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A botanical polysaccharide extracted from abandoned corn stalks: Modification and evaluation of its scale inhibition and dispersion performance ☆

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HIGHLIGHTS

- A corn stalk extract was modified by 2,3-epoxypropanesulfonic acid sodium.
- The sulfonated derivative(PS-NAEP) was employed as an antiscalant and dispersant.
- The scale inhibition efficiency of PS-NAEP was high against calcium sulfate.
- Special dispersion to ferric-oxide was apparent.

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ABSTRACT

A botanical hetero-polysaccharide sulfonated salt was prepared with hetero-polysaccharide extracted from abandoned corn stalks and cheap starting materials such as epichlorohydrin, and sodium bisulfite commercially available. The structures were characterized by FT-IR and ^{1}H-NMR. Then, the novel sulfonated botanical hetero-polysaccharide derivative (PS-NAEP) was employed as an anti-scaling and dispersing agent. Its scale inhibition performance was evaluated by static test against calcium sulfate and calcium phosphate scaling while the dispersity test was performed for ferric oxide. The impact factors of scale inhibition performance such as agent concentration, pH value, total hardness and temperature, were investigated. The experimental results demonstrated that scale inhibition efficiency of PS-NAEP was close to 95% top against calcium sulfate and 55% against calcium phosphate in the simulation experiment. Scanning electron microscope (SEM) and X ray diffraction (XRD) analysis were also utilized to characterize morphology and crystal form of calcium sulfate and calcium phosphate scale. It appears that the higher scale inhibition efficiency and the worse distortion of the crystal form of calcium sulfate and calcium phosphate are all due to PS-NAEP. Moreover, special dispersion to ferric oxide was studied through observation of light transmittance of the dispersing solution, which suggested PS-NAEP was an effective dispersant.

1. Introduction

In recent decades, polysaccharides isolated from botanical sources (bamboo, grass, corn stalks, sorghum stalks, etc.) had attracted a great deal of attention in energy reuse because of their broad spectrum of chemical properties and relatively low toxicity [1]. Additionally, polysaccharides whose structure contained many active groups such as hydroxyl, amino and carbonyl had the advantages of chemical modification. The corresponding studies provided lots of available experiment and application for hetero-polysaccharides. Especially, many sulfonation and carboxymethyl modification were reported in literatures [2,3], which implied that polysaccharide modification was available and successful.

Since the sulfonated polymers, first developed by Calgon Corps. of US, have good performances not only in scaling inhibition against calcium carbohydrate, calcium sulfate and calcium phosphate but also in dispersing clay, ferric oxide, silicate and other suspended particles in water, the sulfonated functional groups became attractive. In this respect, sulfated derivatives of polysaccharides have been reported for

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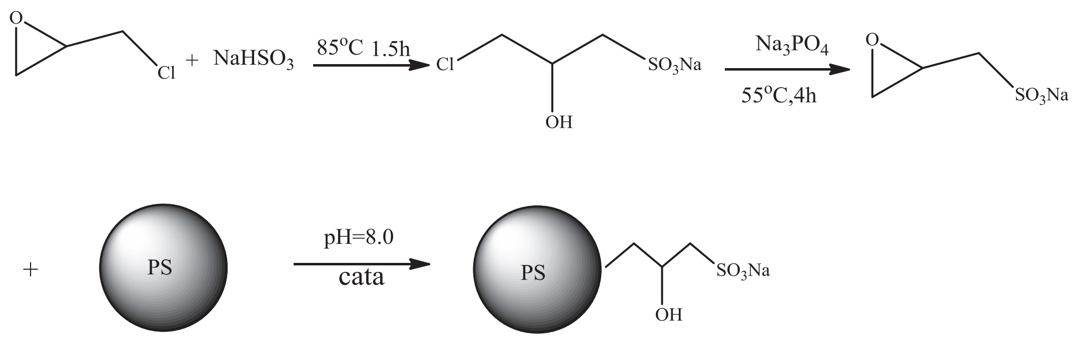

Scheme 1. The synthesis of PS-NAEP.

their various chemical and biological activities. For example, sulfonated cellulose was reported to be used as flocculant [4], anticoagulant [5], adsorbent [6] and anti-adipogenic effect [7].

Scale on heat transfer surface widely occurred in numerous industrial processes when natural water was used as thermal fluid [8]. The damage and therein resulting problems greatly impaired the normal industrial processes, especially corrosion caused under the scale when various equipments and facilities in cooling water systems were mainly made of ocean carbon steels and stainless steels. Deposit formation may cause severe corrosion and deteriorate conditions of the heat exchange [9]. Besides, although the synthesized polymer scale inhibitor and phosphorus-containing scale inhibitor were highly efficient as a scale inhibitor, they really had some fatal flaw such as difficult biodegradation in the water and eutrophication of the phosphorus-containing scale inhibitor [10]. Therefore, the research using natural products and their modified derivatives as biodegradable and eco-friendly scale inhibitors brought great development.

In this report, a novel sulfonated hetero-polysaccharide derivative (PS-NAEP) was prepared by 2,3-epoxypropanesulfonic acid sodium modification. PS-NAEP was characterized by infrared spectroscopy (IR) and nuclear magnetic resonance (NMR). The performance of scale inhibition and dispersity were determined under different conditions by static tests or transmittance observation. The mechanism was studied through determining the morphology and crystal structure by scanning electron microscopy (SEM) and X-ray diffractometer (XRD), respectively.

2. Experimental section

2.1. Instruments and agents

The instruments used in the present research included a BUCHI-R200 rotary evaporator from BUCHI in Switzerland, a TENSOR 27 Fourier Transform Infrared Spectrometer (FT-IR) from Bruker in German, an AVANCE 400 Pulse Fourier Transform Ultrashield Nuclear Magnetic Resonance Spectrometer (PFT-NMR) from Bruker in Switzerland, a precise pHs-3C meter and a 722-spectrophotometer from Shanghai LEI-CI in China, a D/max 2200PC X-ray diffractometer (XRD) and an S-4800 field emission scanning electron microscope (SEM) from HITACH in Japan. The chemicals used in this paper included analytical grade epichlorohydrin and sodium hydrogensulfite supplied by the third Chemical Reagent Company of Tianjin in China, except for hetero-polysaccharides powder extracted by demonized water. Ammonium chloride buffer solutions (0.1 mol/L) were prepared by adding an appropriate amount of ammonia to ammonium chloride solutions to obtain solutions of pH 7.0. A borate buffer solution (0.01 mol/L) was prepared to result in pH 9.0.

2.2. Polysaccharides' extraction

The corn stalks were obtained from north plain area in China, and repeatedly extracted with distilled water at 90 °C for twice or three times. The extraction was concentrated by a BUCHI rotation vapor

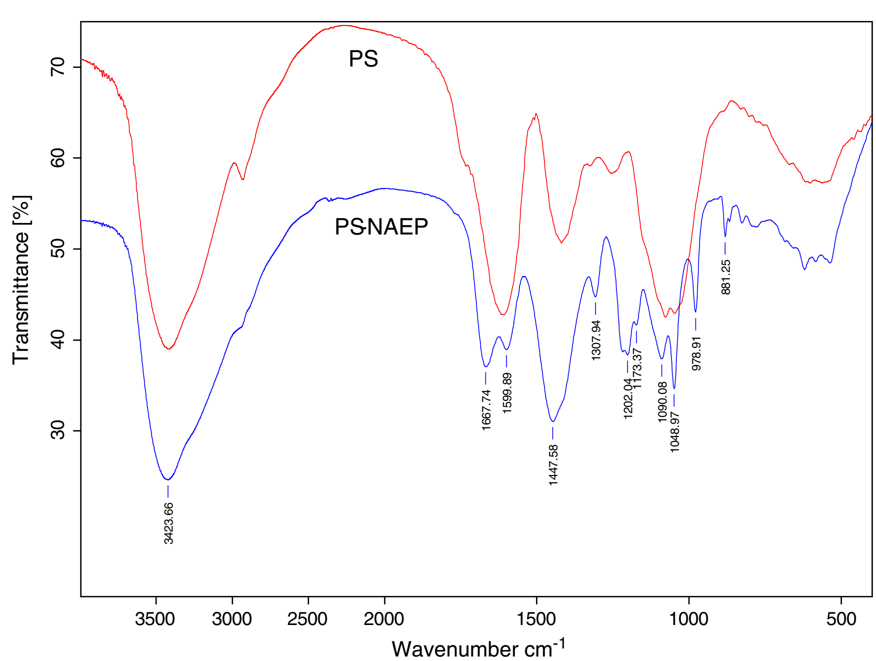

Fig. 1. FT-IR spectra of PS and PS-NAEP.