Support information

1. Synthesis of SLBA

LBA, betaine, and mandelic acid were synthesized into SLBA with different molar ratios (1:1:1, 2:1:1, 1:2:1, 2:1:1, 2:2:1, 1:1:2, 1:2:2), and the results are shown in the **Table S1.** The SLBA with the molar ratio of 1:1:1 was selected for subsequent experiments and its 60-day stability at different temperatures was investigated (**Figure S1**).

Table S1 Different mole ratio of SLBA feature

	LBA	Betaine	Mandelic acid	Feature
Ratio	1	1	1	Transparent light yellow liquid
	2	1	1	Transparent light yellow liquid
	1	2	1	Transparent light yellow liquid
	2	1	1	Transparent light yellow liquid
	2	2	1	Transparent light yellow liquid
	1	1	2	Turbid white liquid
	1	2	2	Viscous solid

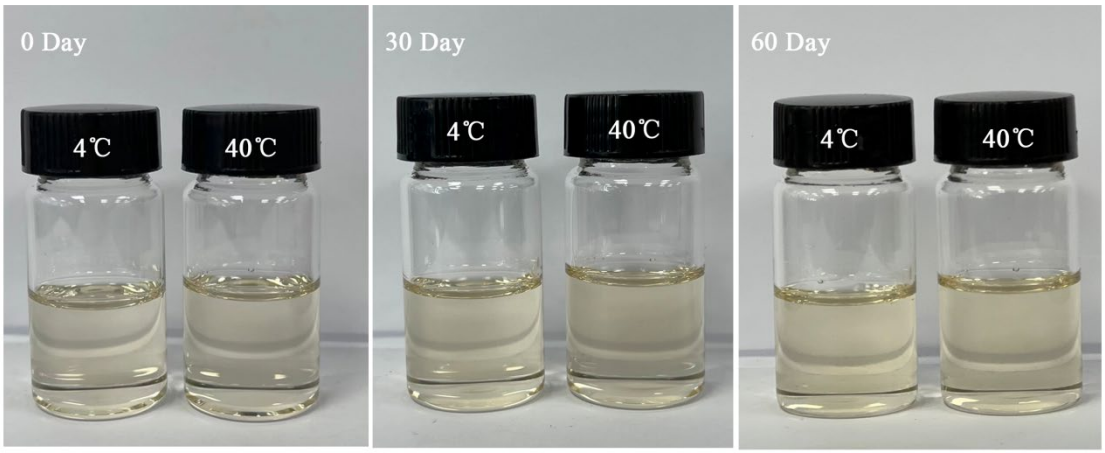

Figure S1. Stability test of SLBA

2. Characterization of SLBA

NMR and FTIR are the most common characterization methods for supramolecular structures, which can intuitively reveal the key to supramolecular binding - the formation and position of hydrogen bonds. The comparison of NMR spectra between SLBA and its components is shown in **Figure S2**. Betaine acts as a hydrogen bond acceptor, and the characteristic peak corresponding to $-N(CH_3)_3$ (**Figure S2(B) a**) is 3.23 ppm. Influenced by electron donating groups (-OH, -COOH, $-O^-$), the electron cloud density around the hydrogen nucleus increases, the shielding effect strengthens, and a high-field chemical shift is generated. That is, the characteristic peak corresponding to $-N(CH_3)_3$ (**Figure S2(A) b**) is 3.18 ppm. Mandelic acid (**Figure S2(C) c**, 7.30 ppm) and LBA (**Figure S2(D) e**, 4.42 ppm), as hydrogen bond donors, are influenced by the strong electron-withdrawing groups of $-N(CH_3)_3$ when combined with betaine. The electron cloud density around the hydrogen nucleus decreases, the shielding effect decreases, and the characteristic peak chemical shift shifts towards a lower field

(**Figure S2(A) d**, 7.38 ppm). In addition, LBA forms hydrogen bonds with mandelic acid and betaine, leading to a decrease in electron cloud density around the hydrogen nucleus and an increase in low-field chemical shifts (**Figure S2(A) f**, 4.49 ppm).

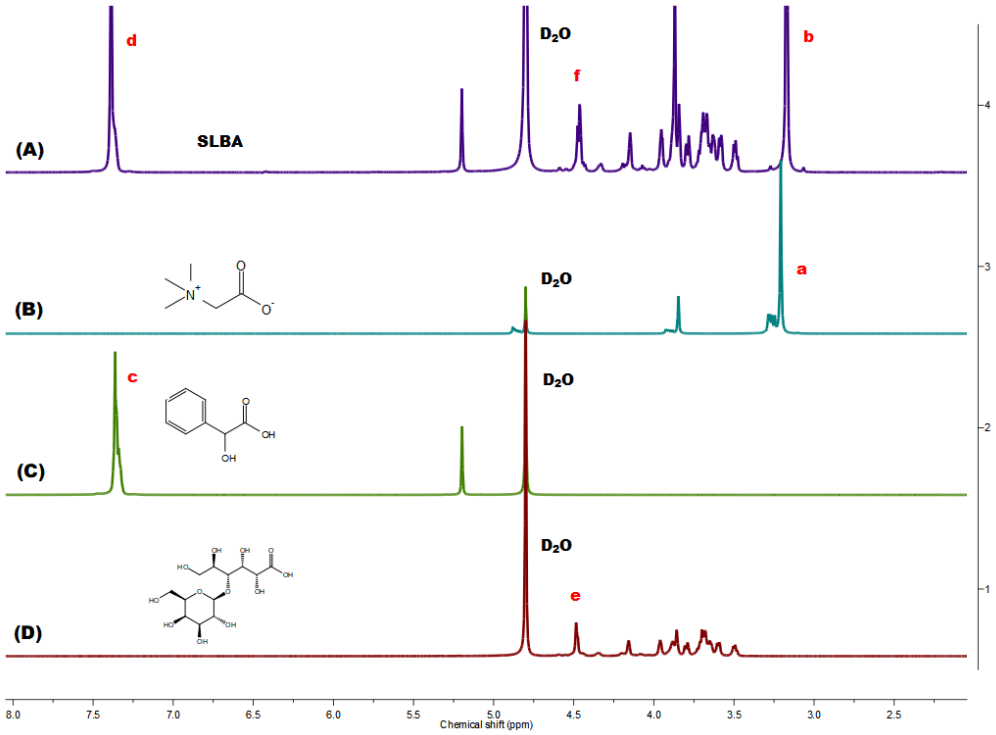

Figure S2. NMR of SLBA and components

Two-dimensional NMR NOESY spectra revealed the Cross peaks of SLBA at δ(H) = 3.18~5.25 ppm and 7.30~7.50 ppm, corresponding to the active hydrogen shift mentioned above (**Figure S3**). The results displayed by NMR fully indicate that the formation of SLBA is due to the interaction of hydrogen bonds between components, which causes protons to approach each other in space, consistent with the DFT calculation prediction (**Figure 1**).

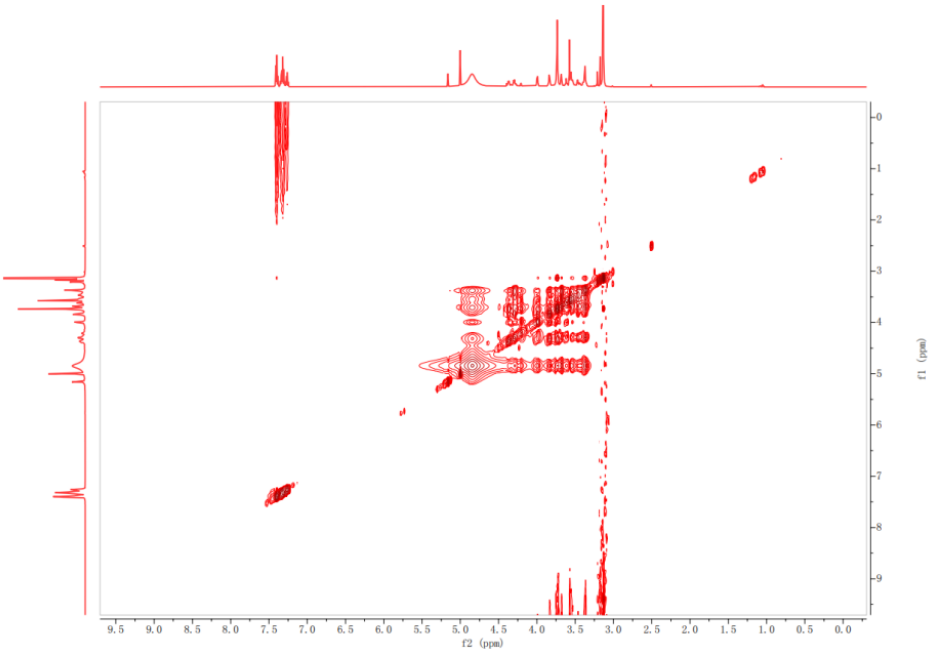

Figure S3. 2D-NMR NOESY spectra of SLBA

FTIR spectra of SLBA and its components also exhibited the same molecular behavior as mentioned above (**Figure S4**). The induction effect of SLBA caused the electron-withdrawing group (-$N(CH_3)_3$, 3300~3200 cm^{-1}) to shifted blue 3650 cm^{-1}, and the -OH stretching peak of LBA (1200~1000 cm^{-1}) was also slightly blue shifted (1250~1050 cm^{-1}) due to its influence. The hydrogen bonding effect of SLBA caused the electron-donating group (-COOH) to shift red, with C=O (1760 cm^{-1}) shifted to 1710 cm^{-1} and the -OH (3300 cm^{-1}) shifted to 3000 cm^{-1}, which was also the reason for the formation of the large broad peak (3650~3000 cm^{-1}) of SLBA.

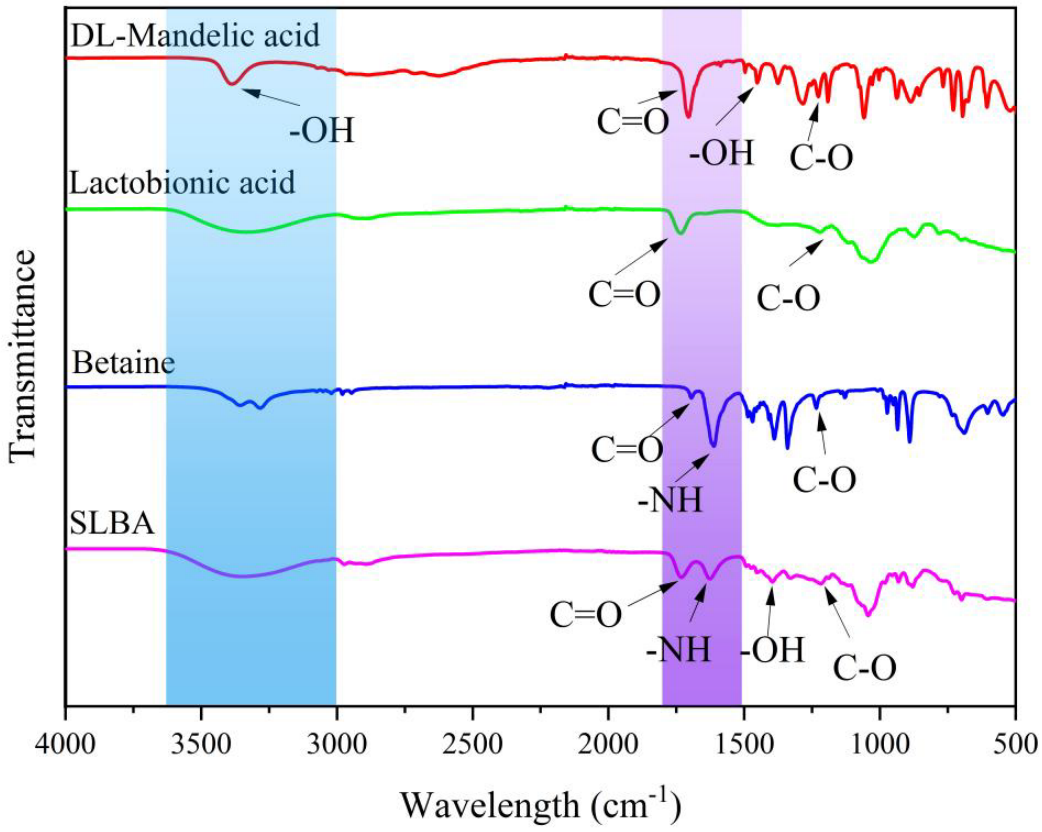

Figure S4. FTIR of SLBA and components

Transmission electron microscopy (TEM) can clearly observe the supramolecular morphology of SLBA, which was aggregated in a spherical shape and uniformly distributed (**Figure S5**).

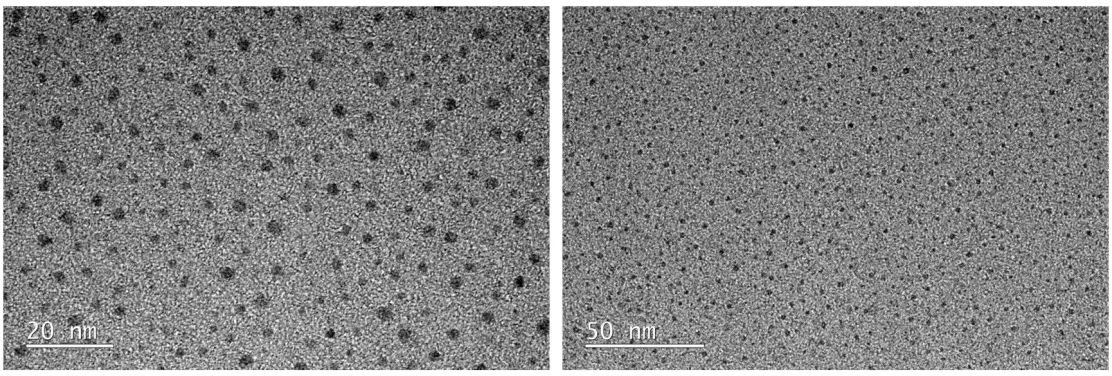

Figure S5. TEM of SLBA

Differential scanning calorimeter (DSC) can monitor the temperature related to the internal thermal transformation of materials, reflecting the thermal effect of materials. The glass transition temperature (Tg) can indirectly characterize the molecular structure of materials, such as when the intermolecular interaction force is strong, Tg is higher, and vice versa. The DSC of SLBA, as shown in **Figure S6**, exhibited a typical Tg, which was the result of the formation of supramolecules through hydrogen bonding between components.

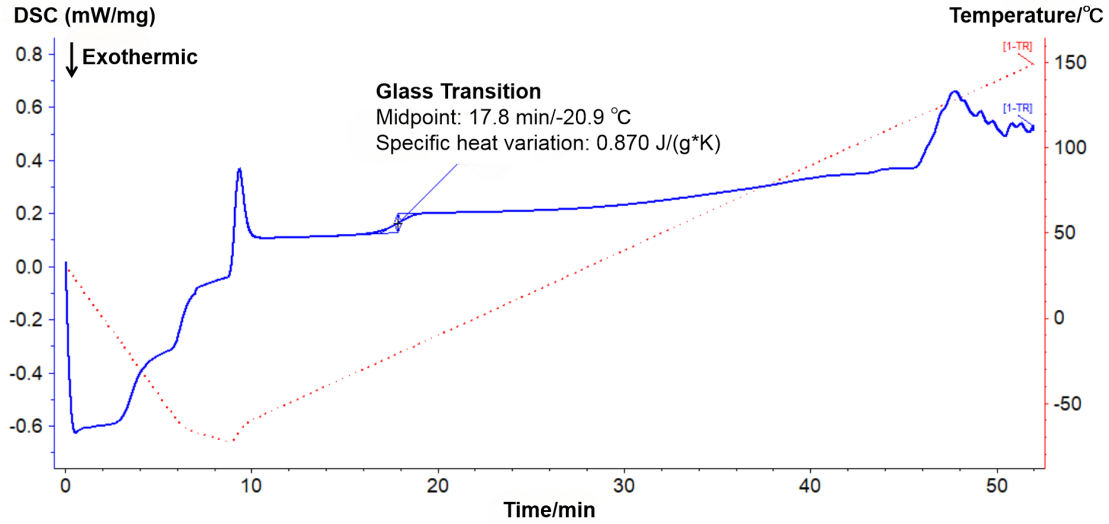

Figure S6. DSC of SLBA

3. Moisture Retention of SLBA

In vitro moisturizing effects of SLBA, LBA and glycerol at 10% concentration were compared in a dryer (Saturated ammonium sulfate, 25℃, 91%RH) and recorded at 0.5h, 1.5h, 3.5h and 5.5h, respectively. SLBA has the best moisturizing effect, especially in the short-term effect, for example, the moisturizing effect of SLBA at 0.5h increased by 51.7% and 42.36% compared with LBA and glycerin, respectively (**Figure S7**).

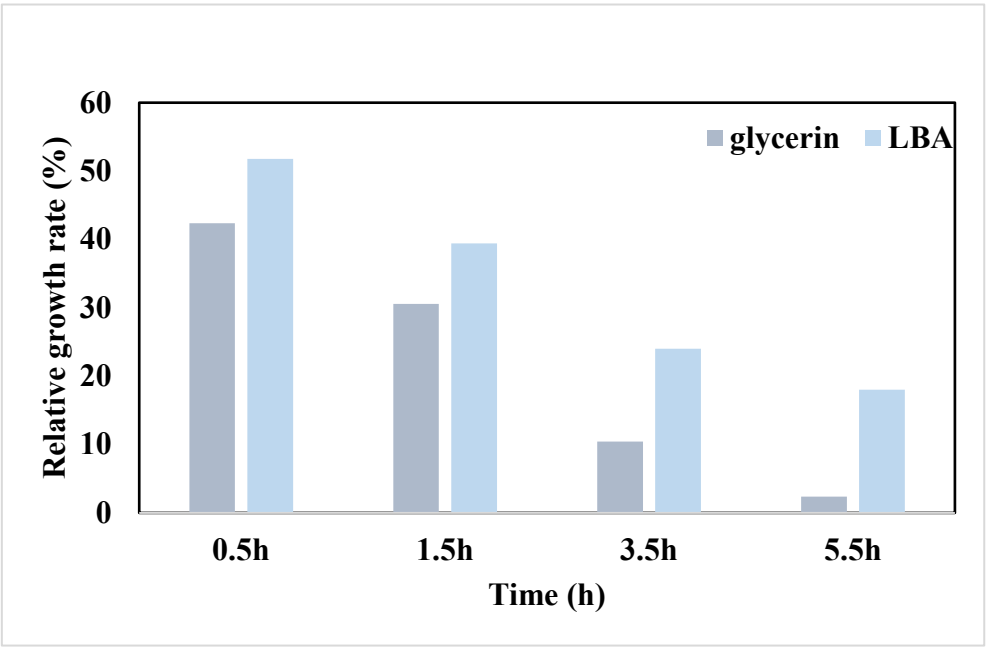

Figure S7. Increased moisturizing effect of SLBA compared to LBA and glycerin

After confirming the superior short-acting moisturizing ability of SLBA, we further evaluated the weight loss rate of SLBA under different concentrations in the constant temperature very wet dryer (Saturated ammonium sulfate, 25℃, 91%RH), and the results showed that the weight loss rate of each concentration was almost the same at 0.5h (**Figure S8**).

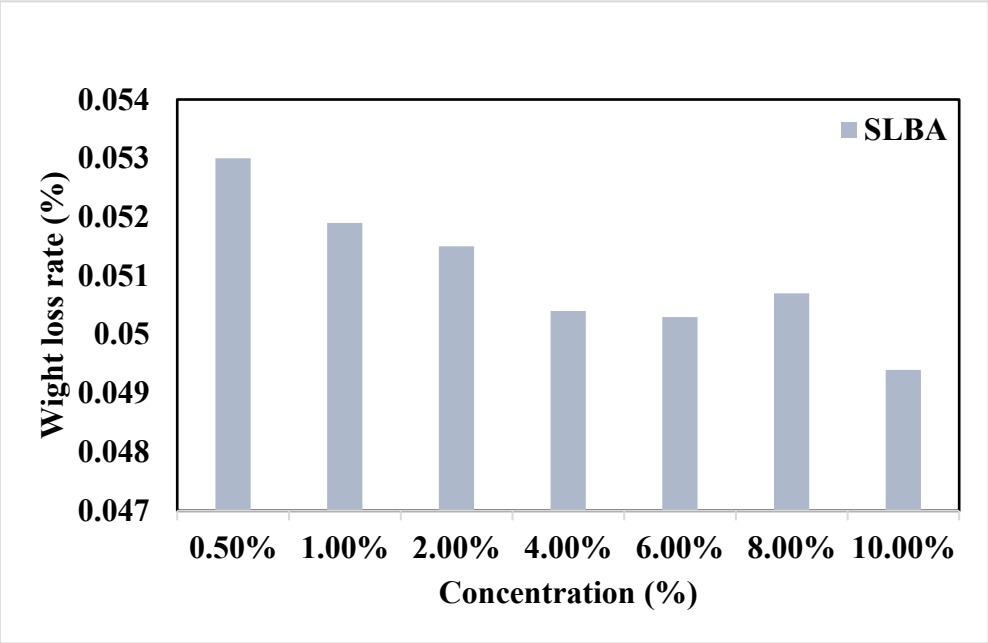

Figure S8. Weightlessness rate of SLBA

4. Permeability test of SLBA

SLBA and LBA were tested at different concentrations in Franz diffusion cell for 24h, and the results showed that SLBA had better permeability and absorption effect than LBA (**Figure S9**).

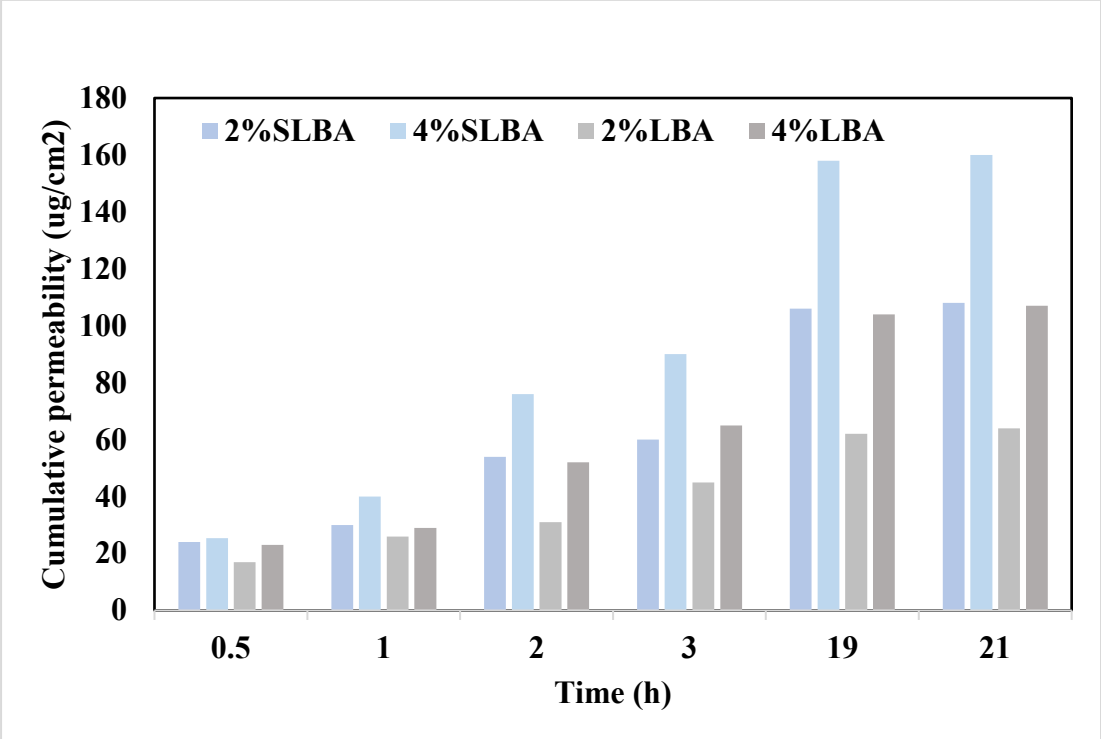

Figure S9. Percutaneous penetration

5. Safety testing of animals

SLBA and LBA were respectively used for acute skin irritation tests on New Zealand rabbits, and it was observed that the highest integral homogeneity at each time point was 0, indicating that both samples were non-irritating (**Table S2-3**).

Table S2 Acute skin irritation tests of LBA

Animal NO.	1h						24h						48h						72h					
	LBA			BC			LBA			BC			LBA			BC			LBA			BC		
	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IM		0			0			0			0			0			0			0			0	

Erythema(ER), Edema(ED), Total score(TS), Integral mean(IM).

Table S3 Acute skin irritation tests of SLBA

Animal NO.	1h						24h						48h						72h					
	SLBA			BC			SLBA			BC			SLBA			BC			SLBA			BC		
	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS	ER	ED	TS
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IM		0			0			0			0			0			0			0			0	

Erythema(ER), Edema(ED), Total score(TS), Integral mean(IM).

Multiple acute irritation skin tests were performed on Hartley Cavia porcellus and the skin irritation response was integrated. 8 Hartley Cavia porcellus showed no abnormal symptoms, no erythema, no edema, no death for 14 days, and all integral values were 0 (**Table S4-5**)

Table S4 Multiple acute skin irritation tests of LBA

Infected days	Quantity	Stimulus response integral					
		LBA			BC		
		ER	ED	TS	ER	ED	TS
1	4	0	0	0	0	0	0
2	4	0	0	0	0	0	0
3	4	0	0	0	0	0	0
4	4	0	0	0	0	0	0
5	4	0	0	0	0	0	0
6	4	0	0	0	0	0	0
7	4	0	0	0	0	0	0
8	4	0	0	0	0	0	0
9	4	0	0	0	0	0	0
10	4	0	0	0	0	0	0
11	4	0	0	0	0	0	0
12	4	0	0	0	0	0	0
13	4	0	0	0	0	0	0
14	4	0	0	0	0	0	0
14 days IM per animal			0			0	
IM per animal per			0			0	

Erythema(ER), Edema(ED), Total score(TS), Integral mean(IM).

Table S5 Multiple acute skin irritation tests of SLBA

Infected days	Quantity	Stimulus response integral					
		SLBA			BC		
		ER	ED	TS	ER	ED	TS
1	4	0	0	0	0	0	0
2	4	0	0	0	0	0	0
3	4	0	0	0	0	0	0
4	4	0	0	0	0	0	0
5	4	0	0	0	0	0	0
6	4	0	0	0	0	0	0
7	4	0	0	0	0	0	0
8	4	0	0	0	0	0	0
9	4	0	0	0	0	0	0
10	4	0	0	0	0	0	0
11	4	0	0	0	0	0	0
12	4	0	0	0	0	0	0
13	4	0	0	0	0	0	0
14	4	0	0	0	0	0	0
14 days IM per animal			0			0	
IM per animal per			0			0	

Erythema(ER), Edema(ED), Total score(TS), Integral mean(IM).

6. Antioxidant experiments in animals

The oxidative damage mice were divided into groups, and different doses of drugs were applied to observe their antioxidant capacity.

Table S6 Dosage and grouping of antioxidant experiments

Group	Subject	Dosage	Concentration	Quantity
BC	Ultra-pure water	0.1mL/per	/	5
Model group		0.1mL/per	/	5
2%LBA	LBA	2mg/per	20mg/mL	5
4%LBA		4mg/per	20mg/mL	5
0.1%SLBA	SLBA	0.1mg/per	1mg/mL	5
0.5%SLBA		0.5mg/per	5mg/mL	5
2%SLBA		2mg/per	20mg/mL	5
4%SLBA		4mg/per	40mg/mL	5
6%SLBA		6mg/per	60mg/mL	5
8%SLBA		8mg/per	80mg/mL	5

The drugs were administered every other day, and ultraviolet irradiation was performed for 1 h each time. SLBA-1 and SLBA-2 had the best effect on protecting skin from oxidative stress reaction, and the damage degree of skin were the lowest (**Figure S10**).

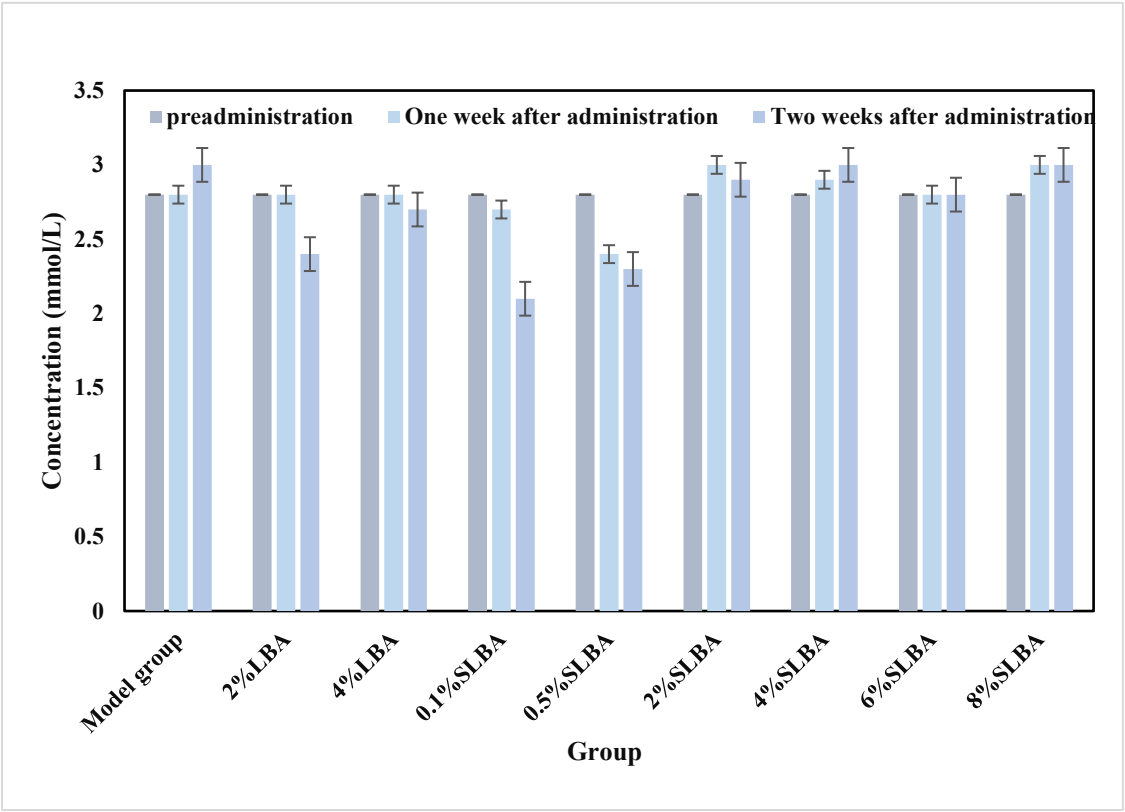

Figure S10. Oxidative damage score of mouse skin by subject

7. Moisturizing experiments in animals

After qualified immunization, 50 rats were divided into 10 groups to compare the immediate

and long-term moisturizing ability of SLBA and LBA (**Table S7**).

Table S7 Dosage and grouping of moisturizing experiments

Group	Subject	Dosage	Concentration	Quantity
BC	NaCl injection	0.25mL/per	/	5
PC	Glycerol	0.25mL/per	/	5
2%LBA	LBA	5mg/per	20mg/mL	5
4%LBA		10mg/per	40mg/mL	5
0.1%SLBA	SLBA	0.25mg/per	1mg/mL	5
0.5%SLBA		1.25mg/per	5mg/mL	5
2%SLBA		5mg/per	20mg/mL	5
4%SLBA		10mg/per	40mg/mL	5
6%SLBA		15mg/per	60mg/mL	5
8%SLBA		20mg/per	80mg/mL	5

8. Clinical patch test

Select appropriate spot testing equipment, place 0.02-0.025mL of the tested substance in the spot tester and apply it to the curved side of the subject's forearm with hyposensitive tape. Remove the tested substance 24 h later and detect skin reactions at 0.5 h, 24 h and 48 h (**Table S8**). None of the 34 subjects had adverse skin reactions.

Table S8 Clinical patch results

Group	Subjects	Time	Skin response level				
			0	1	2	3	4
SLBA	34	0.5h	34	0	0	0	0
		24h	34	0	0	0	0
		48h	34	0	0	0	0
LBA	34	0.5h	34	0	0	0	0
		24h	34	0	0	0	0
		48h	34	0	0	0	0
BC	34	0.5h	34	0	0	0	0
		24h	34	0	0	0	0
		48h	34	0	0	0	0

The skin reaction was graded as 0,1,2,3,4.0: no reaction; 1: Suspicious reaction, weak erythema; 2: erythema reaction with infiltration, edema, and papules; 3: herpes reaction, accompanied by erythema, infiltration, edema, papules, herpes, and beyond the subject area; 4: Fusion herpes reaction with marked erythema, severe infiltration, edema, fusion herpes, and reaction beyond the subject area.