increased amount of the furanose form of D-(-)-fructose as indicated by 200 MHz ^1H-NMR[7] and 50 MHz ^{13}C-NMR[8] study of the corresponding system. The furanose form, which is expected to be important for the formation of furan compounds, seems to have a more favorable interaction with magnesium (II) ion ("sugar-cation complex")[7] than the corresponding pyranose form does.

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