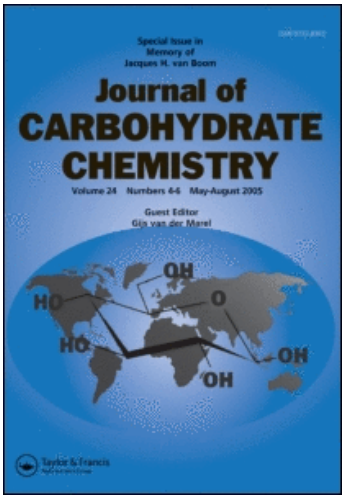


Journal of Carbohydrate Chemistry

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713617200

The Selective Formose Reaction in Dimethylformamide in the Presence of Vitamin B_1

Yoshihiro Shigemasa[a]; Hideki Matsumoto[a]; Yoshihiro Sasaki[a]; Nasuo Ueda[a]; Ruka Nakashima[a]; Ken-Ichi Harada[b]; Naohito Takeda[b]; Makoto Suzuki[c]

[a] Department of Industrial Chemistry, Faculty of Engineering, Tottori University, Tottori, Japan [b] Faculty of Pharmacy, Meijo University, Nagoya, Japan Seiki Saito [c] Department of Synthetic Chemistry, School of Engineering, Okayama University, Okayama, Japan

To cite this Article Shigemasa, Yoshihiro , Matsumoto, Hideki , Sasaki, Yoshihiro , Ueda, Nasuo , Nakashima, Ruka , Harada, Ken-Ichi , Takeda, Naohito and Suzuki, Makoto(1983) 'The Selective Formose Reaction in Dimethylformamide in the Presence of Vitamin B_1', Journal of Carbohydrate Chemistry, 2: 3, 343 — 348

To link to this Article: DOI: 10.1080/07328308308057879

URL: http://dx.doi.org/10.1080/07328308308057879

J. CARBOHYDRATE CHEMISTRY, 2(3), 343-348 (1983)

Communication

THE SELECTIVE FORMOSE REACTION IN DIMETHYLFORMAMIDE IN THE PRESENCE OF VITAMIN B_1 +

Yoshihiro Shigemasa*, Hideki Matsumoto, Yoshihiro Sasaki, Nasuo Ueda and Ruka Nakashima

Department of Industrial Chemistry, Faculty of Engineering, Tottori University, Tottori 680, Japan

Ken-ichi Harada, Naohito Takeda, and Makoto Suzuki

Faculty of Pharmacy, Meijo University, Nagoya 468, Japan

Seiki Saito

Department of Synthetic Chemistry, School of Engineering, Okayama University, Okayama 700, Japan

Received July 20, 1983

The formose which was obtained from formaldehyde in the presence of base was a mixture of sugars and sugar alcohols containing over 30 components. The formose reaction has drawn much attention for 122 years from several standpoints; the chemical synthesis of edible carbohydrates from C_1 compounds, an important process in the recycling of carbon sources during sustained space flights, and as a model for the prebiotic synthesis of monosaccharides. Nevertheless, because of the complexity of this product mixture (Fig. 1b), the formose reaction has not been completely elucidated and the product (so called formose) has not been useful yet. During the long formose history few products were isolated from the formose mixture and identified, except in work from our laboratories.

+Formose Reactions. Part 20. For Part 19, see ref. 1.

 0732-8303/83/0203-0343$3.50/0

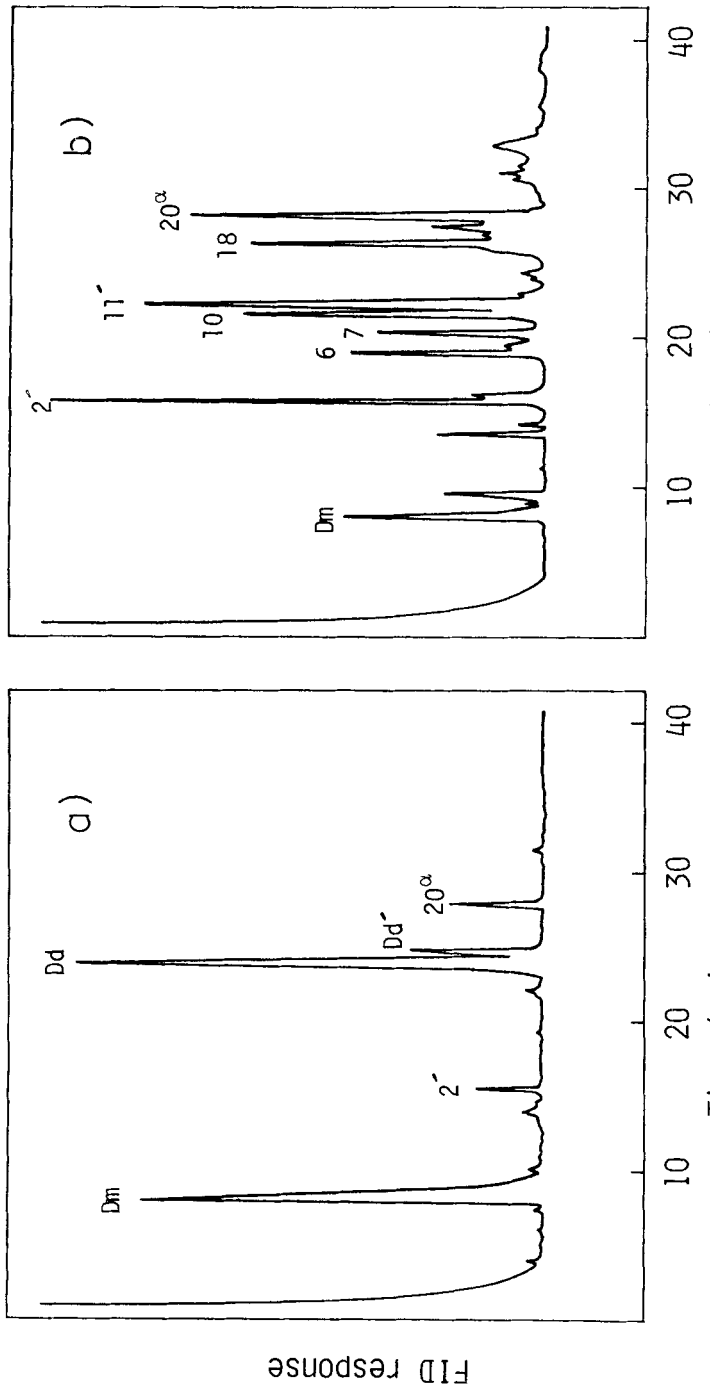


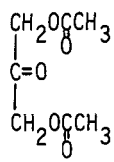
Fig. 1 The glc patterns of trimethylsilylated products from: (a) the selective formose reaction for 180 min starting from [HCHO]=1.1M, [N,N-dimethylaminoethanol]=0.1M, [vitamin B_1-HCl]=0.028M and DMF=180ml at 60°C, and (b) non-selective formose reaction for 5 min starting from [HCHO]=1.1M, [$Ca(OH)_2$]=0.11M, [vitamin B_1-HCl]=0.028M and DMF=180ml at 100°C.

In a series of our studies[2-7] concerned with the formose reaction, some selective formose reactions in H_2O or methanol which lead to 2-C-(hydroxymethyl)glycerol (2-HG), 3-C-(hydroxymethyl)pentitol (3-HP), 2,4-bis(hydroxymethyl)pentitol (2,4-BHP), pentaerythritol (PE), 2,4-bis(hydroxymethyl)-3-pentulose (2,4-BH-3-P), 3-C-(hydroxymethyl)pentofuranose (3-HPF), or 3,3-bis(hydroxymethyl)-3-deoxy-furanorono-1,4-lactone (3,3-BH-3-DF-1,4-L) have been found and these products were isolated in a pure form. On the other hand, glucose,[8] 2-HG,[9] PE,[9] ethylene glycol,[10] glycolaldehyde,[11] 3-ketopentulose,[12] or glyceraldehyde[13] were reported to form selectively in the formose reaction using H_2O or methanol as a solvent, although these compounds except 2-HG[9] and PE[9] were not isolated in a pure form. J.Castells et al.[14] have reported that, if the reaction was quenched after 15 min, the formose reaction in dimethylformamide (DMF) at 100 ℃ led to a very simple mixture in which the main component was glyceraldehyde dimer. Therefore, we have studied the catalytic effect of various bases on the formose reaction in DMF and now found out that dihydroxyacetone (DHA) is formed selectively in the presence of N,N-dimethylaminoethanol and vitamin B_1. The role of vitamin B_1 in the present system seems noteworthy: in the absence of vitamin B_1, formaldehyde vaporized and a self-condensation of vaporized formaldehyde to paraformaldehyde took place very readily under the given reaction conditions. In the presence of vitamin B_1, however, such reaction was suppressed sufficiently for the formose reaction in DMF to occur very smoothly. A product derived from vitamin B_1 was also isolated and assigned to 2-(1,2-dihydroxyethyl)-5-(2-hydroxyethyl)-4-methylthiazole on the basis of spectroscopic data.

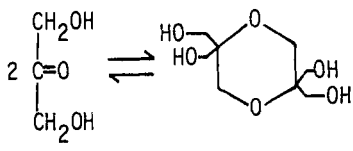
In a typical experiment, the reaction was conducted with paraformaldehyde (Merck Co., 6.3 g) in 180 mL DMF in the presence of N,N-dimethylaminoethanol (1.8 g) and vitamin B_1-HCl (1.7 g) under nitrogen for 180 min at 60 °C. At convenient intervals, 5 mL aliquots were withdrawn into a 10 mL flask, and the reaction was quenched

immediately by acidification with 9N HCl. These aliquots were analyzed for formaldehyde following the method of Bricker et al.,[15] except that the optical density was measured at 579 nm. The product distribution as pertrimethylsilylated products was determined by gas-liquid chromatography. The glc pattern (Fig. 1a) clearly indicates the selective formation (90 %) of the product corresponding to the peaks Dm, Dd, and Dd', the retention time of which is the same as that of pertrimethylsilylated dihydroxyacetone. Furthermore, the glc analysis of peracetylated products indicated one major peak in the same manner as authentic dihydroxyacetone.

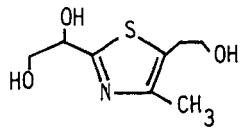
The product corresponding to glc peaks Dm, Dd, and Dd' was isolated as follows: the formose syrup (6.5 g) obtained by the above reaction was acetylated with acetic anhydride in pyridine, and the reaction mixture was poured into ice water. The acetylated product was extracted with chloroform, the extract was concentrated, and extracted with water. Then, the water layer was concentrated and active carbon was added into the concentrated solution. The product 1 (2.6 g,hygroscopic) was obtained as a yellow crystalline form by eluting the active carbon with methanol, followed by concentrating the methanol solution. The ^{1}H-NMR spectrum showed six equivalent $-CH_3$ protons and four equivalent $-CH_2O-$ protons. The molecular ion was observed at m/z 174 in the electron impact mass spectrum. The IR spectrum was in fair agreement with that of authentic sample of acetylated dihydroxyacetone. These results led us to assign the structure 1 (1,3-di-O-acetyl dihydroxyacetone) for the product 1.



1



2



3

Deacetylation of the product 1 with barium hydroxide gave again the original product, and the trimethylsilyl derivative

showed exactly the same glc behaviour as that for the directly trimethylsilylated product. The product corresponding to peaks Dm, Dd, and Dd', therefore, was assigned as a mixture of dihydroxyacetone monomer and its diasteroisomeric dimers 2.

The product 3 (40 mg, colorless syrup) corresponding to glc peak 20^{α} was also isolated by chromatography on an active carbon column with water and methanol as the eluent, followed by purification of the acetyl derivative of 20^{α} with thin layer chromatography (Bz/EtOAc=1/1). The ^{13}C-NMR spectrum showed a methyl carbon, three CH_3 carbons of acetyl group, three CH_2 carbons, a CH, a =C<, a $=C\lesssim^{N}$, a $=C\lesssim^{N}_{S}$, and three carbonyl carbons. The chemical ionization mass spectra using i-C_4H_{10}, NH_3, or ND_3 as a reagent gas[16] showed quasi-molecular ion at m/z 330(MH^+), 347 ($M{\cdot}NH_4^+$), or 351 ($M{\cdot}ND_4^+$), respectively, which precisely indicated the molecular weight of 329. These results suggested that the acetate of the product 3 had no active hydrogen in the molecule. Deacetylation of the acetate with barium hydroxide gave product 3 as a colorless syrup. Its ^{13}C-NMR[17] showed a CH_3, three CH_2, a CH, a =C<, a $=C\lesssim^{N}$, and a $=C\lesssim^{N}_{S}$ carbon. The chemical ionization mass spectra using i-C_4H_{10}, NH_3, or ND_3 as a reagent gas showed quasi-molecular ion at m/z 204 (MH^+), 221 ($M{\cdot}NH_4^+$), or 228 ($d_3M{\cdot}ND_4^+$), respectively, which precisely indicated the molecular weight of 203 and the presence of three active hydrogens in the molecule. Above results and ^{1}H-NMR spectrum[18] of the product corresponding to 20^{α} led us to assign 2-(1,2-dihydroxyethyl)-5-(2-hydroxyethyl)-4-methylthiazole as a product derived from vitamin B_1.

REFERENCES AND FOOTNOTES

1. Y. Shigemasa, N. Ueda, and R. Nakashima, J. Syn. Org. Chem. Jpn., in press.

2. Y. Shigemasa, K. Oogaki, N. Ueda, R. Nakashima, K. Harada, N. Takeda, M. Suzuki, and S. Saito, J. Carbohydr. Chem., 1, 325 (1983).

3. Y. Shigemasa, O. Nagae, C. Sakazawa, R. Nakashima, and T. Matsuura, J. Am. Chem. Soc., 100, 1309 (1978).

4. Y. Shigemasa, Y. Matsuda, C. Sakazawa, and T. Matsuura, Bull. Chem. Soc. Jpn., 50, 222 (1977).

5. Y. Shigemasa, S. Akagi, R. Nakashima, and S. Saito, Carbohydr. Res., 80, C1 (1980).

6. Y. Shigemasa, T. Hamada, M. Hirabayashi, E. Waki, R. Nakashima, K. Harada, N. Takeda, and M. Suzuki, Chem. Lett., 1981, 899.

7. Y. Shigemasa, M. Kawahara, C. Sakazawa, R. Nakashima, and T. Matsuura, J. Catal. 62, 107 (1980).

8. V. A. Likholobov, A. H. Weiss, and M. M. Sakharov, React. Kinet. Catal. Lett., 8, 155 (1978).

9. T. Matsumoto and S. Inoue, J. Chem. Soc. Perkin Trans 1, 1982, 1975; Chem. Lett., 1980, 839.

10. S. Trigerman, E. Biron and A. H. Weiss, React. Kinet. Catal. Lett., 6, 269 (1977).

11. N. W. Gabel and C. Ponnamperuma, Nature, 216, 453 (1967).

12. P. Decker, Proceeding 2nd ISSOL Meeting and 5th ICOL, Kyoto, April 1977.

13. A. H. Weiss, Kinetika Kataliz, 18, 539 (1977).

14. J. Castells, F. Geijo, and F. Lopez-Calahorra, Tetrahedron Lett., 21, 5417 (1980).

15. C. E. Bricker and H. R. Johnson, Ind. Eng. Chem., 17, 400 (1945).

16. M. Suzuki, K. Harada, N. Takeda, and A. Tatematsu, Biochemical Mass Spectrometry, 81, 332 (1981).

17. ^{13}C NMR (CD_3OD) (chemical shifts given in parts per million from Me_4Si and the multiplicities based on an off-resonance spectrum and number of carbon are given in parenthesis): 14.7(q, 1), 30.5(t, 1), 63.1(t, 1), 67.4(t, 1), 73.5(d, 1), 129.8(s, 1), 148.9(s, 1), 171.8(s, 1).

18. ^{1}H NMR (CD_3OD; internal standard, Me_4Si): δ(ppm) 2.29(s, 3H, $-CH_3$), 2.90 and 3.69(two t, 4H, $-CH_2-$), 3.74(d, 2H, $-CH_2OH$), 3.83(t, 1H, $-CH_2CHOH$).