Carbohydrate Research, 71 (1979) 339–343

Note

Some *N*-arylidenechitosan gels*

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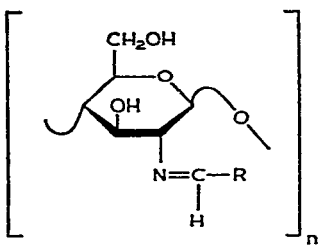
(Received May 5th, 1978, accepted for publication, June 13th, 1978)

N-Acylchitosan gels have been prepared at room temperature by *N*-acylation of chitosan, a (1→4)-2-amino-2-deoxy-β-D-glucan, with carboxylic anhydrides in aqueous acetic acid–methanol[2,3]. Another novel group of gels can be formed from chitosan and aldehydes[1].

Nud'ga *et al.*[4] reported that the amino groups of chitosan react with 2-hydroxybenzaldehyde to give the Schiff-base derivatives (d.s. 1.0), but only a few amino groups of chitosan reacted with benzaldehyde and its 4-methoxy and 2-nitro derivatives. Some enzymes have been immobilised with glutaraldehyde on chitin[5–8] and chitosan[9,10].

We now report in more detail[1] on gels (**1**) formed from chitosan and arylaldehydes. These gels are important as polymer supports for organic synthesis using the phenolic hydroxyl groups, for use in affinity and gel chromatography, and as model compounds for the study of pigments linked to chitin by the Schiff base present in crab shells.



1 R = phenyl or substituted phenyl

Gels were produced by treatment of chitosan with 4 mol or more of benzaldehyde per hexosaminyl residue (see Table I for yields and analytical data). Gels formed within a few seconds at ~28°, and within a few minutes at ~4°, after the addition of benzaldehyde. Gels formed at ~19° within ~5, ~15, and ~30 min

*A preliminary report appeared in Ref. 1.

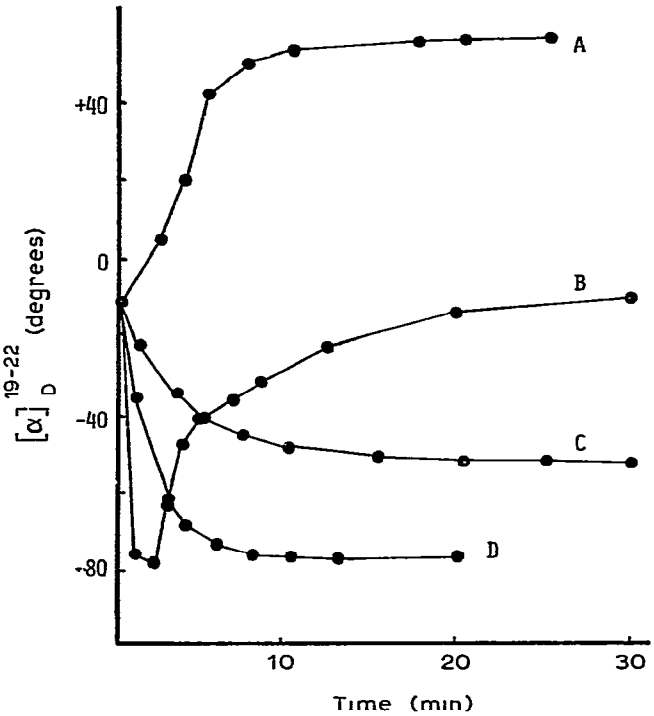


Fig 1 Changes in the specific rotation of chitosan in 10% acetic acid–methanol during Schiff-base formation with 3-methylbenzaldehyde (A), benzaldehyde (B), 3,4-dimethoxybenzaldehyde (C), and 4-hydroxybenzaldehyde (D)

TABLE I

DATA FOR THE REACTION OF BENZALDEHYDE WITH CHITOSAN

Benzaldehyde added (mol /GlcN residue)	*Gelation*[a]	*Dried products*		
		Yield (%)	*C/N (mol)*[b]	*D s*[c]
0 8	—	74	n d	n d
4 0	+	92	12 20	0 94
8 0	+	93	12 85	0 99
16	+	94	12 70	0 97
56	+	92	13 00	1 00

[a]Key —, no gels formed, +, gels formed [b]Calculated from the elemental analytical data, C/N = 13 00 corresponds to d s = 1 00 [c]Degree of substitution (see footnote *a* in Table II)

with 2-, 3-, and 4-substituted benzaldehydes, respectively The variety of $[\alpha]_D$ changes during Schiff-base formation and gelation is shown in Fig 1. These changes may be due to conformational differences of the *N*-arylidenechitosan molecules in the gels, and this aspect is under investigation

The gels thus prepared were transparent or semi-transparent, colourless or

TABLE II

DATA FOR SOME *N*-ARYLIDENECHITOSAN GELS

Arylidene group	*Yield (%)*	*D.S.*[a]	*Formula*[b]	*Calc (%)*			*Found (%)*		
				C	*H*	*N*	*C*	*H*	*N*
Benzylidene	94	1.00	$C_{13}H_{15}NO_4 \cdot 0.75H_2O$	59.45	6.28	5.33	59.58	6.25	5.49
2-Hydroxy	98	1.00	$C_{13}H_{15}NO_5 \cdot 0.52H_2O$	56.85	5.89	5.10	57.06	5.69	4.84
3-Hydroxy	50	0.76	$C_6H_9NO(C_7H_8O_6)_{0.76}(C_2H_6O_2)_{0.24} \cdot 0.40H_2O$	54.11	6.08	5.35	54.31	6.45	5.38
4-Hydroxy	86	0.84	$C_6H_9NO_4(C_7H_6O)_{0.84}(C_2H_6O_2)_{0.16} \cdot 0.31H_2O$	55.54	5.97	5.31	55.54	5.87	5.32
2-Nitro	79	1.00	$C_{13}H_{14}N_2O_6 \cdot 0.29H_2O$	52.14	4.92	9.35	52.14	5.01	9.21
3-Nitro	85	1.00	$C_{13}H_{11}N_2O_6$	53.06	4.80	9.52	53.38	5.12	9.18
4-Nitro	80	1.00	$C_{13}H_{14}N_2O_6 \cdot 0.11H_2O$	52.71	4.83	9.45	52.96	4.99	9.31
2-Methyl	80	0.84	$C_6H_9NO_4(C_8H_8)_{0.84}(C_2H_6O_2)_{0.16}$	61.04	6.57	5.46	61.12	6.60	5.46
3-Methyl	75	0.80	$C_6H_9NO_4(C_8H_8)_{0.80}(C_2H_6O_2)_{0.20}$	59.47	6.63	5.42	59.41	6.82	5.58
4-Methyl	95	0.82	$C_6H_9NO_4(C_8H_8)_{0.82}(C_2H_6O_2)_{0.18} \cdot 0.20H_2O$	59.67	6.64	5.39	59.82	6.79	5.59
2-Chloro	81	1.00	$C_{13}H_{14}NO_4Cl \cdot 0.52H_2O$	53.13	5.20	4.77	53.14	5.18	4.94
3-Chloro	78	1.00	$C_{13}H_{14}NO_4Cl \cdot 0.39H_2O$	53.70	5.13	4.82	53.91	5.05	4.74
4-Chloro	95	1.00	$C_{13}H_{14}NO_4Cl \cdot 0.52H_2O$	53.27	5.24	4.78	53.27	5.08	4.83
4-Fluoro	58	0.82	$C_6H_9NO_4(C_7H_5F)_{0.82}(C_2H_6O_2)_{0.18}$	54.78	5.95	5.28	54.53	6.09	5.55
3,4-Dimethoxy	85	1.00	$C_{15}H_{19}NO_6 \cdot 0.54H_2O$	56.46	6.36	4.39	56.74	6.34	4.39

[a]Degree of substitution, the value is based on the elemental analyses, as shown in the formula [b]The repeating unit is shown

slightly yellow to brown, and contained 1–3% of *N*-arylidenechitosans, the remainder being solvent. The gels did not melt on heating at 200° for 10 min The dried xerogels, which were gelatinous, hygroscopic, slightly coloured, and isolable in yields of 50–100%, began to decompose at 240–260°, and the decomposition temperature was little influenced by the structure of the *N*-substituents They were insoluble and stable in cold and boiling water, alkali, methyl sulphoxide, formamide, and other organic solvents, and were unchanged on soaking in 2M NaOH at room temperature for 24 h, but were degraded easily in 0 5M HCl within a few hours or in 10% acetic acid within 24 h Chitosan hydrochloride, or hydroacetate, and aldehyde were detected in the reaction mixture (see Experimental) The dried xerogels had ν_{max}^{KBr} 1650–1640 (C=N of the Schiff base), 1600 (phenyl), and 900–650 cm^{-1} (substituted phenyl) The elemental analyses (Table II) agreed with the Schiff-base structure and a d s of 1 00. A few derivatives contained 0 16–0 20 mol of $-N^+H_3AcO^-$ groups, as reflected by the elemental analyses and by the weak i r bands at 1560 and 1410 cm^{-1} It is not known whether these groups reflect sterically hindered amino groups or arise by degradation of the Schiff base with aqueous acetic acid during the isolation *N*-Arylidenechitosan gels were rigid, but the gels containing $-N^+H_3AcO^-$ groups were soft. The ultrastructure of the xerogels was microporous and polyphasic, and resembled that of chitin gels[11]

It is concluded that the gels described herein consist of small droplets of solvents and polyphasic micropores produced from *N*-arylidenechitosan chains by way of membrane formation[12] The heat stability of the gel may be due to this ultrastructure

EXPERIMENTAL

Materials and methods — Chitosan, $[\alpha]_D^{17}$ −10 5° (*c* 1 3, 10% acetic acid), was prepared[3] from chitin (crab shells) by *N*-deacetylation with 40% NaOH in the presence of 0 01% of $NaBH_4$ The p m r. spectrum (D_2O–DCO_2D, 10 1) of the product contained no signals for NAc at δ ~2, and no i r. absorptions at ~1650 and ~1550 cm^{-1} (C=O and NH of NAc)

The other methods have been described previously[13]

Preparation of N-*arylidenechitosan gels* — Chitosan (0 25 g) was dissolved in 1–10% aqueous acetic acid (10 ml) at room temperature to afford a viscous solution which was diluted with methanol (10 ml) and treated with a solution of an aryl-aldehyde (4–8 mol) in methanol (10 ml) The mixture, when stored at room temperature overnight, solidified to afford a gel (13–15 g) The gels were fragmented, and suspended in methanol (100 ml) at room temperature for 24 h. The process was repeated several times with fresh methanol to remove acetic acid and aldehyde The gels were collected by centrifugation, suspended in ethanol (100 ml) and then in ether (100 ml), collected, washed with ether, and dried over P_2O_5 at 100° for 5 h *in vacuo*.

Reaction of N-*benzylidenechitosan with acid.* — A suspension of dry *N*-benzylidenechitosan (0 4 g) in 0 5M HCl (20 ml) was stored at room temperature overnight

to give a clear solution which was then treated with ethanol (60 ml). The mixture was stored at room temperature overnight, and the precipitate was collected by centrifugation, washed with ether, and dried over P_2O_5 at 100° for 5 h *in vacuo* to give chitosan hydrochloride (293 mg, 92%), ν_{max}^{KBr} 3400 (OH, NH), 2050, 1630, 1520 ($N^+H_3Cl^-$), 1140–1000 (C–O), and 900 cm^{-1} (β-D-glycoside)

The i r. spectrum was identical with that of an authentic sample prepared from chitosan by dissolution in 0 5M HCl and isolation as described above

Changes in $[\alpha]_D$ *during gelation* — To a solution of chitosan (25 mg) in 10% acetic acid (0 5 ml) in a 1-cm cell was added a methanolic solution (2 ml) of 8 mol of an arylaldehyde The changes in $[\alpha]_D$ are shown in Fig 1

ACKNOWLEDGMENTS

This work was supported by research grants from the Iwatani Naoji, Naito, and Sanyohoso Foundations

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