

Supplementary information for

## **Alginate Biopolymers Grafted with *p*-Menthane-3,8-diol: Synthesis and Textile Composite for Sustainable and Efficient Mosquito Repellency**

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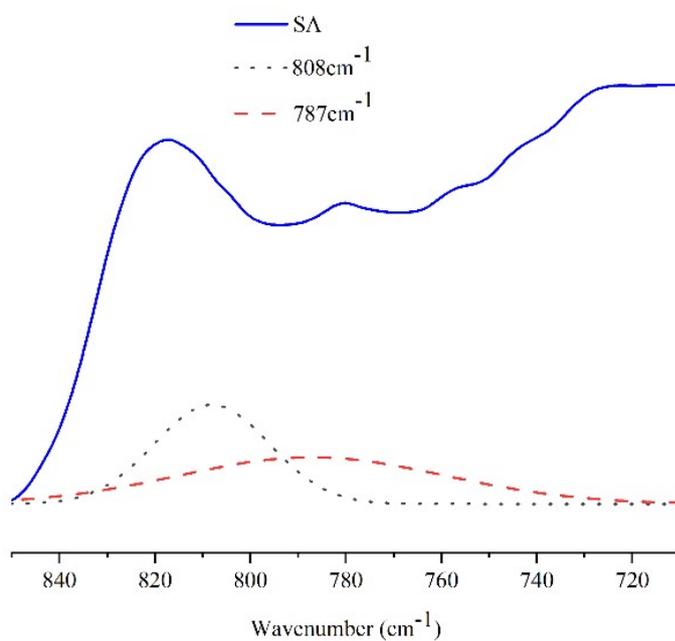
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## 1. The Determination of Composition of Sodium Alginate by Infrared Spectroscopic

### Method.



**Fig. S1** Infrared spectra of sodium alginate and peak resolution.

Sodium alginate with an M/G (D-mannuronic acid to L-gulonic acid) ratio of 1:1 was purchased from Aladdin Chemistry Co., Ltd. The M/G ratio of sodium alginate was further determined on the basis of infrared spectra applying the KBr technique. The M/G ratio was determined as 0.977 which is close to 1 through the estimation of the ratio of absorbances at 787 and 808  $\text{cm}^{-1}$ .

## 2. Preparation of alginate derivatives grafted with *P*-Menthane-3,8-Diol (SA-PMD-4, SA/PMD ratio of 20:1)

At room temperature, 0.5006 g of SA should be dissolved in a 20 mL deionized water. The pH of the solution should be adjusted to 4 with 0.1 mol/L hydrochloric acid solution. Subsequently, 0.0199 g of *p*-menthane-3,8-diol, 0.0221 g of EDC·HCl, and 0.0133 g of NHS were added the solution. The resulting mixture was mechanically stirred for 48 h, after which it was subjected to freeze-drying and washed three times with anhydrous ethanol and dichloromethane, respectively. Subsequently, the washed sample was subjected to vacuum drying at 40°C for 48 h. This process was employed to eliminate the detergent, thereby the 0.4646 g of *p*-menthane-3,8-diol-grafted alginate derivative **SA-PMD-4** was obtained. 89.4% yield.

### 3. Sample images of *P*-Menthane-3,8-Diol -Grafted Alginates

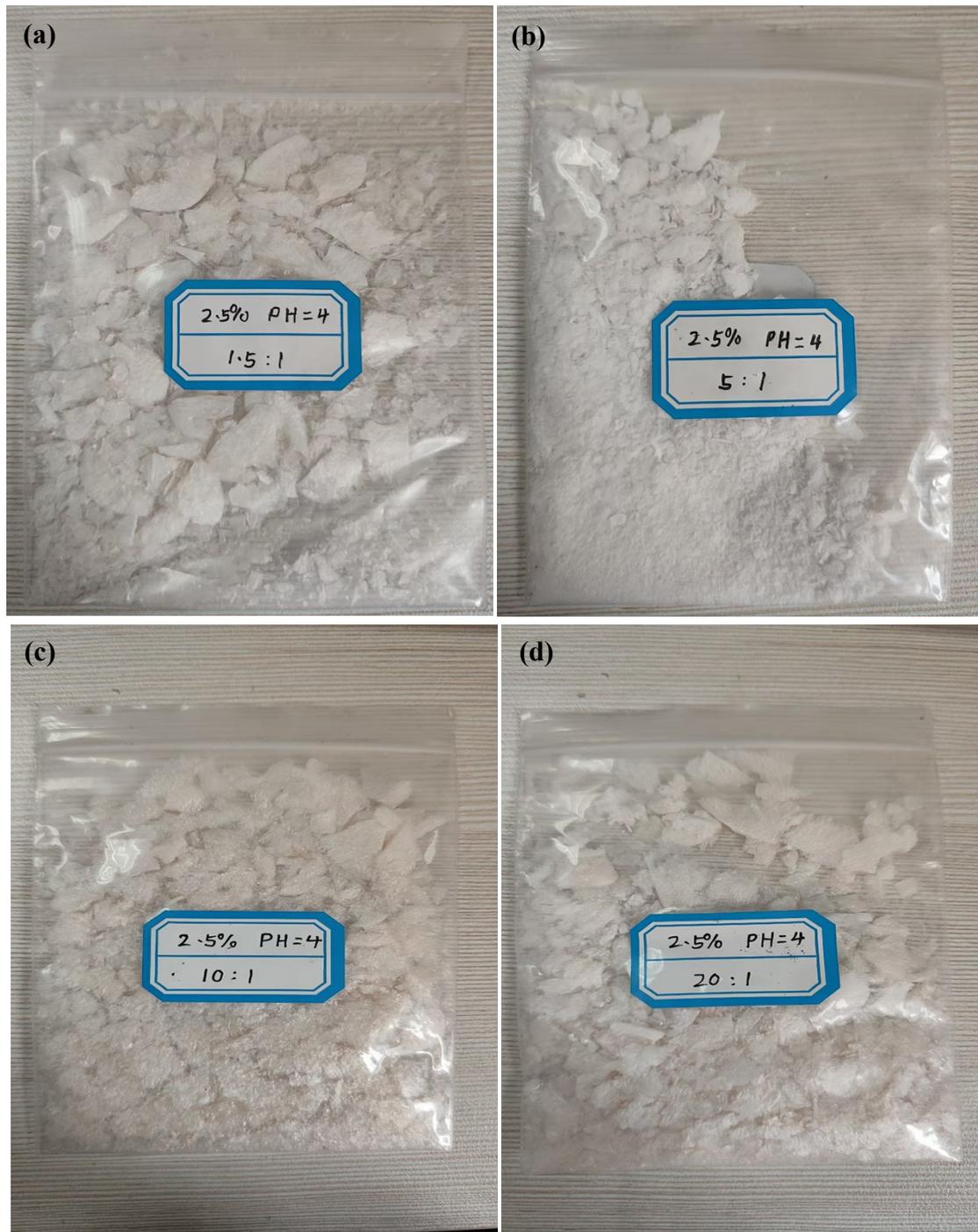


Fig. S2 (a) Samples of SA-PMD-3; (b) Samples of SA-PMD-2; (c) Samples of SA-PMD-1; (d) Samples of SA-PMD-4.

#### 4.1 FTIR Spectra

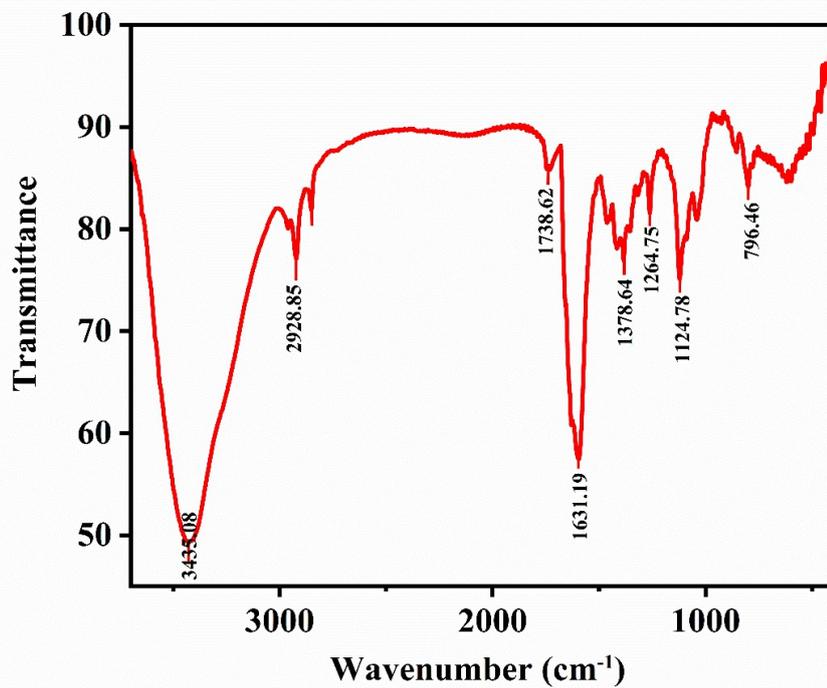


Fig. S3 FTIR of SA-PMD-3.

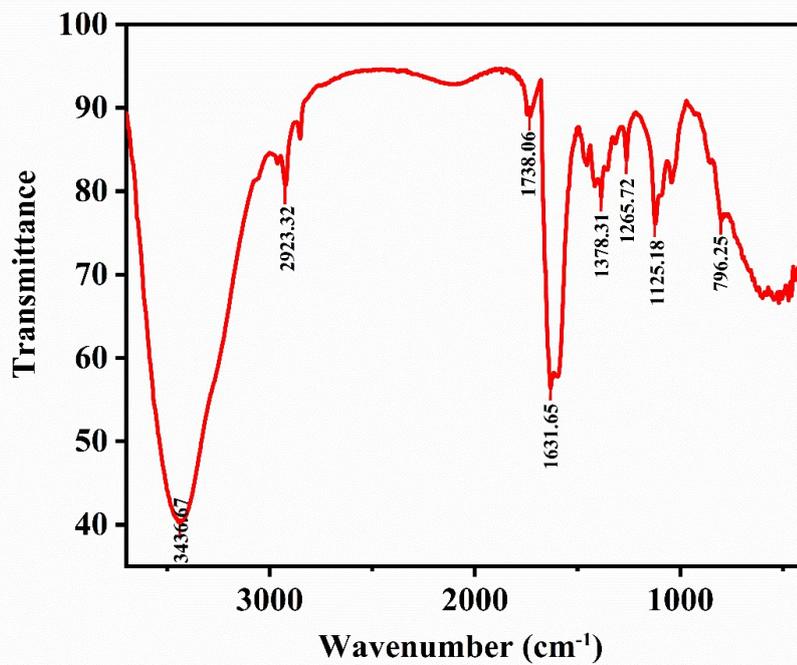


Fig. S4 FTIR of SA-PMD-2.

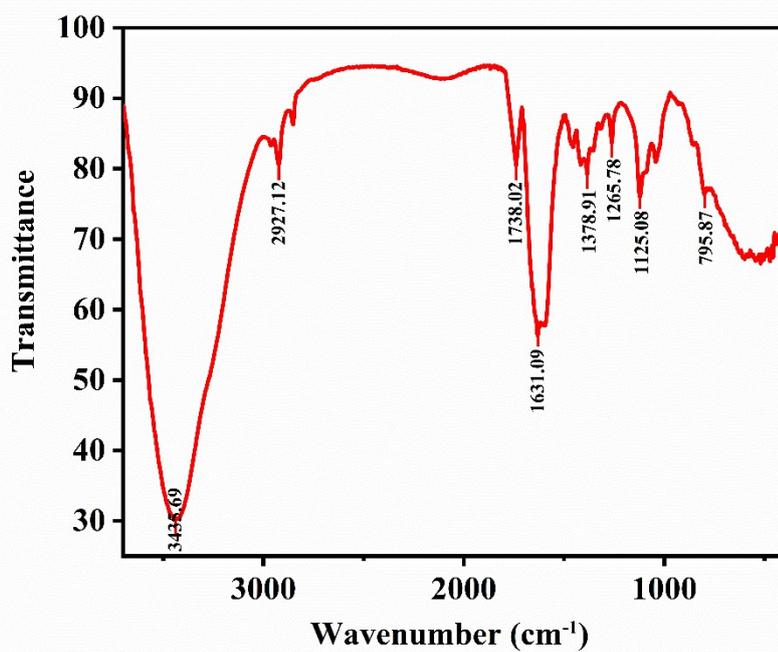


Fig. S5 FTIR of SA-PMD-1.

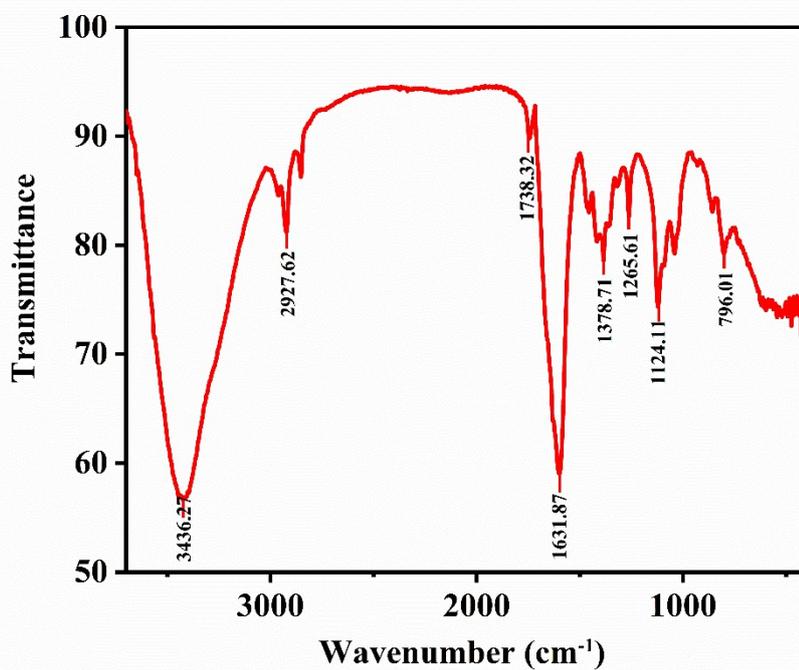
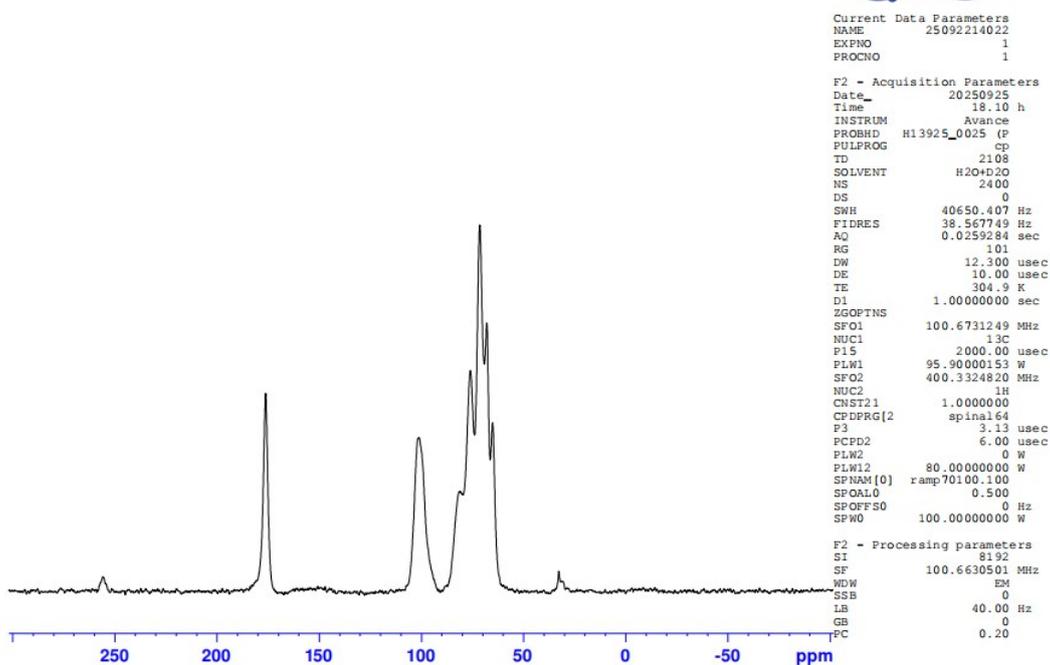


Fig. S6 FTIR of SA-PMD-4.

## 4.2 NMR Spectra

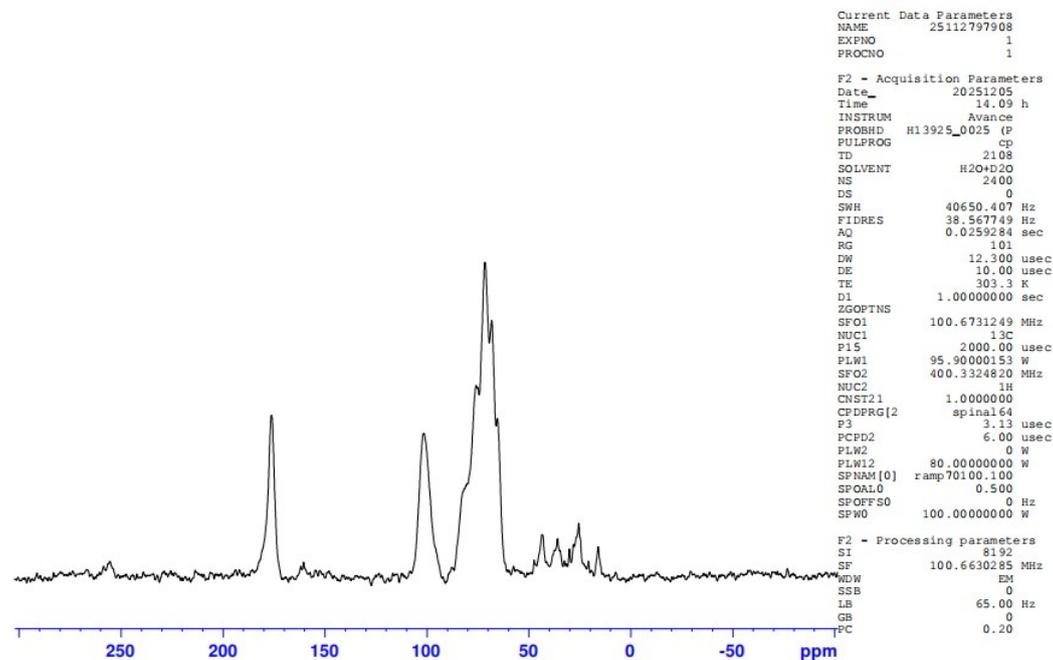
8k

(a)



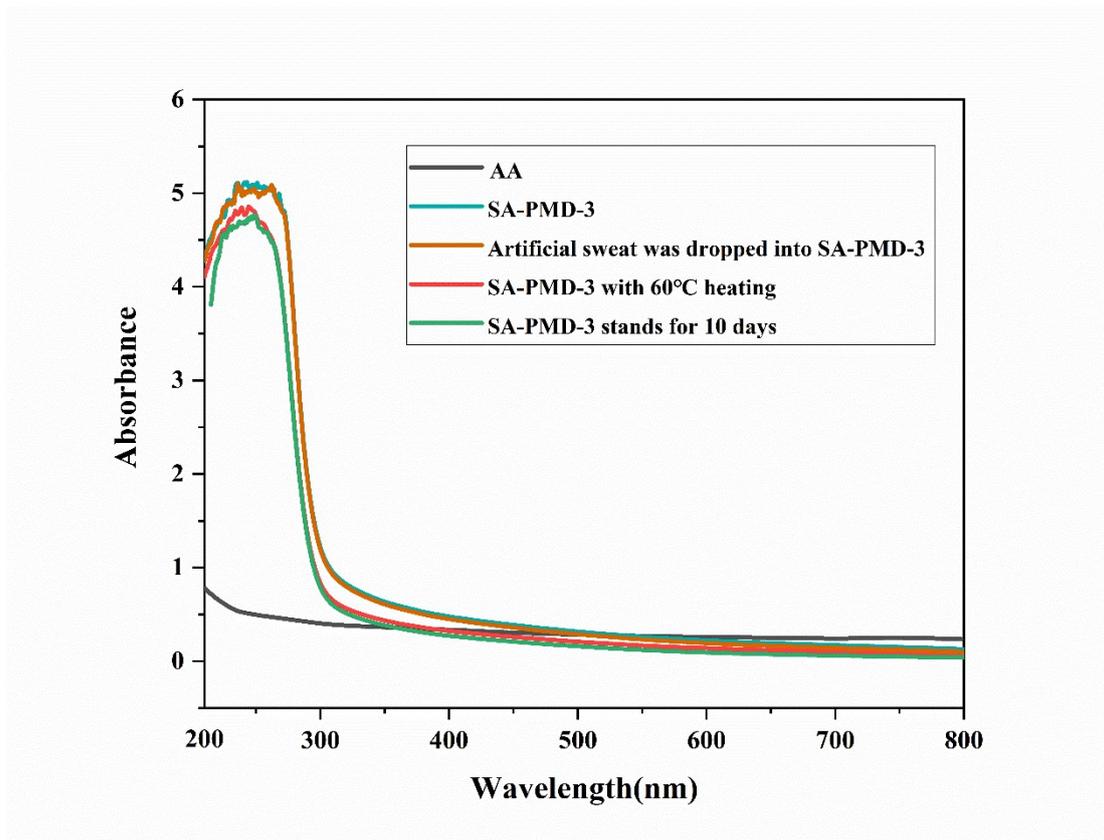
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(b)



**Fig. S7** (a) Solid-state nuclear magnetic resonance carbon spectra of AA. (b) Solid-state nuclear magnetic resonance carbon spectra of SA-PMD-3.

### 4.3 UV-Vis Absorption Spectra

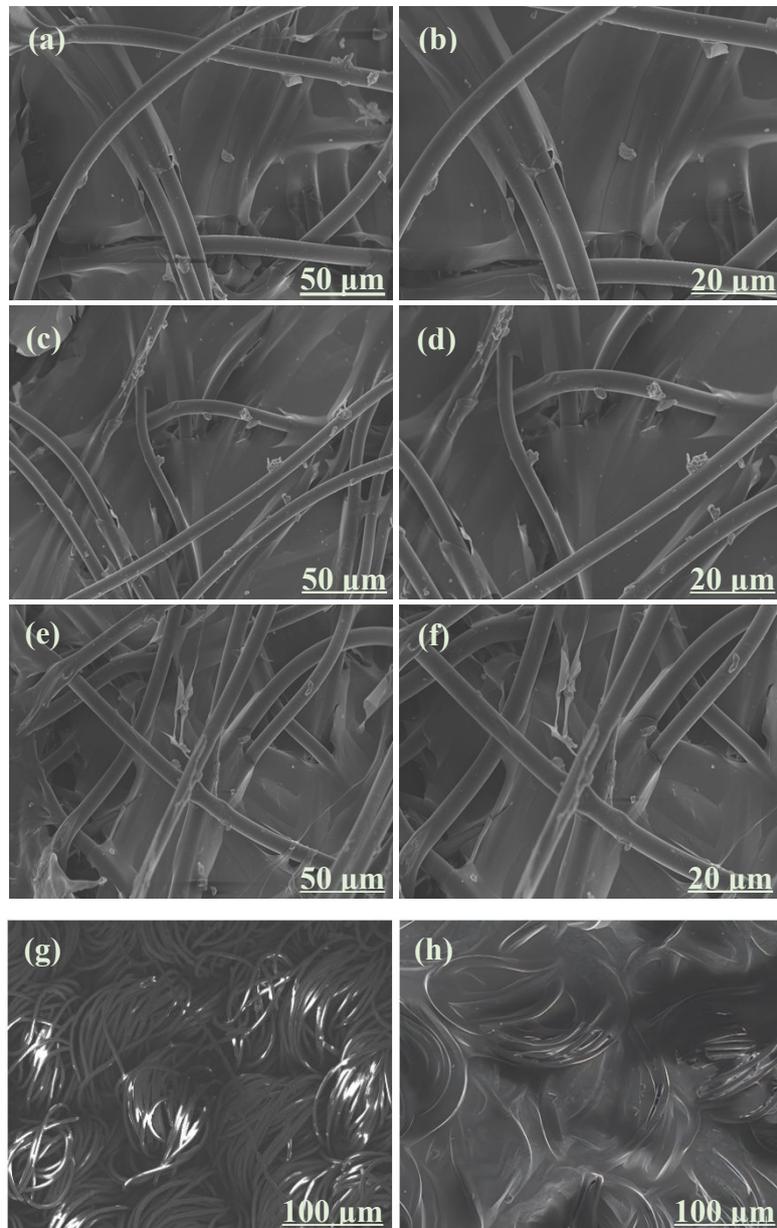


**Fig. S8** UV-Vis absorption spectra of AA, SA-PMD-3 with 60°C heating, stored for 10 days, and after artificial sweat addition.

**Table 1.** Organic element analysis of AA, SA-PMD-2 and SA-PMD-3.

Sample	C (%)	H (%)	N (%)	S (%)
AA	36.097	5.881	0.000	0.000
SA-PMD-2	43.776	5.145	0.000	0.000
SA-PMD-3	50.683	6.393	0.000	0.000

## 5. SEM Spectra



**Fig. S9** SEM of *p*-menthane-3,8-diol-grafted alginate/PP non-woven fabric at different proportions. (a,b) SEM of **SA-PMD-1/PP**; (c,d) SEM of the **SA-PMD-2/PP**; (e,f) SEM of **SA-PMD-4/PP**; (g,h) SEM of **SA-PMD-3/Ice sleeve** with 0.2mm coating thickness.

## 6. Air Permeability Test

# Inspection report

## TESTING REPORT

Sample name: Ice sleeve

Sample

Entrusting unit: Qingdao University

Clientele

Testing unit: Fanrui Yunzhi Technology (Zhengzhou)

Co., Ltd. (e-test)

Detection Company

Detection category: entrusted test

Inspection Sort

Fan Rui yun zhi technology (Zhengzhou) co., ltd. (e test)



Test Sample	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average air permeability(mm/s )
Ice sleeve	288.9	287.6	292.1	295.0	295.6	297.3	294.5	291.8	296.7	297.5	293.7
0.1mm SA- PMD-3/Ice sleeve	208.3	201.4	207.8	206.6	206.9	210.4	205.3	207.8	205.6	203.9	206.4
0.2mm SA- PMD-3/Ice sleeve	186.8	188.9	190.3	185.7	184.0	189.7	191.2	193.9	189.9	187.6	188.8

Divece picture:



### Permeability test

Equipment model: SDL Atlas, M021A, USA

Standard: GB/T 5453

Sample pressure difference: 200 Pa

Test head area: 20cm<sup>2</sup>

Air permeability: Ice sleeve-293.7mm/s ; 0.1mm  
SA-PMD-3/Ice sleeve-206.4mm/s ;  
0.2mm SA-PMD-3/Ice sleeve-188.8mm/s

**Fig. S10** Average air permeability rates off ice sleeve, 0.1 mm **SA-PMD-3/Ice sleeve** and 0.2 mm **SA-PMD-3/Ice sleeve**.

## 7. Moisture Permeability Test

### Moisture permeability test

Standard: GB/T 12704.1-2009

Air velocity: 0.3-0.5m/s

Temperature: 38°C

Relative humidity: 90%

Calculation formula:

Device picture:



Sample name	Mass before test /g	Mass after test /g	Weight difference e /g	Moisture permeability wvt [g/m <sup>2</sup> day]
Ice sleeve	164.101	164.898	0.797	6759.010600707
0.1mmSA-PMD-3/Ice sleeve	169.886	170.413	0.527	4469.25795053
0.2mmSA-PMD-3/Ice sleeve	168.351	168.805	0.454	3850.176678445

Fan Rui yun zhi technology (Zhengzhou) co., ltd. (e test)



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**Fig. S11** Moisture permeability rates off ice sleeve, 0.1 mm SA-PMD-3/Ice sleeve and 0.2 mm SA-PMD-3/Ice sleeve.

## 8. Mosquito Repellent Efficiency of SA-PMD/PP Non-woven Fabrics

**Table 2.** The mosquito repellent efficiencies of **SA-PMD-3 Ice sleeve and SA-PMD/PP** non-woven fabrics with different grafting rates of *p*-menthane-3,8-diol.

Sample name	Subjects	2 min stops (times) of experimental group	2 min stops (times) of control group	Repelling rate(%)	Average of the repelling rate(%)	Evaluation
<b>SA-PMD-1/PP</b>	1	4	8.5	52.9	52.3	B
	2	5.5	10.5	47.6		
	3	5.0	9.5	47.4		
	4	3.5	9.0	61.1		
<b>SA-PMD-2/PP</b>	1	3	12.5	76.0	73.7	A
	2	3.5	11.5	69.6		
	3	3	13.5	77.8		
	4	4	14.0	71.4		
<b>SA-PMD-3/PP</b>	1	1	13.5	92.6	96.2	A
	2	0.5	12.5	96.0		
	3	0	11.0	100.0		
	4	0.5	13.0	96.2		
<b>SA-PMD-3/PP (after washed )</b>	1	3	8.5	64.7	64.9	B
	2	4	9.5	57.9		
	3	2.5	8.0	68.8		
	4	3	9.5	68.4		
<b>SA-PMD-3/Ice sleeve</b>	1	0.5	7.5	93.3	95.6	A
	2	1.0	9.0	88.9		
	3	0	8.0	100.0		
	4	0	8.5	100.0		

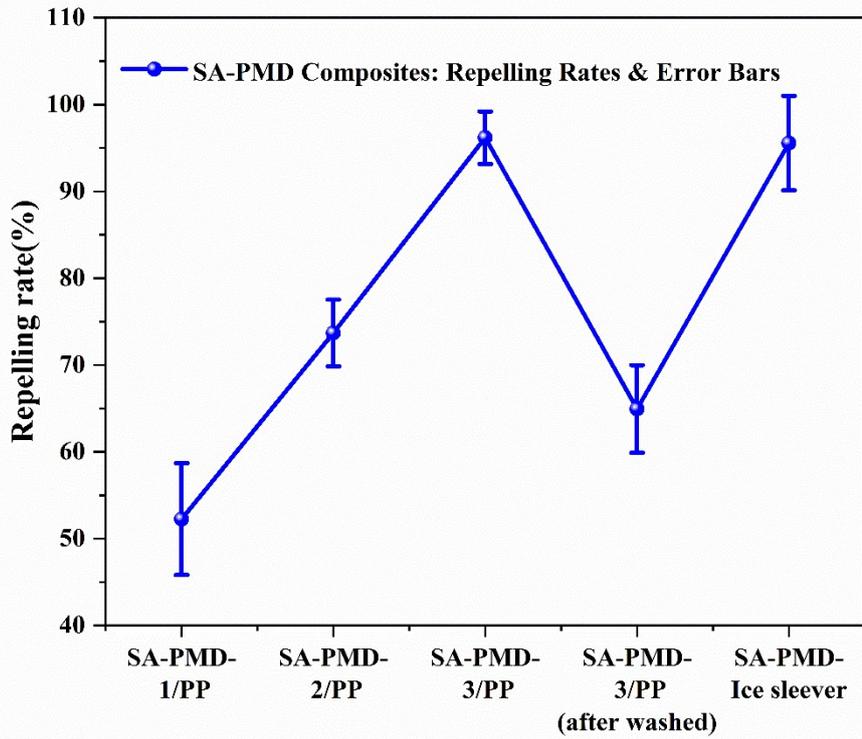


Fig. S12 SA-PMD Composites: Repelling Rates & Error Bars. Error bars represent the standard deviation (SD) of four independent replicate experiments (n=4).

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Website: www.feifan-test.com

### REPORT FOR ANALYSIS

**Report No.** FFT20250009E

**Sample Name** Anti-mosquito fabric

**Applicant** School of Materials, Qingdao university

**Test Type** Entrusted Inspection

FeiFan standard technical service (suzhou) Co., Ltd.  
检测专用章

#### Test report

Sample number	Sample name	Group	Average number of stops for mosquitoes on the sample side	Average number of stops for mosquitoes on the control side	Repelling rate (%)	Average of the repelling rate (%)	Evaluation
202501009	Anti-mosquito fabric	1	4.0	8.5	52.94	52.3	B
		2	5.5	10.5	47.62		
		3	5.0	9.5	47.37		
		4	3.5	9.0	61.11		

**Remarks**

**Test instructions:** For test insects: *Aedes albopictus* (*Aedes albopictus*), Female adults without blood feeding 4-7 days after eclosion. Test conditions: temperature 26.3°C and relative humidity 65%.

**Effective evaluation:**  
 Class A Repelling rate  $R, R > 70\%$ , has a very strong repelling effect.  
 Class B Repelling rate  $R, 50\% \leq R \leq 70\%$ , has good repelling effect.  
 Class C Repelling rate  $R, 30\% < R < 50\%$ , has repelling effect.

**Sample photos**

Fig. S13 Mosquito repellent efficiency of SA-PMD-1/PP non-woven fabrics.

### REPORT FOR ANALYSIS

Report No. FFT20250048E  
 Sample Name Anti-mosquito fabric  
 Applicant School of Materials, Qingdao university  
 Test Type Entrusted Inspection

FeiFan standard technical service (suzhou) Co., Ltd.



### Test report

Sample number	Sample name	Group	Average number of stops for mosquitoes on the sample side	Average number of stops for mosquitoes on the control side	Repelling rate(%)	Average of the repelling rate (%)	Evaluation
202503004	Anti-mosquito fabric	1	3.0	12.5	76.00	73.7	A
		2	3.5	11.5	69.57		
		3	3.0	13.5	77.78		
		4	4.0	14.0	71.43		

#### Remarks

**Test instructions** For test insects: *Albopictus (Aedes albopictus)*, Female adults without blood feeding 4-7 days after eclosion.  
 Test conditions: temperature 26.0°C and relative humidity 65%.  
**Effective evaluation** Class A Repelling rate  $R, R > 70\%$ , has a very strong repelling effect.  
 Class B Repelling rate  $R, 50\% \leq R \leq 70\%$ , has good repelling effect.  
 Class C Repelling rate  $R, 30\% < R < 50\%$ , has repelling effect.

#### Sample photos



Fig. S14 Mosquito repellent efficiency of SA-PMD-2/PP non-woven fabrics.

### REPORT FOR ANALYSIS

Report No. FFT20250047E  
 Sample Name Anti-mosquito fabric  
 Applicant School of Materials, Qingdao university  
 Test Type Entrusted Inspection

FeiFan standard technical service (suzhou) Co., Ltd.



### Test report

Sample number	Sample name	Group	Average number of stops for mosquitoes on the sample side	Average number of stops for mosquitoes on the control side	Repelling rate(%)	Average of the repelling rate (%)	Evaluation
202503003	Anti-mosquito fabric	1	1.0	13.5	92.59	96.2	A
		2	0.5	12.5	96.00		
		3	0	11.0	100.00		
		4	0.5	13.0	96.15		

#### Remarks

**Test instructions** For test insects: *Albopictus (Aedes albopictus)*, Female adults without blood feeding 4-7 days after eclosion.  
 Test conditions: temperature 26.0°C and relative humidity 65%.  
**Effective evaluation** Class A Repelling rate  $R, R > 70\%$ , has a very strong repelling effect.  
 Class B Repelling rate  $R, 50\% \leq R \leq 70\%$ , has good repelling effect.  
 Class C Repelling rate  $R, 30\% < R < 50\%$ , has repelling effect.

#### Sample photos



Fig. S15 Mosquito repellent efficiency of SA-PMD-3/PP non-woven fabrics.



**REPORT FOR ANALYSIS**

Report No. FFT20250072E

Sample Name Anti-mosquito fabric

Applicant School of Materials, Qingdao university

Test Type Entrusted Inspection



**Test report**

Sample number	Sample name	Group	Average number of stops for mosquitoes on the sample side	Average number of stops for mosquitoes on the control side	Repelling rate(%)	Average of the repelling rate (%)	Evaluation
202503022	Anti-mosquito fabric	1	3.0	8.5	64.71	64.9	B
		2	4.0	9.5	57.89		
		3	2.5	8.0	68.75		
		4	3.0	9.5	68.42		

**Remarks**

Test instructions: For test insects: *Aedes albopictus* (*Aedes albopictus*), Female adults without blood feeding 4-7 days after eclosion. Test conditions: temperature 26.1°C and relative humidity 65%.

Effective evaluation: Class A Repelling rate  $R_R > 70\%$ , has a very strong repelling effect.  
Class B Repelling rate  $R_{50} \leq R \leq 70$ , has good repelling effect.  
Class C Repelling rate  $R_{30} < R < 50\%$ , has repelling effect.



**Fig. S16** Mosquito repellent efficiency of SA-PMD-3/PP non-woven fabrics after washed 10 times with ECE detergent.



**REPORT FOR ANALYSIS**

Report No. FFT20250073E

Sample Name Anti-mosquito fabric

Applicant School of Materials, Qingdao university

Test Type Entrusted Inspection



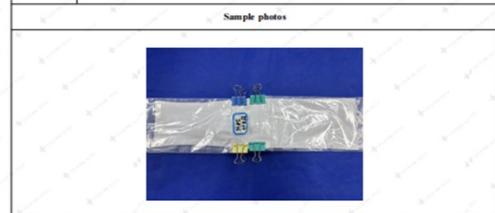
**Test report**

Sample number	Sample name	Group	Average number of stops for mosquitoes on the sample side	Average number of stops for mosquitoes on the control side	Repelling rate(%)	Average of the repelling rate (%)	Evaluation
202503023	Anti-mosquito fabric	1	0.5	7.5	93.33	95.6	A
		2	1.0	9.0	88.89		
		3	0	8.0	100.00		
		4	0	8.5	100.00		

**Remarks**

Test instructions: For test insects: *Aedes albopictus* (*Aedes albopictus*), Female adults without blood feeding 4-7 days after eclosion. Test conditions: temperature 26.1°C and relative humidity 65%.

Effective evaluation: Class A Repelling rate  $R_R > 70\%$ , has a very strong repelling effect.  
Class B Repelling rate  $R_{50} \leq R \leq 70$ , has good repelling effect.  
Class C Repelling rate  $R_{30} < R < 50\%$ , has repelling effect.



**Fig. S17** Mosquito repellent efficiency of SA-PMD-Ice sleeve.