

Novel Synthesis of Diketopectate Coordination Biopolymer Derivatives as Alternative Promising In Biomedicine, Pharmaceuticals and Food Industrial Applications

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Abstract

Diketopectates (PDK) was quantitatively synthesized by the oxidation of pectin sol with potassium permanganate in alkaline solutions at pH's > 12. The yield was 97.3 %. The chemical structure of such synthesized pectate-diketones was elucidated by elemental analysis and spectroscopic data. Sol-gel transformation and/or precipitation were observed when PDK was added to polyvalent metal ion electrolytes. The reaction mechanism of synthesis process was suggested and discussed.

Keywords: pectin; permanganate; oxidation; FTIR; ketones

Introduction

Pectin is the methyl ester of pectic acid which consists of long chains of galacturonic acid [1]. The structure of pectic acid is closed related to that of alginic acid which composed of β -D-mannuronic acid and α -L-guluronic acid units linked through (1 \rightarrow 4) position [2-4] in a linear block copolymer structure [5,6]. The principle structural between them is the position of the hydroxyl groups C-2 and C-3, being cis in alginic acid and trans in pectic acid or, axial-equatorial and equatorial-equatorial, respectively, when the conformation is considered. Pectin biopolymer and its derivatives have wide applications in food and pharmaceutical industries owing to its great gelling ability, stabilizing properties and high viscosity in aqueous solutions [7,8]. Also, it has a variety of biomedical applications in drug delivery and cell transplantation [9,10], dental impression materials [11] and wound dressing [12] as well as in food industry [13]. Pectin and pectic oligosaccharides have been shown to induce apoptosis in human colonic adenocarcinoma cells and to have anti-metastatic properties [14]. Recently, a great attention has been focused to use pectin as inhibitors for the corrosion of metals in either acidic [15] or alkaline [16] solutions.

The literature survey available on synthesis of the keto-derivatives was scarce until few years ago. One possible reason may be the complexity of the oxidation kinetic studies which do not allow reliable mechanistic conclusions. However, Hassan and Co-worker have investigated the oxidation kinetics of some macromolecules such as alginate [1, 17, 18], pectates [19-21], chitin [22, 23], chondroitin-4-sulfate [24], carboxymethyl cellulose [25], methyl cellulose [26, 27], kappa carrageenan [28, 29] polysaccharides as natural polymers and poly (vinyl alcohol) [30-32] as synthetic polymer by potassium permanganate in strong alkaline solutions. They reported that the oxidations were proceeding by formation of detectable intermediate complexes involving green manganate (VI) and / or blue hypomanganate (V) transient species, followed by slow decomposition of such 41.86(41.52); H, 2.33 (2.26). IR: 3435 (OH of COOH group); 1740-1720 (broad) (C=O of diketone); 1690~1643 (C=O of COOH group); and 1260 cm⁻¹ (C-O-C of pectin) [33].

intermediates to give rise to its corresponding keto-derivatives as final oxidation products. The formation of mono- or diketo-derivatives was found to be dependent on the stoichiometric ratios of the reactants and the pH of the media. Therefore, the present work seems to merit a further investigation with the aims at shedding some light on the nature of oxidation products in this alcoholic macromolecule as a part of a series of investigations performed in our laboratory.

Experimental

Sodium pectate (BDH grade) was used without further purification. All other materials used were of analytical grade. Doubly distilled water was used in all preparations. Sodium pectates powder (5 g) was dissolved in 400 ml of deionized water whose pH's was previously adjusted to pH \geq 12 using sodium hydroxide. This process was performed by stepwise addition of the powder pectate reagent white rapidly stirring the solution to avoid formation of a lumpy precipitate that swells with difficulty. To this solution, 7.96 g of potassium permanganate solution was added portion wise, and then 8.3 g of sodium fluoride solution was added to this mixture while stirring. The reaction mixture was stirred for 36 hr at room temperature, the formed MnF₄ was filtered off, and the solution was concentrated to about 60 ml using a rotary evaporator. A portion of this solution was acidified with acetic acid and the formed diketopectic acid was precipitated by ethanol. The solid product was filtered off, washed several times by ethanol, dried under vacuum, and then subjected to elemental analysis and Infra- red (IR) spectroscopy. The infrared (IR) spectra were scanned on a Pye unicam Sp3100 spectrophotometer using KBr disc technique (4000-200 cm⁻¹).

ANAL: Diketopectate C₆H₄O₆ (172): Calcd (found). C,

2, 4 –Dinitrophenyl Hydrazone Derivative

ANAL: C₁₈H₁₂O₁₂N₈ (532): Calcd (found): C, 40.60 (40.52); R, 2.25 (2.36); N, 21.05 (21, 02). IR: 3422 (OH of COOH group), 3321 (NH

of hydrazine); 1670 (C= N of hydrazine); 1256 cm^{-1} (C-O-C of pectin).

Dioxime Derivative

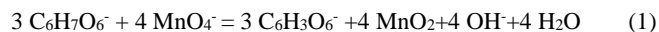
ANAL: $\text{C}_6\text{H}_6\text{O}_6 \text{N}_2(202)$; Calcd (found): C, 35.64 (35.70); H, 2.97 (2.99); N, 13.86 (13.74), IR; 3340-3360 (OH of COOH and oxime); 1672 (C=N); 1683 (C=O of COOH) 1236 cm^{-1} (C-O-C of pectin).

Polymerization Test

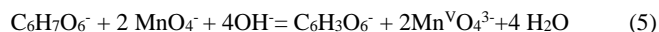
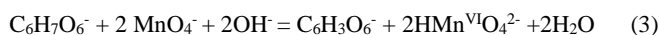
The possibility of formation of free-radicals was examined by adding 10 % (v/v) of acrylonitrile to partially oxidized reaction mixture. No polymerization was observed indicating that the reaction did not proceed via free-radical mechanism.

Results and Discussion

Pectate sols can be readily oxidized by the alkaline permanganate ion to give its corresponding diketopectate derivative precursors. The stoichiometry of the overall reaction conforms to the following equation:



The formation of mono- or diketopectates depends on the molar concentration ratio of the reactants and the pH of the medium as follows,



Where $\text{C}_6\text{H}_7\text{O}_6^-$, $\text{C}_6\text{H}_5\text{O}_6^-$ and $\text{C}_6\text{H}_3\text{O}_6^-$ denote the pectate, monoketo- and diketopectate, respectively. These monoketo- and diketopectates can be isolated and identified by elemental analysis and spectral data.

It is well known that manganese (IV) tends to complex with fluoride ion to form MnF_4 , which can be easily removed from the reaction mixture by filtration after the reaction completion.

The structure of formed diketone derivative was based on the elemental analysis and infrared spectroscopy. The diketopectate formed gave satisfactory elemental analysis and broad IR absorption bands at 1740-1720 (broad) cm^{-1} that characterize the carbonyl group of α -diketones [34] as shown in Figure 1.

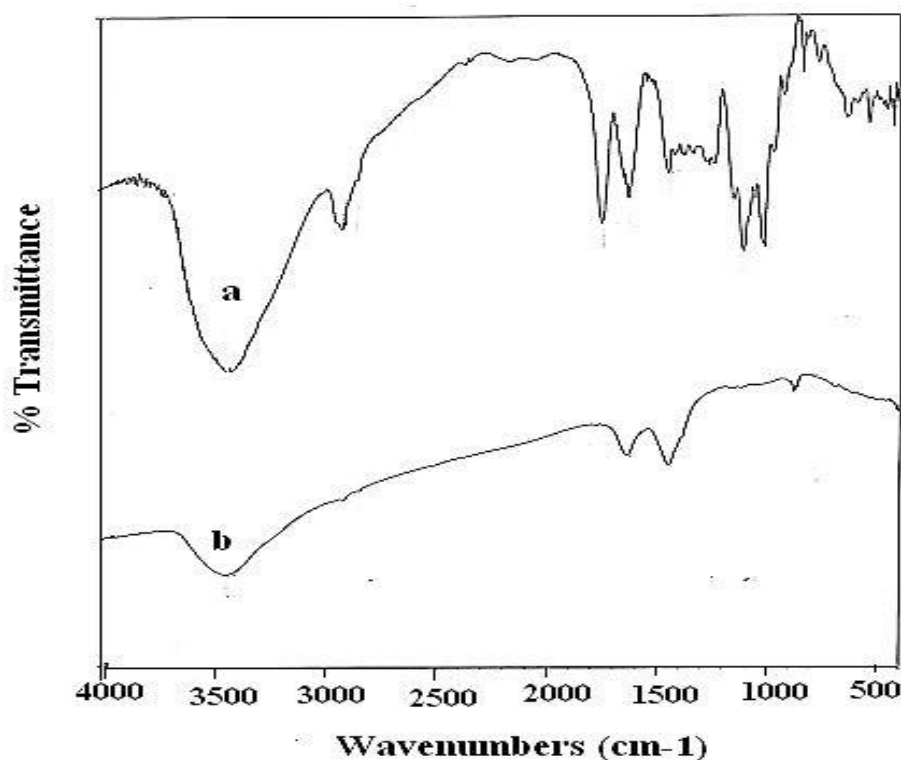


Figure 1. FTIR spectra of the reactants and products; (a) pectin; (b) keto- precursor derivatives of pectin.

The enhancement of the absorption band of the OH group in the IR spectra at a wavelength of 1700 cm^{-1} indicates the oxidation of OH group of pectate to keto (C=O) groups. The product was found to react with 2,4- dinitrophenyl hydrazine and hydroxyl amine to afford the corresponding bis 2,4- dinitrophenyl hydrazone and dioxime derivatives, which gave satisfactory elemental analysis and IR absorption band at 1672 cm^{-1} (C=N). The yield was 97.3 %. This

diketopectate was easily soluble in water and in some organic solvents. The oxidation of pectate by alkaline permanganate was occurred stepwise through formation of an intermediate complex involving green manganate (VI) and/or blue manganate (V) transient species that could be detected by a conventional spectrophotometer for the first time [19], as shown in Figure.2.

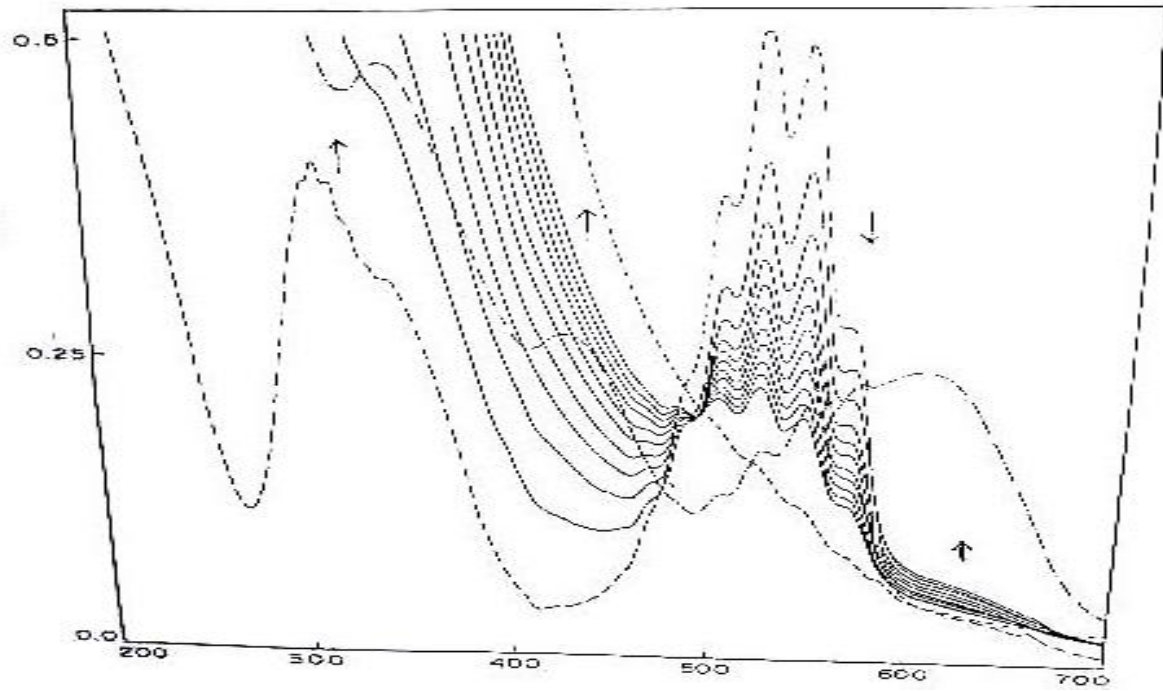
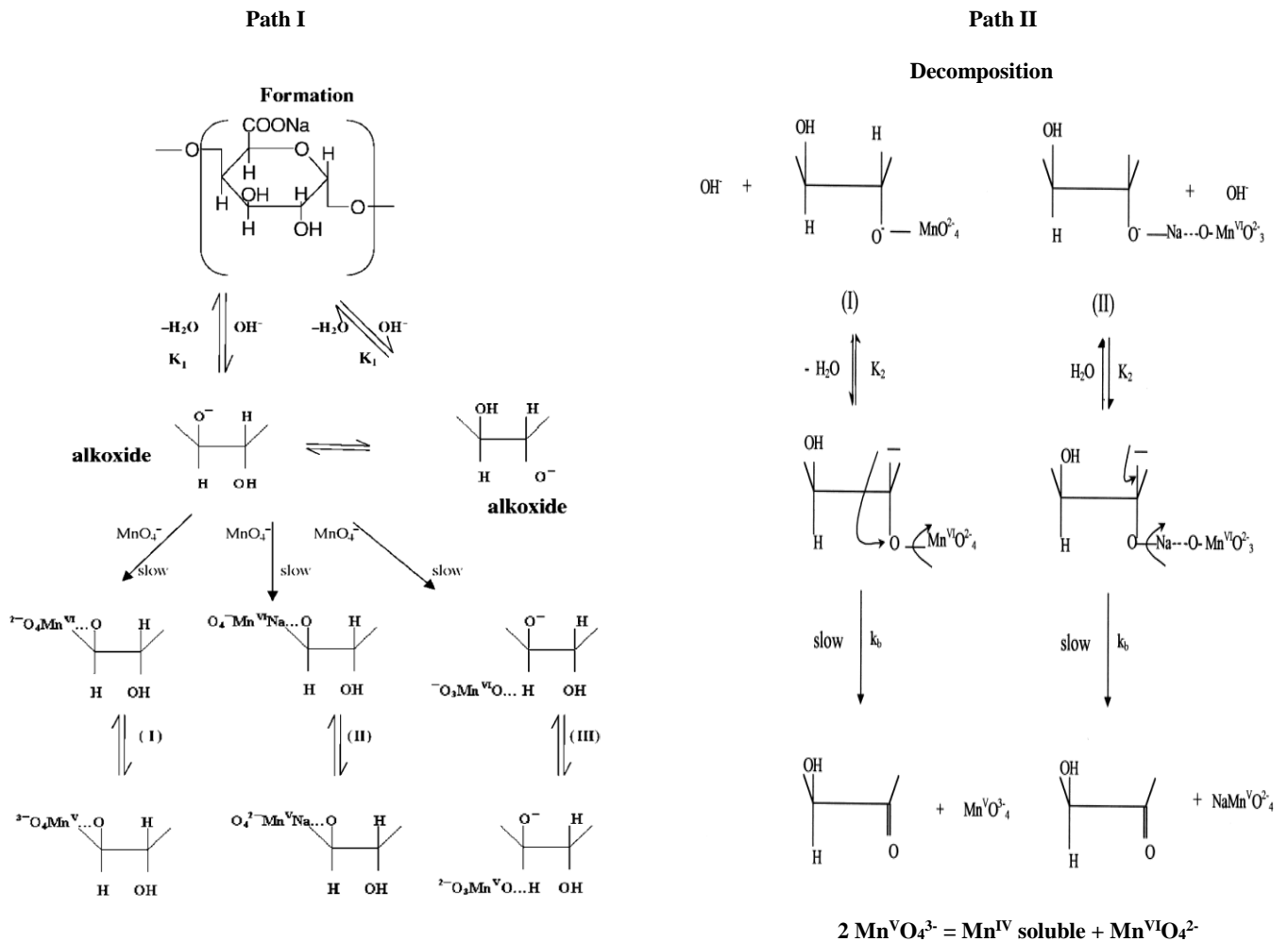


Figure 2. Spectral changes (200-700 nm) in the oxidation of pectate by permanganate ion. $[MnO_4^-] = 2.2 \times 10^{-4}$, $[PEC] = 2.5 \times 10^{-3} \text{ mol dm}^{-3}$ at 50 °C.



Scheme I: Speculated mechanisms for formation and decomposition of intermediate complexes in the oxidation of pectate by alkaline permanganate.

A tentative reaction mechanism for oxidation is suggested in Scheme 1. The suggested reaction mechanisms by paths (I) and (II) were found to be in a good agreement with the experimental observations based on the dependence of decomposition rate constant on the alkali concentrations [19]. Similar reaction mechanisms for synthesis of keto-derivatives by the oxidation of other alcoholic polysaccharides by alkaline permanganate have been reported earlier [35, 36].

Conclusion

Diketo-pectin has wide applications in food and pharmaceutical industries owing to its great gelling ability, stabilizing properties and high viscosity in aqueous solutions. In addition, it found that the product has a high affinity for chelation with most of divalent and polyvalent metal ions forming stable coordination biopolymer complexes of pectin. The product is characterized by its non-toxicity, low cost and high performance. Diketo-pectin can be used effectively for removal of poisonous heavy metal ions along with other divalent and polyvalent metal ions which are contaminated in wastewater and environment.

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