



IFSCC 2025 full paper (IFSCC2025-1445)

## **Research on the Tolerance to Hard Water of a Body Wash**

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### **1. Introduction**

With rising consumer demands for cleansers, Hard water tolerance and cleansing efficacy have become critical performance metrics. Over two-thirds of China, particularly northern regions, faces hard water challenges. Hard water contains soluble calcium and magnesium compounds that react with surfactants, causing flocculation, reduced cleansing efficiency, and potential skin irritation. These issues may also lead to pore clogging, acne, and other skin problems<sup>[1-2]</sup>.

Hard water tolerance refers to a cleanser's ability to maintain performance in hard water. Strategies include adding chelating agents to bind calcium/magnesium ions or using hard water-tolerant surfactants<sup>[3-4]</sup>.

This study developed a body wash with sodium lauroyl sarcosinate as the primary surfactant. Its Hard water tolerance was tested per \*GB/T 7381-2010\*, while DFT and molecular dynamics simulations elucidated its mechanism. Cleansing efficacy for sunscreen and foundation was assessed via VISIA-7, and safety was evaluated through human trials<sup>[5]</sup>.

### **2. Materials and Methods.**

#### **2.1 Materials**

Calcium chloride dihydrate ( $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , Sinopharm Group); deionized water; test body wash (Fufu Acne-Control Body Foam, Uproven Medical Technology); 12 oil-in-water sunscreens, 12 water-in-oil sunscreens, 3 body BB creams, and 3 foundations.

#### **2.2 Methods**

Protocol: \*GB/T 7381-2010\*. Surfactant solutions (0.03%, 0.06%, 0.12%, 0.25%, 0.5%) were mixed with hard water (6, 9, 12 mmol/L  $\text{Ca}^{2+}$ ). After 2-hour incubation at 20°C, samples were scored: Clear (5), milky (4), turbid (3), slight precipitate (2), heavy precipitate (1).

Total scores determined stability levels (1 = poor; 5 = excellent).

Sunscreen/foundation was applied to six forearm areas, photographed under VISIA-7 UV light, cleansed for 1–2 min, and re-photographed after 15-minute drying.

Adverse reactions were graded per 2015 Cosmetic Safety Technical Specifications:

0 (none), 1 (mild erythema), 2 (erythema/infiltration), 3 (erythema/edema), 4 (severe erythema/blisters).

Volunteers rated the product post-use (7/14 days) via questionnaire (A = strongly agree; E = strongly disagree). Agreement % = (A+B responses)/total × 100%.

Density Functional Theory (DFT) and molecular dynamics simulations were employed to investigate the surfactant-calcium ion docking mechanism.

### 2.3 Instruments

50 mL plastic bottles; 1000 mL glass beakers; 100 mL graduated cylinders; 1000  $\mu$ L pipettes (Dragon Lab, Beijing); VISIA-7 (Canfield, USA).

### 2.4 Volunteers

30 volunteers (aged 18–36, randomized gender) were recruited, excluding individuals meeting Diagnostic Criteria and Management Principles for Cosmetic Contact Dermatitis.

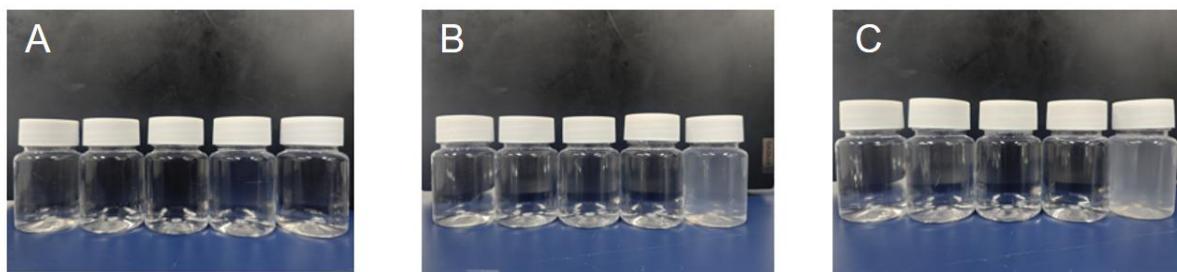
## 3. Results

### 3.1 Hard water tolerance

As shown in table 1, scores reached 73/75 (Level 4). Only 9/12 mmol/L  $\text{Ca}^{2+}$  with 0.5% surfactant showed milky appearance (Figure 1).

**Table 1.** Appearance State Scores of Samples at Different Concentrations

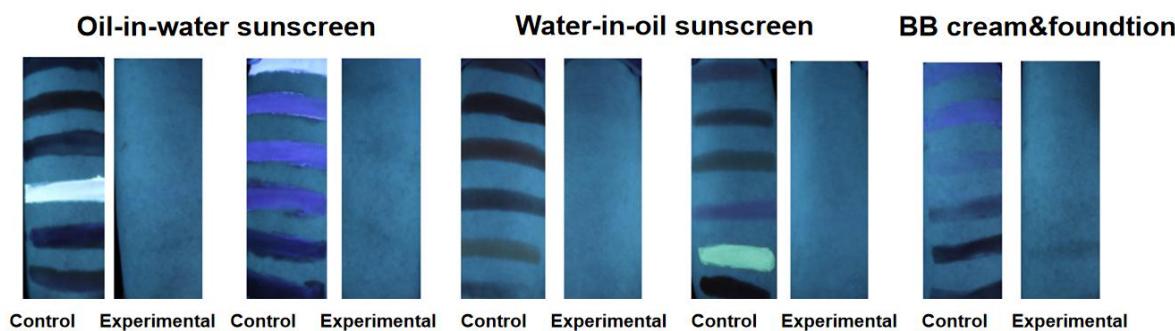
Calcium Ion Concentration	Appearance State Scores					Total Score
	0.3mL	0.6mL	1.2mL	2.5mL	5mL	
6mmol/L	5	5	5	5	5	
9mmol/L	5	5	5	5	4	73
12mmol/L	5	5	5	5	4	



**Figure 1.** Hard water tolerance test results (A:6mmol/L,B:9mmol/L,C:12mmol/L)

### 3.2 Cleansing Efficacy

The body wash effectively removed sunscreen and foundation (Figure 2).



**Figure 2.** Sunscreen cleansing efficacy test results of the body wash

### 3.3 Safety

No adverse reactions were reported among 30 volunteers (Table 2).

**Table 2.** Adverse Reactions Observed in Volunteers During Product Use

Test Period	Number of Participants	Skin Adverse Reactions				
		0	1	2	3	4
After 7-day use	30	30	0	0	0	0
After 14-day use	30	30	0	0	0	0

### 3.4 Subjective Feedback

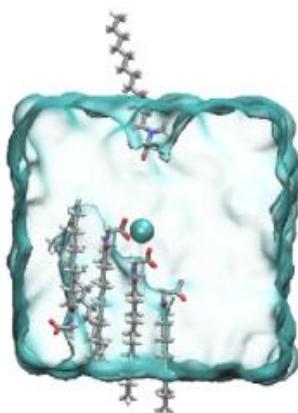
100% agreed on strong cleansing, non-slippery feel, and mildness (Table 3).

**Table 3.** Subjective User Satisfaction Ratings

Questionnaire Items	After 7-day Use		After 7-day Use
	After 7-day Use	After 7-day Use	After 7-day Use
"The product has strong cleansing efficacy"	100%		100%
"No slippery residue after washing"	100%		100%
"The product is mild and non-irritating"	100%		100%

### 3.5 Molecular mechanism

Sodium Lauroyl Sarcosinate(SLS) was applied as the main surfactant in the formula. As shown in Figure 3, calcium ions could be effectively stabilized forming a salt bridge effect under the action of SLS. In the formed molecular clusters, the distance between calcium ions with SLS was 2.74Å which calculated by DFT.



**Figure 3. The Molecular dynamics simulation process diagram calculated based on DFT theory. Spherical represents calcium ions.**

#### 4. Discussion

This study assessed a SLS-based body wash using \*GB/T 7381-2010\* for Hard water tolerance. While VISIA-7 tests demonstrated effective removal of sunscreen, BB cream, and foundation. Human trials confirmed its mildness (Level 4 Hard water tolerance). Results revealed a stable salt bridge formation ( $\text{Ca}^{2+}$ -SLS distance: 2.74 Å), explaining the surfactant's high hard water tolerance.

#### 5. Conclusion

The constructed evaluation model is scientific and intuitive and can be effectively used for the performance evaluation and function research of liquid cleaning products.

#### References

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