

Polysaccharide B-1459: A New Hydrocolloid Polyelectrolyte Produced from Glucose by Bacterial Fermentation*

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INTRODUCTION

Each of the many polysaccharides values industrially as a hydrocolloid owes its specific usefulness to its own characteristic physical and chemical constitution. In some cases disadvantages and limitations of usefulness of these plant-derived materials may result from other aspects of inherent properties, as well as from variability in quality and from economic factors involved with any import. In use areas where plant gums and mucilages do not satisfy industrial requirements, opportunities exist for new products of domestic origin having novel combinations of properties and controlled quality.

Our research objective was to meet such needs through discovery and development of "polysaccoloids"¹ obtainable by microbial transformation of sugars derived from cereal starches. The polymeric products we obtained differ fundamentally from starch in composition, properties, and structure. The first product of our program was a phosphomannan synthesized by the yeast *Hansenula holstii* NRRL Y-2488.²

Reported here are the composition and properties of our second product, a heteropolysaccharide produced from glucose by the plant pathogen *Xanthomonas campestris* NRRL B-1459.

The major components of this bacterial polysaccharide are D-mannose, D-glucose, and D-gluconic acid (as the potassium salt). Also present is about 5% of acetyl groups. Details on the identification, proportion, and structural arrangement of these components are reported elsewhere.³ We have worked mainly with the potassium salt of the polysaccharide for experimental convenience; however, the sodium salt has the same properties.

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Previous investigations have not been concerned with practical utility, but with polysaccharide production (from *Xanthomonas* species)⁴ and characterization (from *X. phaseoli*).⁵

EXPERIMENTAL

Production and Laboratory Purification of Native Polysaccharide B-1459

This polysaccharide is produced by culturing *X. campestris* NRRL B-1459 on a well-aerated medium containing commercial glucose, organic nitrogen sources, dipotassium hydrogen phosphate, and appropriate trace elements.⁶ When fermentation was finished, the culture fluids had a viscosity as high as 17,000 centipoises; they appeared homogeneous and had very short flow characteristics. The purification procedure described resulted in a product suitable for compositional and structural analysis; more practical procedures have been reported by others.⁶

The culture fluid was diluted with 2.5 volumes of water; then potassium chloride, ethanol, and chloroform were added successively with vigorous agitation to give concentrations (based on total water) of 1% (w/v), 30% (v/v) and 0.7% (v/v), respectively. After the mixture stood for an hour to insure inactivation of the bacteria, it was passed slowly four times through a Sharples continuous supercentrifuge to remove bacterial cells. Increasing the concentration of ethanol in the supercentrifugate to 55% caused the polysaccharide to precipitate in finely divided, noncohesive gellike particles that did not settle but were separated out by supercentrifugation.

The crude polysaccharide was purified further by reprecipitating it from a solution 0.25% in polymer and 1% in potassium chloride by an ethanol concentration of 55%. The noncohesive product was recovered by centrifugation, and the reprecipitation was repeated three times.

After the final reprecipitation, the residue as collected in the centrifuge rotor was dehydrated by adding it to 14 parts (w/w) of vigorously agitated methanol previously made up with 0.05% potassium chloride. The fibrous precipitate was separated by filtration, resuspended successively several times in methanol, and finally freed from adhering methanol *in vacuo* over anhydrous calcium chloride at room temperature. These treatments with methanol decreased the potassium chloride content and removed most of the remaining bacterial pigment. Alternatively, the aqueous solution of the polysaccharide was dialyzed for 24 hr., adjusted to pH 6, and freeze-dried.

Typical analyses are: sulfated ash, 13.0%; chloride, 0.3%; nitrogen, 0.08%; phosphorus, 0.03%. The theoretical ash value, calculated from the content of potassium glucuronate units present, is about 11.0%.

Analytical Methods

The procedures for humidifying, storing, sampling, and analyzing the polysaccharide products for moisture have been reported previously.² All calculations for other analyses were made on a dry basis.

Total carbohydrate was determined by the phenol-sulfuric acid method⁷ standardized on a highly purified sample of the polysaccharide. Uronic acid was determined by a modification of the carbazole method⁸ and acetyl by a hydroxamate procedure.⁹

Analytical fractional precipitation (summative)¹⁰ was carried out as follows: To 20-ml. aliquots of a solution of the polysaccharide (0.05% concentration, w/v) and potassium chloride (1.0%, w/v) at pH 6.0-6.5 contained in 45-ml. stainless-steel centrifuge tubes, was added absolute ethanol in 0.5% increments to make concentrations in the range 25-47% (v/w). Mechanical stirring was employed during the addition. The mixtures were equilibrated at $25^{\circ} \pm 0.5^{\circ}\text{C}$. and then centrifuged (Servall, SS-1 rotor) at 15,000 rpm for 60 min. at 25°C . After the supernatants were decanted, the residues were dissolved in water and analyzed for polysaccharide.

Analytical fractional precipitation (stepwise cumulative)¹⁰ was carried out at 25°C . on 50 ml. of 0.2% polysaccharide solution containing 1% potassium chloride by adding absolute ethanol as previously described.¹¹ Centrifugation was at

15,000 rpm for 60 min. at 25°C . The residues were analyzed as stated.

Viscosity

Viscosity measurements were made with Brookfield viscometers types LVF and LVT at 25°C . and 30 rpm, unless otherwise indicated.

Solutions for viscosity-concentration curves were prepared by gravimetric, serial dilution although the same results were obtained from individually prepared solutions. Salt effects were observed by incremental addition of small amounts of solid salt to homogeneous, completely dispersed solutions of the polysaccharide; uniform admixture was achieved by hand stirring. Readings usually were made after 10 revolutions, or when the values had become constant.

Viscosity of solutions containing calcium acetate or potassium phosphate increased with time; only initial values are included here.

Heat Treatment and Reisolation of Polysaccharide B-1459

Two solutions were given identical treatment: Solution A contained 5 g. of native polysaccharide dissolved in 1 l. of water at pH 6.5; solution B differed only in that 1% potassium chloride was present. Each solution, contained in a three-necked flask equipped with a mechanical stirrer and condenser, was heated 30 min. in an oil bath to 90°C . The solutions were cooled rapidly, solution A was made 1% in potassium chloride, and the polysaccharides from both solutions A and B were precipitated by adding 1.2 volumes of 95% ethanol. In striking contrast to the voluminous, noncohesive precipitates characteristic of the native polysaccharide, these were cohesive and stringy. The precipitates were recovered in a Sharples centrifuge, dissolved in water, and dialyzed to remove remaining salt. The pH of the residues were adjusted from about 5.3 to 6.5, and the solutions were freeze-dried. The recovery was 97% of the starting weight.

Deacetylation

An 0.25% solution of native polysaccharide was treated under an atmosphere of nitrogen with 0.025*N* potassium hydroxide in the presence of 1% potassium chloride for 1 hr. at 25°C . to accomplish deacetylation. Titration of an aliquot showed neutralization of alkali equivalent to 95% of the acetyl content of the native polysaccharide. The

solution was cooled to 15°C. and neutralized with 0.25*N* hydrochloric acid; the product was purified and isolated in the same manner as the heat-treated polysaccharide. Recovery was 98% of the theoretical.

RESULTS AND DISCUSSION

Stability and Solubility of the Solid

Polysaccharide B-1459, as dehydrated by methanol, is a bulky, somewhat fibrous powder slightly colored by bacterial pigment. Samples of the powder, containing about 14% moisture, have been stored for over a year at 20°C. without any decrease occurring in viscosity or in content of uronic acid or acetyl.

Solid particles swell markedly in water. Homogeneous dispersions free of gelatinous masses can be obtained by adding the dry solid either to a small amount of water (0.1–0.2 the final volume desired) or to the total volume of water to be used. Under the first condition, the mixture is stirred or allowed to stand (about an hour at 25°C. or overnight at 4°C.) until hydration is uniform, and then the remainder of the water is stirred in. Under the second condition, viscosity increases during the hydration and swelling of the particles and then decreases during dispersion of the swollen masses. The constant final viscosity is reached within an hour or two.

The polysaccharide disperses almost as readily in 1% potassium chloride solution as in water, but more slowly in a 5% solution of the salt. When dissolution is complete, these solutions show the same viscosity as water solutions to which salt has been added.

Polysaccharide B-1459 is solvated, but not dissolved, by formamide and tetraethylammonium hydroxide (10% solution). However, brilliantly clear, gellike dispersions result when equal volumes or more of these liquids (or of dimethylformamide) are added to solutions of the polysaccharide in water.

Solution Characteristics: Effect of Nonsolvents and Precipitants

Cell-free solutions of Polysaccharide B-1459 show some opalescence. The pH usually is in the range 7.0–6.0 for concentrations of 0.1 to 1.0%. At concentrations as low as 0.25%, solutions show weak gelation at room temperature; in the cold they set to soft, reversible gels, especially in the presence of salt or alcohol.

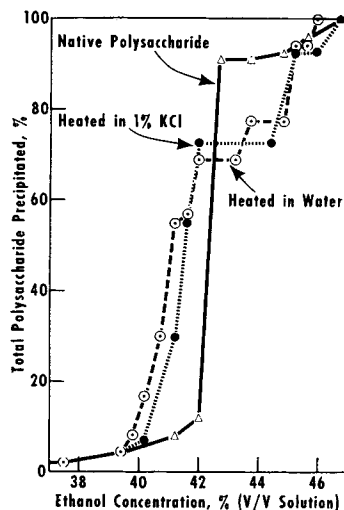


Fig. 1. Molecular distribution obtained by analytical fractionation (summative) of native and heat-treated Polysaccharide B-1459.

In the absence of salt, the polysaccharide is not precipitated from water solution by addition of 2 volumes of ethanol, methanol, or glacial acetic acid; and it is only partially precipitated by 3 volumes.

Quaternary ammonium salts react with Polysaccharide B-1459 to form precipitates insoluble in water but soluble in salt solutions. These observations, which are in keeping with the known behavior of acidic polysaccharides,¹² are the basis for a practical method of recovery and purification.¹³

Molecular Homogeneity

The extent of molecular distribution in native Polysaccharide B-1459 is indicated by the precipitation of the major component (comprising 83% of the total) within an ethanol increment of 1% by analytical fractionation (summative) in the presence of electrolyte (Fig. 1). This distribution appears to result from differences in molecular size because individual fractions obtained by ethanol in the presence of potassium chloride or by use of cetyltrimethylammonium bromide showed no differences in uronic acid and acetyl contents.

Factors Affecting Viscosity

As shown in Figure 2, the viscosity-concentration relationship of Polysaccharide B-1459 compares favorably with that of two well-known polysaccharoids, high viscosity sodium alginate and gum guar.

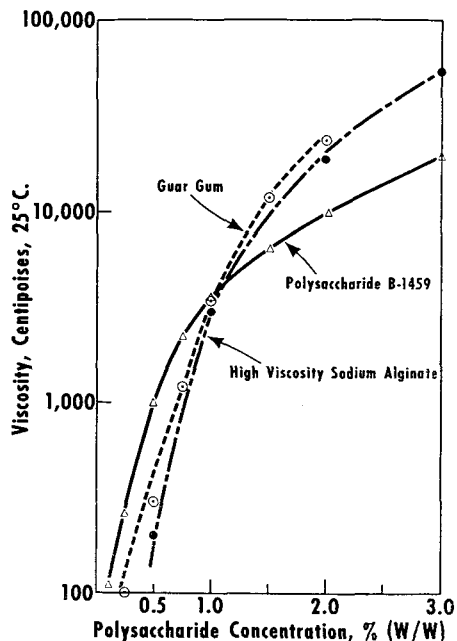


Fig. 2. Viscosity-concentration relationships of Polysaccharide B-1459 compared with those of some commonly used gums.

1. Effect of Shear

Plastic rheological characteristics are indicated by viscosity-rate of shear relations (Fig. 3) and by rate of shear-torque plots that show yield values.

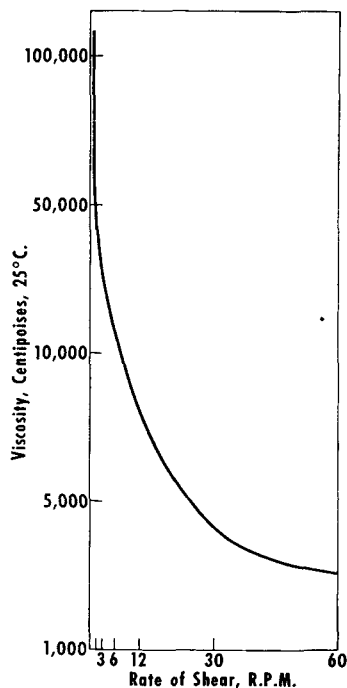


Fig. 3. Viscosity vs. rate of shear for Polysaccharide B-1459. Concentration of aqueous solution, 1%.

Thixotropy is weak, especially at concentrations less than about 1%. Decrease in viscosity resulting from vigorous agitation (as with a Waring Blender) is in direct relation to the concentration. Thus five minutes under such conditions resulted in decreases of about 5% and 15% for concentrations of 0.5% and 3%, respectively; the initial decrease occurred quickly.

2. Effect of pH

The viscosity of Polysaccharide B-1459 solutions in water is essentially independent of pH between 6 and 9. Decreasing the pH to 5 and then to 4 by adding acetic acid results in a progressive increase in viscosity; below pH 4, solutions buffer strongly and show a linear decrease in viscosity with pH. Adjustment of pH to within the range of 9 to 11 results in a rapid increase in viscosity followed by a slower decrease to a value near that of a neutral water solution. A concurrent decrease in pH occurs.

3. Effect of Salts

The changes produced in the viscosity of Polysaccharide B-1459 solutions by increasing concentrations of inorganic salts are influenced by the polysaccharide concentration, by the pH, and in some cases by the specific composition of the salt.

The gradation in effect of potassium chloride on viscosity with an increase in polysaccharide concentration is shown in Figures 4a and 4b. Polysaccharide solutions of less than about 0.2% concentration show an initial restrained decrease in viscosity that levels off, with no further decrease, as the salt concentration is increased. For polysaccharide concentrations greater than 0.4%, salt addition produces an initial increase in viscosity and then a leveling off without decrease as the salt concentration is raised even to 5%. Polysaccharide solutions of intermediate concentrations (0.2-0.4%) show a slight increase, then a decrease, followed by a slight increase.

An inverse relation between polyelectrolyte concentration and the effectiveness of salt for decreasing the viscosity is commonly found. In view of this fact, it may be inferred that the viscosity decreases shown by Polysaccharide B-1459 solutions of concentrations less than about 0.2% are atypically small. Viscosity increase or stabilization by salt is atypical of polyelectrolytes and is in striking contrast to the behavior of most polysaccolloids having acidic constituents. For ex-

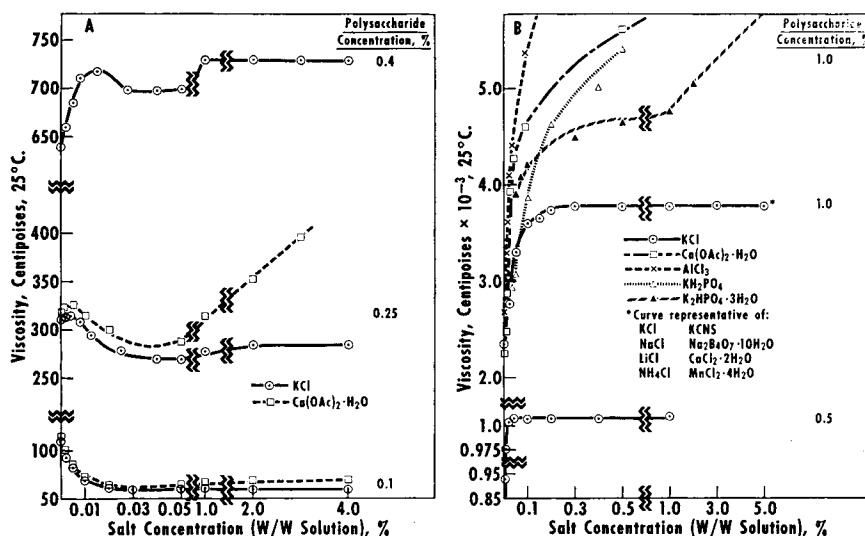


Fig. 4. Viscosity of Polysaccharide B-1459 solutions in the presence of various salts, for polysaccharide concentrations of (a) 0.1–0.4%, (b) 0.5–1.0%.

ample, our measurements show that additions of 1% potassium chloride to 1% solutions of gum karaya, gum tragacanth, and sodium alginate reduce the viscosities by 90, 50, and 30%, respectively. There is some similarity between the increase in viscosity of our bacterial polysaccharide due to salts and the increase in gel strength of carrageenin due to certain specific salts.¹⁴

Salt addition curves closely similar to that for potassium chloride (Fig. 4b), were obtained for the chlorides of lithium, ammonium, sodium, calcium, and divalent manganese, as well as for potassium thiocyanate and borax. Our results do not show any consistent relation to equivalent weights or specific cation effects. No general correlation can be made with pH, since borax increased the pH value of 1% polysaccharide solution (which was 6.2 in water) to 9.0, whereas all the other salts in this group decreased the pH to within the range of 6.0–5.0.

Curves that rise rapidly but with varying degrees of sharpness resulted from addition of aluminum chloride, calcium acetate, potassium dihydrogen phosphate, and dipotassium hydrogen phosphate (Fig. 4b). These mixtures became increasingly firm gels as their viscosities increased from about 4,000 cpoise; the development of full gel strength was time-dependent. Low concentrations of aluminum chloride and the primary potassium phosphate reduced pH values well below 5; at pH values less than about 4, decreases in viscosity occurred. Secondary potassium phosphate (1%) gave a pH near 9.

The difference in behavior of calcium acetate and calcium chloride suggests a critical pH dependence for calcium ion. Although calcium chloride concentrations up to 1% produced a pH of near 6.0, the pH resulting from calcium acetate addition was about 6.6 below 0.1% concentration and then increased to 7.3 at 1%. Adjustment of the pH of solutions containing 1% calcium acetate to the corresponding value for calcium chloride reduced the viscosity of the acetate solution to that of the chloride solution. Crosslinking probably is a factor in the effects caused by calcium acetate; it becomes effective when the polysaccharide concentration is sufficiently high (Fig. 4a). These observations suggest that augmented viscosity or gel formation might be obtained as desired from any di-, tri-, or even monovalent cation through suitable pH control. This hypothesis is supported by the observed effects of combined potassium chloride and alkali.

4. Effect of Salt and Alkali

When certain critical concentrations of both potassium chloride and potassium hydroxide are satisfied in Polysaccharide B-1459 solutions, a time-dependent, synergistic effect on viscosity occurs. As shown in Figure 5, the molar ratio of hydroxyl ion to the polysaccharide weight per uronic acid unit (that is, to the repeating unit weight) appears to be significant. These solutions, which were protected from carbon dioxide of air during the period of observation, showed a decrease

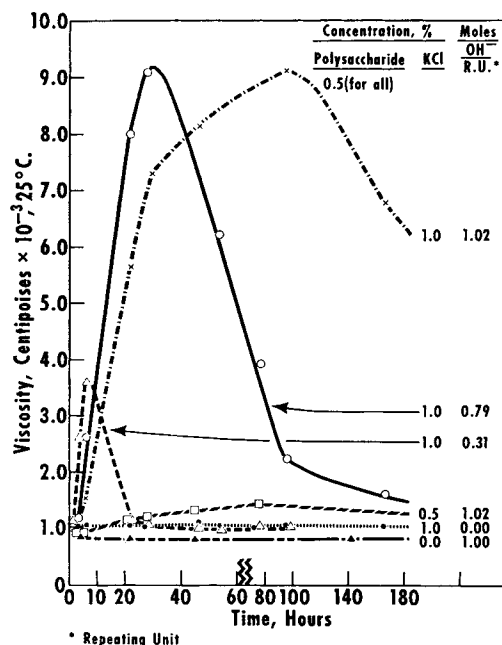


Fig. 5. The synergistic, time-dependent changes produced in the viscosity of Polysaccharide B-1459 solutions by various proportions of potassium chloride and alkali.

in pH from initial values in the range 10.8–11.9, to 7.0–9.6.

The nature of the chemical and physical changes corresponding to these shifts in viscosity is unknown. Preliminary observations indicate that the physical effects are largely reversible. Deacetylation of the polysaccharide accounts, at least in part, for the decrease in pH, but apparently does not affect viscosity, as is shown later.

The increased viscosity maintained over a period of days by this bacterial polysaccharide at high pH is exceptional for a polysaccolloid. Under comparable conditions alginate and gum tragacanth suffer sharp decreases in viscosity; locust bean gum shows little change. The viscosity of pectin decreases drastically in dilute alkali and degradation occurs.¹⁵

5. Effect of Temperature

The measurement of viscosity of Polysaccharide B-1459 solutions at successively increasing temperatures shows the influences of polysaccharide concentration and presence of salt superimposed on that of the decreasing viscosity of the solvent (Fig. 6). Structural organization is indicated by the gradation in the magnitude of change, but maintenance of the same general pattern, with polysaccharide concentration in the absence of salt.

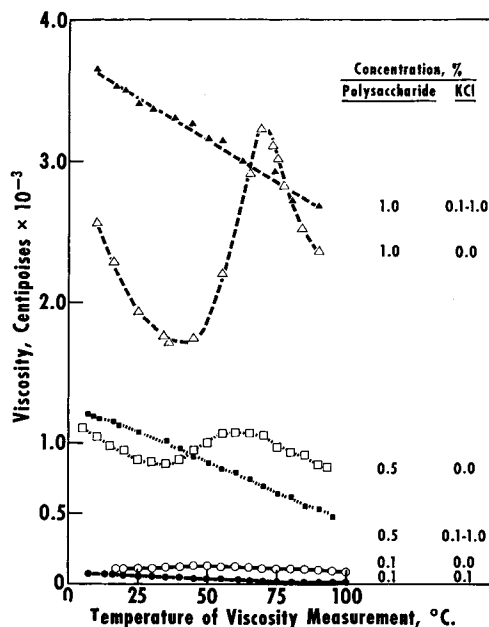


Fig. 6. The effects of temperature and potassium chloride concentration on the viscosity of Polysaccharide B-1459 solutions.

However, the solutions employed were free of macroscopic undispersed aggregates. The sigmoid-type curves, which were observed only in the absence of salt, might result from modification of the degree of extension or entanglement of the molecules. These changes, with or without salt, are largely reversible and may be repeated upon the same solution.

6. Effect of Heating

Measurement of viscosity at 25°C. after an aqueous polysaccharide solution had been heated for a time at a higher temperature showed a rapid initial drop followed by a reduced rate of change or a virtual leveling off. A 1% polysaccharide solution (in water) after being heated 5 hr. at 60°C. retained 46% of the original viscosity when measured in water and 93% when measured in 0.5% potassium chloride solution. After being heated 4 hr. at 100°C., another solution showed corresponding values of 30% and 80%, respectively.

The curves in Figure 7 were obtained by heating a Polysaccharide B-1459 solution rapidly to a stated temperature, cooling, measuring the viscosity at 25°C., and then heating to the next higher temperature. The similar curves for 1% and 0.5% aqueous solutions indicate magnitudes of change proportional to the polysaccharide concentration.

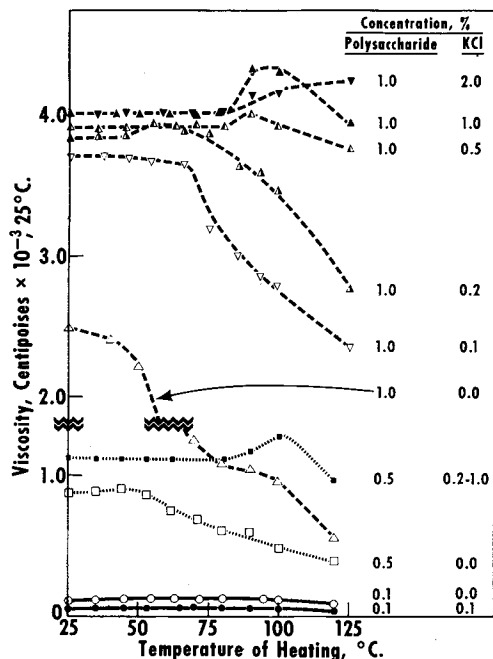


Fig. 7. Modification of the effects of heating on Polysaccharide B-1459 solutions by the presence of potassium chloride.

For 1% polysaccharide concentration, 0.1% salt moderated the effect of heating, whereas 0.5 to 2.0% salt had a pronounced influence. Salt concentration is related directly to the temperature at which decrease in viscosity commences and inversely to the extent of viscosity decrease. The viscosity decrease was eliminated completely by adding 2% salt, increasing viscosities being obtained from 85° through 120°C. For 0.5% polysaccharide concentration, both 0.2 and 1% salt produced the same amount of moderation.

The percentage decrease in viscosity resulting from heating a 1% Polysaccharide B-1459 solution from 25° to 120°C. is 75% in water and 3% in 1% potassium chloride solution. Corresponding values were observed under identical conditions for gum karaya (95% in water; 90% in salt) and for gum tragacanth (75% in water; 53% in salt).

Modified Forms of the Polysaccharide

Heating or deacetylating Polysaccharide B-1459 causes no impairment of its properties but actual improvement. The polysaccharide reisolated after rapid heating to 90°C. in either water or 1% potassium chloride solution gave viscosity-concentration curves and salt-addition curves slightly higher than those of the native polysaccharide. No change occurred in uronic acid or acetyl con-

tents, but some fragmentation or dissociation resulted, especially in the product heated without salt (Fig. 1).

The viscosity behavior observed during heating (Fig. 7) appears to be caused mainly by physical changes in molecular shape and/or entanglement. These changes are believed to account for the increased cohesiveness of the precipitated gum-phase and for the improved quality of films obtained from polysaccharide solutions after heating.¹⁶

In comparison with the native polysaccharide, the deacetylated material shows somewhat higher viscosity, both in water and in salt solution, and greatly improved flexibility of its plasticized films.¹⁶ The deacetylated polysaccharide can be precipitated by alcohol alone, but the presence of 1% potassium chloride permits precipitation by a 12% lower concentration of alcohol.

Constitutional Basis for Properties

The atypical behavior of the B-1459 bacterial polysaccharide with salt appears to be a molecular property based on aspects of structure and conformation rather than on its composition as a poly-electrolyte. The glucuronic acid residues present show typical chemical behavior: the salt form can be converted to the acid form by exchange resins or by dialysis of an acidified solution; the acid form has normal ionic activity in the stoichiometric amount expected. The behavior with salt is not changed by deacetylation, showing that carboxyl groups in the native polysaccharide are not sterically affected by acetyl groups.

Limited reduction of molecular dimensions by salt occurs when the polysaccharide concentration is sufficiently low. At higher concentrations the apparent increase, rather than decrease, of molecular dimensions indicates the predominant influence of structural organization or molecular interaction. Additional indications of molecular entanglement or interaction are the changes that occur when sufficient kinetic energy is supplied through heat.

These observations appear compatible with the behavior characteristic of rigid, linear molecules.¹⁷ The β -configuration of the glycosidic bonds in Polysaccharide B-1459³ is in accord with the concept of a molecule of low flexibility.

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Mention of trade names should not be construed as a recommendation or endorsement by the Department over those not mentioned.

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Synopsis

The exocellular polysaccharide fermented from glucose in good yield by *Xanthomonas campestris* NRRL B-1459, has been characterized. The general aspects of chemical constitution have been established, as well as the physical properties related to practical applicability. This macromolecular polysaccharide is composed of D-mannose, D-glucose, D-glucuronic acid (as the potassium salt), and a small proportion of acetyl groups. It can be produced on an industrial scale and is stable in storage. Analytical fractionation indicates fairly sharp molecular distribution for the native polysaccharide. The polysaccharide forms homogeneous dispersions in water which show plastic rheological properties and viscosity comparable with that of high-grade plant gums. Outstanding characteristics of practical significance are the atypical insensitivity of solution viscosity to salt effects and to heat, especially when salt is present. Solutions of low concentration show a restricted viscosity decrease upon salt addition; those of higher concentrations show substantial increases. Viscosity is enhanced still further by monovalent cations at basic pH and by divalent cations at neutral or slightly basic pH. Salt moderates or eliminates any viscosity decrease due to heat and, in somewhat higher concentrations, it increases the viscosity of heated solutions. Heating or deacetylating Polysaccharide B-1459 causes no impairment of its properties, but actual improvement. The constitutional basis for these unusual properties is discussed.

Résumé

On a étudié les caractéristiques du polysaccharide exocellulaire préparé avec de bons rendements par fermentation

du glucose avec le *Xanthomonas campestris* NRRL B-1459. On en a établi les aspects généraux de constitution chimique aussi bien que les propriétés physiques en rapport avec les possibilités d'application pratique. Ce polysaccharide macromoléculaire est composé de D-mannose, D-glucose, D-acide glucuronique (en tant que sel potassique) et d'une petite proportion de groupes acétyles. On peut le fabriquer à l'échelle industrielle et il est stable au stockage. Le fractionnement analytique indique une distribution moléculaire passablement reserrée pour le polysaccharide (natif). Le polysaccharide forme dans l'eau une dispersion et une viscosité comparable à celle des gommages de plante. Des caractéristiques exceptionnelles avec signification pratique consistent dans l'insensibilité de la viscosité de la solution aux effets de sel et à la chaleur, spécialement en présence de sel. Les solutions à basses concentrations présentent une diminution de viscosité peu importante lors de l'addition de sel; les solutions de concentrations plus élevées présentent des accroissements non négligeables. La viscosité est augmentée encore davantage par des cations monovalents à des pH basiques et par des cations divalents à des pH neutres ou faiblement basiques. Le sel modère ou élimine tout abaissement de viscosité dû à la chaleur et en concentration quelque peu supérieure, le sel accroît la viscosité des solutions chauffées. En chauffant et en déacétylant le polysaccharide B-1459, on ne détériore pas ses propriétés, on les améliore plutôt. On discute de ces propriétés inhabituelles sur la base de la constitution du polymère.

Zusammenfassung

Das mittels des Ferments *Xanthomonas campestris* NRRL B-1459 aus Glukose in guter Ausbeute erhaltene exocelluläre Polysaccharid wurde charakterisiert. Die chemische Struktur wurde in grossen Zügen aufgeklärt und auch die für die praktische Anwendbarkeit wichtigen physikalischen Eigenschaften untersucht. Dieses makromolekulare Polysaccharid besteht aus D-Mannose, D-Glukose, D-Glukuronsäure (als Kaliumsalz) und einem kleinen Anteil von Acetylgruppen. Es kann in industriellen Massstab erzeugt werden und ist lagerungsfähig. Analytische Fraktionierung zeigt für das natürliche Polysaccharid eine recht scharfe Molekulargewichtsverteilung. Das Polysaccharid bildet in Wasser homogene Disperionen, die plastische rheologische Eigenschaften und eine mit der Viskosität von hochgradigem Pflanzengummi vergleichbare Viskosität zeigen. Eine aussergewöhnliche Eigenschaft von praktischer Bedeutung ist die atypische Unempfindlichkeit der Viskosität von Lösungen gegen Salzeffekte und gegen Wärme, besonders in Gegenwart von Salz. Lösungen geringer Konzentration zeigen bei Salzzusatz eine beschränkte Viskositätsabnahme; solche höherer Konzentrationen zeigen ein wesentliches Ansteigen. Die Viskosität wird weiters durch monovalente Kationen bei basischem pH und durch divalente Kationen bei neutralem oder schwach basischem pH gesteigert. Salzzusatz vermindert oder eliminiert die durch Wärme hervorgerufene Viskositätsabnahme; in etwas höherer Konzentration vergrössert Salzzusatz die Viskosität von erhitzten Lösungen. Erhitzen oder Deacetylierung des Polysaccharids B-1459 verursacht keine Verschlechterung sondern eher eine Verbesserung seiner Eigenschaften. Die konstitutionelle Grundlage für diese ungewöhnlichen Eigenschaften wird diskutiert.

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