

To Explore the Effect of Different EO Number AES on the Performance of Hand Sanitizer

Lingdan Fang^{1*}, Ruijie Xiang², Huiye Cao¹, Tian Zhong¹, Yinghui Chen¹, Junhao Ding¹

¹ Zanyu Technology Group Co., Ltd., Hangzhou, China

² Zhejiang Gongzheng Inspection Center Co., Ltd., Hangzhou, China

*Correspondence: Lingdan Fang

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Abstract:

In hand sanitizers with AES and CAB as the main surfactants, an application study was conducted on AES with different EO numbers and CAB with different carbon chains, and comparisons of foam, viscosity, and irritation properties were investigated. The experimental results show that as the EO number increases, the foam of the hand sanitizer decreases, and the irritation decreases accordingly. With the increase of the EO number, the amount of sodium chloride added to the hand sanitizer increases, and the viscosity is relatively low.

Keywords:

Hand Sanitizer, Foam, Irritating

1. Introduction

In modern society, health and hygiene have become major concerns in people's daily lives. As the part of the body that comes into frequent contact with the external environment, hands are highly susceptible to various bacteria, viruses, and dirt, making them important vectors for disease transmission. According to statistics from the World Health Organization (WHO), hand-borne diseases account for a considerable proportion of various infectious diseases, such as influenza and intestinal infectious diseases. Therefore, maintaining hand cleanliness is of critical significance for preventing the occurrence and spread of diseases.

Hand sanitizer, as a care product specifically designed for hand cleaning, plays an indispensable role in personal hygiene. With continuous technological advancements and increasing consumer demands for health and quality of life, the hand sanitizer market has shown vigorous growth, and the variety of products has become increasingly diverse, including general-purpose hand sanitizers, antibacterial hand sanitizers, moisturizing hand sanitizers, and children's hand sanitizers, to meet the specific needs of different groups of people in different scenarios.

Sodium fatty alcohol polyoxyethylene ether sulfate (AES) has become one of the core ingredients in hand sanitizer formulations due to its excellent surface activity, detergency, and foaming performance. The length of the ethylene oxide (EO) chain

segment in the molecular structure of AES, i.e., the EO number, has a significant impact on its physicochemical properties and performance in formulations. AES with different EO numbers may exhibit varying characteristics in hand sanitizer systems, such as detergency, emulsification, solubilization, and foaming, thereby affecting the overall quality and user experience of hand sanitizers. Therefore, in-depth research on the application of AES with different EO numbers in hand sanitizers holds important practical significance.

1.1. Raw Materials and Instruments

Raw materials: Sodium fatty alcohol polyoxyethylene ether sulfate (AES), fatty amide propyl betaine (CAB), fatty amide propyl betaine (C12AB) are all industrial products of Zanyu Technology Group Co., Ltd. Kathon (Shanghai Huiheng Industrial Co., Ltd.), citric acid monohydrate (manufactured by Shandong Yingxuan Industrial Co., Ltd.), tetrasodium glutamate diacetate (Hebei Chengxin Group Co., Ltd.)

Instruments: Whiteness meter, model: WSD-3U, Beijing Kangguang Optical Instruments Co., Ltd.; Vertical detergency tester, model: RHLQ-III, China Research Institute of Daily Chemical Industry; 2151 Ross-Miles foam tester, water bath, model: XMTD-8222, Shanghai Jinghong Experimental Equipment Co., Ltd.; Brookfield DV-II viscometer; Kjeldahl nitrogen analyzer, model: K1160, Shandong Hanon Scientific Instruments Co., Ltd.

1.2. Experimental Methods

1.2.1. Viscosity determination of hand sanitizer

Tested according to GB/T 5561—2012 “Surface active agents — Determination of viscosity and flow properties using a rotational viscometer”. The prepared samples were dispensed into 100 mL plastic bottles, kept in a water bath at 25 °C for 2 hours, and then measured using a Brookfield DV-II viscometer at an appropriate rotational speed.

1.2.2. High and low temperature stability of hand sanitizer

According to GB/T 34855-2017 “Hand cleaner”, high and low temperature stability tests were conducted. 100 mL of the prepared hand sanitizer was placed in a refrigerator at (-5 ± 2) °C for 24 hours, then removed and allowed to return to room temperature to observe its stability; another sample was placed in an incubator at (40 ± 1) °C for 24 hours, then removed and allowed to return to room temperature to observe its stability.

1.2.3. Foam performance test of hand sanitizer

According to “GB/T Surface active agents — Determination of foaming power — Improved Ross-Miles method”. The test sample was prepared as a 0.25% (mass fraction) solution using hard water with a concentration of 150 mg/L. At (40 ± 0.5) °C, the initial foam height and the foam height after 5 minutes were recorded. Foaming ability was compared using the initial foam height, and foam stability was compared using the ratio of foam height after 5 minutes to the initial foam height.

1.2.4. Irritation performance test of hand sanitizer

Using the zein method, the test sample was prepared as a solution with an active matter mass fraction of 1%. A certain amount of zein was added, and the mixture was stirred at (25 ± 0.5) °C for 2 hours, then filtered. The nitrogen mass fraction in the filtrate was measured by micro-Kjeldahl method. The nitrogen mass fraction in the

sample solution without zein was measured following the same procedure. The irritation strength was determined by the difference in nitrogen mass fraction before and after, with a larger difference indicating stronger irritation.

1.2.5. pH test of hand sanitizer

After calibrating the pH meter, the electrode was immersed in the neat sample at 25 °C, and the reading was taken after the pH meter stabilized. The measurement was performed twice in parallel, with a difference of no more than 0.1 pH units. The pH value of the hand sanitizer was measured using a Mettler Toledo pH meter.

2. Results and Discussion

2.1. Performance Tests and Results

2.1.1. Hand Sanitizer Formulation

Table 1. Basic formulation of hand sanitizer.

Raw Material	Mass fraction %
GLDA-4Na	0.2
AES (70%)	10
CAB (35%)	4
Kathon	0.05
Citric acid	Appropriate amount
Water	Balance
pH(Concentrate)	4 ~ 5

Note: In Table 1, AES is replaced with AES of different EO numbers for comparison; CAB is replaced with mixed-carbon CAB and C12AB for comparison.

2.1.2. Viscosity of Hand Sanitizer Formulations

After adjusting the pH of the hand sanitizer to 4–5 with citric acid, different amounts of sodium chloride were added to plot the viscosity curve. Viscosity: As the EO number increases, the salt tolerance of AES improves. This is because a higher EO number helps enhance the flexibility of the AES molecular chain, making it more stable in high-salt environments. The viscosities of mixed-carbon CAB and C12AB are similar, as shown in Figure 1 below.

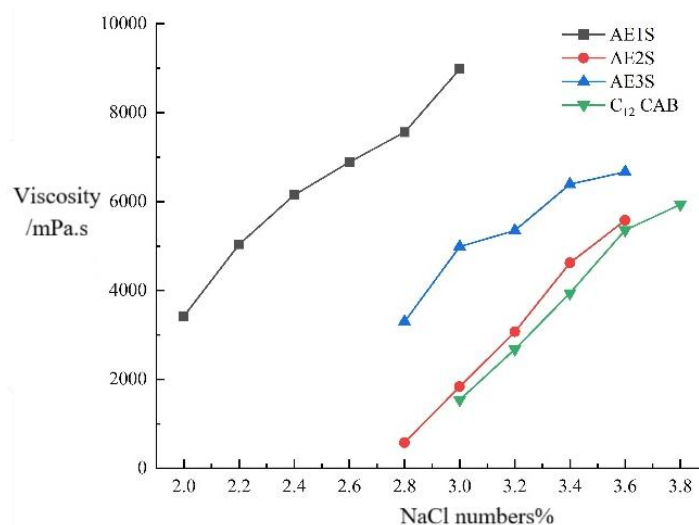


Figure 1. Viscosity curves of AES with different EO numbers.

2.1.3. Foam of Hand Sanitizer

The hand sanitizer exhibits good foaming performance. AES with a lower EO number produces richer foam. This is because the hydrophobic portion of its molecular structure accounts for a larger proportion, making it easier to form a tightly arranged monomolecular layer at the air-liquid interface in an aqueous solution. This tight arrangement makes the foam walls more stable, allowing them to hold more gas, thus generating abundant foam.

Preparation of test sample: Weigh 10 g of the test sample, mix well with hard water at a concentration of 150 mg/kg, then dilute to 100 mL with hard water at 150 mg/kg.

Test procedure: Take 40 mL of the prepared test solution and place it into the test cup, then start the test according to the procedure in Table 2.

Table 2. Example of Sample Testing Conditions.

	Test solution
Foaming mode selection	Bubbling
Automatic program settings	Gas pumping volume: 0.15L
	Gas flow rate: 0.3L/min
Height illumination	Blue light wavelength $\lambda = 469$ nm
Sample concentration	100mg/L

2.1.3.1. Effect of AES with Different EO Numbers on Foam

According to the formulation in Table 1, the effect of AES with different EO numbers on the foam of hand sanitizer was investigated. As shown in Figure 2, the foamability and foam stability are comparable, with the defoaming rate following the order: AE1S > AE3S > AE2S.

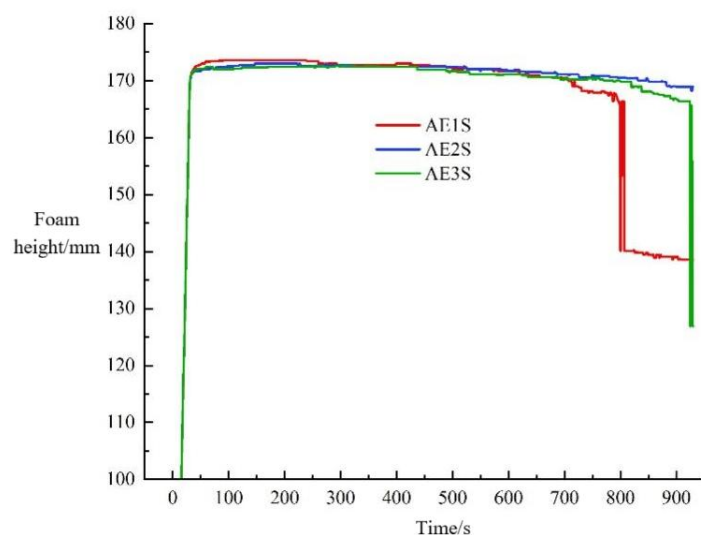


Figure 2. Comparison of Foam Heights of AES with Different EO.

2.1.3.2. Analysis and Characterization of Foam Stability of AES with Different EO Numbers

Foam stability mainly depends on the drainage rate and liquid film strength [8]. Therefore, a comprehensive evaluation using both the drainage half-life and the bubble count half-life can provide a more complete analysis of foam stability. As shown in Table 3, TFLS 50% represents the time at which 50% of the liquid within the foam is lost. A shorter time indicates a faster drainage rate, which is detrimental to

foam stability. Thus, AE2S exhibits the best foam stability. $t_{BC\ 1/2}$ represents the half-life of bubble count. The faster the bubble count decays, the poorer the foam stability. Therefore, the data in the table indicate that foam stability follows the order: AE2S > AE3S > AE1S.

Table 3. Results of the important parameters of foam stability.

	AE ₁ S	AE ₂ S	AE ₃ S
$t_{BC\ 1/2}/S$	116.41	137.39	133.59
$V_{foam\ max}/mL$	209.3	208.1	208.4
$T_{FLS50\%}/S$	221.9	244.9	230.3
$V_{liquid\ foam\ max}/mL$	37.4	37.4	37.4

2.1.4. Irritation Test of Hand Sanitizer

Under the same reaction conditions, the influence of different grades of AES on the irritation of hand sanitizer was investigated. The experimental data obtained by the zein method are shown in Table 4. It can be seen from Table 4 that the hand sanitizer with AE1S shows the strongest irritation, while the hand sanitizer with AE3S shows the weakest irritation. That is, among different grades of AES, a higher EO number corresponds to lower irritation [7]. This is because as the EO number increases, the hydrophilicity of the molecule is relatively enhanced. Its solubility in water improves, and when in contact with the skin, it does not disrupt the lipids on the skin surface as strongly as AES with a low EO number. The results are shown in Table 4.

Table 3. Irritation test results.

Surfactant type	Irritation
AE ₁ S	1.85
AE ₂ S	1.57
AE ₃ S	1.01
C ₁₂ AB	1.53
Mixed-carbon CAB	1.57

3. Conclusions

In this study, hand sanitizers were formulated using different grades of AES (Sodium Alcohol Ether Sulphate). By systematically investigating the differences in application performance—such as foaming capacity, viscosity, and salt responsiveness—a theoretical basis for hand sanitizer formulation is provided. The main conclusions are as follows: In hand sanitizers using AES as the primary surfactant, AES with a lower ethylene oxide (EO) number produces richer and more abundant foam. Furthermore, in hand sanitizers formulated with different grades of AES, a lower EO number requires a lower amount of sodium chloride to achieve optimal thickening, yet results in higher final viscosity compared to higher EO grades. These findings provide a clear and practical scientific basis for hand sanitizer manufacturers in selecting appropriate AES raw materials and optimizing their formulations to balance foam performance, viscosity, and cost-efficiency.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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