Study on the Performance of a New Type of Anionic-nonionic Surfactant

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Abstract. A series of new anionic-nonionic surfactants, biophenol polyoxyethylene ether carboxylate (BPPC), were synthesized using biophenol as raw material. The chemical structure of anionic-nonionic surfactant was determined by Fourier transform infrared spectroscopy and elemental analysis. The effects of concentration and degree of polymerization on surface tension were investigated. These new surfactants have good surface activity. The critical micelle concentration (cmc) is 9.30 × 10⁻³ mol / L, 8.50 × 10⁻³ mol / L, 8.10 × 10⁻³ mol / L, and 7.71 × 10⁻³ mol / L. The corresponding surface tensions at CMC are 28.38 mN / m, 28.60 mN / m, 30.40 mN / m, and 30.00 mN / m. Then focus on the foaming properties of BPPC. The results showed that the concentration of surfactant and Ca²⁺ / Mg²⁺ had certain effects on the foaming properties and foam stability of cashew nut-based surfactants. Due to the relatively good foam properties of BPPC, it has broad application prospects in detergents and petroleum recovery.

1. Introduction

It is well known that anionic surfactants tend to precipitate and lose their surface activity in high salinity formation water, and nonionic surfactants are not easily dissolved when the temperature exceeds the cloud point. However, anionic-nonionic surfactants can overcome these two shortcomings and be applied under high salinity reservoir conditions [1-2]. In the process of finding alternative raw materials for the production of amphoteric surfactants, some organic biomolecules may have good utilization potential. Among these biomolecules, unsaturated hydrocarbon phenols have very interesting structural characteristics in the synthesis of special surfactants, such as renewable natural resource cardanol extracted from cashew nut shell liquid. Cashew nut shell liquid is a rich agricultural by-product in China, a promising source of unsaturated hydrocarbon phenols, and an excellent substance for the production of surfactants. The synthesis of biophenols and anionic-nonionic surfactants meets the requirements of green surfactants [3] for "green raw materials", and there have been no reports in this regard. The synthesis of a novel biophenol polyoxyethylene-carboxyl anionic-nonionic surfactant and its surface activity characterization were studied. In addition, surface tension and foam tests were performed to show its good surface activity [4].
2. Analytical Methods
The structure of the product was determined by infrared spectroscopy and elemental analysis. Infrared spectra were recorded on Nicolet FT-IR750. Elemental analysis was performed using a Heraeus elemental analyzer from Germany.

3. Measurements
The synthetic BPPC was dissolved in water of different concentrations. The surface tension of the aqueous solution at 25°C was measured by the droplet volume method. The cmc value was obtained using a surface tension-concentration diagram. The Krafft point is determined by visual inspection [7]. Pour 2mL of a 1.0% aqueous solution into a test tube with a thermometer, and then gradually cool it down. Take the Krafft point as the temperature at which the solution is cloudy when it is cooled or the solution is clear when heated. Then use the initial height of the foam to measure the foaming ability; According to the international standard ISO 696-1975, which is the Rose-Myers method, the foam stability after 5 minutes is highly measured.

4. Results and Discussion
4.1 Characterization of BPPC
A, B, C, and D were structurally confirmed by IR separately. Detailed analysis data for BPPC are as follows. IR: 1715-1760 cm⁻¹ (C=O), 1680-1620 cm⁻¹ (-CH=CH⁻), 1340-1380 cm⁻¹ (CH₃), 1210-1275 cm⁻¹ (-O⁻), 1110-1225 cm⁻¹ (-CH₂CH₂O⁻), 750-810 cm⁻¹ (ph-H) and 725-780 cm⁻¹ (CH₂) [8]. The peak of –OH group at about 3429 was very faint, however, the new peak appeared at 1749.26 assigned to C=O was very strong. It indicated that the actions of epoxidation and carboxymethylation have been carried out successfully. A, B, C, and D are confirmed by IR structure. The detailed analysis data of BPPC is as follows IR: 1715-1760 cm⁻¹ (C=O), 1680-1620 cm⁻¹ (-CH=CH⁻), 1340-1380 cm⁻¹ (CH₃), 1210-1275 cm⁻¹ (-O⁻), 1110-1225 cm⁻¹ (-CH₂CH₂O⁻), 750-810 cm⁻¹ (ph-H), 725-780 cm⁻¹ (CH₂) [8]. The -OH group had a very weak peak at around 3429, while the C=O group had a very strong new peak at 1749.26. The results show that both epoxidation and carboxymethylation have achieved good results. Elemental analysis results are shown in Table 1. The experimental value is very close to the expected value. We can draw a preliminary conclusion that the BPPC synthesized in this paper conforms to the theoretical structure.

Table 1 Elemental analysis of biological phenol polyoxyethylene-carboxylates modified anionic-nonionic surfactants

| Compounds | Units of EO | %C  | %H  | %O  |
|-----------|-------------|-----|-----|-----|
|           |             | Cale. | Found | Cale. | Found | Cale. | Found |
| A         | 8           | 63.93 | 64.36 | 8.88 | 9.33 | 24.04 | 24.39 |
| B         | 10          | 62.39 | 60.15 | 8.90 | 8.72 | 25.37 | 27.69 |
| C         | 12          | 62.11 | 60.79 | 8.92 | 8.89 | 26.43 | 28.15 |
| D         | 14          | 61.45 | 60.84 | 8.94 | 9.02 | 27.31 | 28.69 |

4.2 Surface Parameters
The surface tension values of aqueous solutions of BPPC with different concentrations at 25 °C were measured by the drop volume method. Figure 1 shows the surface tension and concentration. As shown in Figure 1, the critical micelle concentration of BPPC is low and it exhibits good surface activity at 25 °C [9, 10]. Due to the similar structure, the change trend of each cell is roughly the same. The surface tension value increases with the increase of the length of the non-ionic

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polyoxyethylene chain. This may be due to the decrease in surfactant on the [11] surface due to hydrophilicity.

![Surface Tension Graph](image)

**Fig. 1** Concentration dependence of the surface tension of BPPC in aqueous solution at 25°C

### 4.3 Foaming properties

In the process of developing new washing products [13], it is of great significance to test the foaming properties of the products. Foaming ability and stability tests were performed at different surfactant concentrations. Obviously, the foamability of BPPC increases with increasing concentration. When the surfactant concentration reaches a certain value, the foam height does not change. There was no significant difference in the foaming properties of the four surfactants. The research on foaming capacity also shows that the foaming height of BPPC-12 is generally higher than other materials. Hydrophilic hydrated EO chains form hydrophilic groups of molecular hydrogen bonds on the molecular surface or cross-cut mutual adsorption at the gas-liquid interface will gradually strengthen the surface film. Therefore, the product has a relatively good foaming ability and foam stability Sex. As the concentration of the surfactant solution increases, the concentration of the hydrophilic photovoltaic group increases, and the foaming ability and foam stability gradually increase, but when the concentration reaches a certain level, the hydrophobic chain of EO starts to rise, so the foaming ability and foam stability hardly changed. The foam height was measured by settling for 5 minutes, and the foam stability was visually observed (see Figure 3). The foam produced by BPPC-12 was more stable than the foam produced by bppc-8, 10, and 12 [14-16].
It can be seen from Fig. 4 that at a Ca$^{2+}$ and Mg$^{2+}$ concentration of 0.35%, the surfactant solution produces the lowest foam height. Because the -CH$_2$COO$^-$ group has poor resistance to hard water, it easily forms a curd-like substance with Ca$^{2+}$ and Mg$^{2+}$. The foam height of BPPC decreases with the increase of Ca$^{2+}$ and Mg$^{2+}$ concentrations. The detection results of BPPC-10, BPPC-12 and BPPC-14 were not significantly different. Similar results were obtained with increasing Ca$^{2+}$ and Mg$^{2+}$ concentrations. Foaming capacity and stability studies show that the new surfactant BPPC has good foaming properties at the concentrations studied$^{[17]}$. 

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**Fig. 2** Influence of concentration on foam height of surfactant solutions

**Fig. 3** Foam stability of BPPC
Fig. 4 Influence of concentration of Ca\(^{2+}\) and Mg\(^{2+}\) on foam height

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