



Research on thermal properties of novel nano PCMs and their application

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CONTENTS

01

Research
Background

02

Research Status

03

Research Contents

04

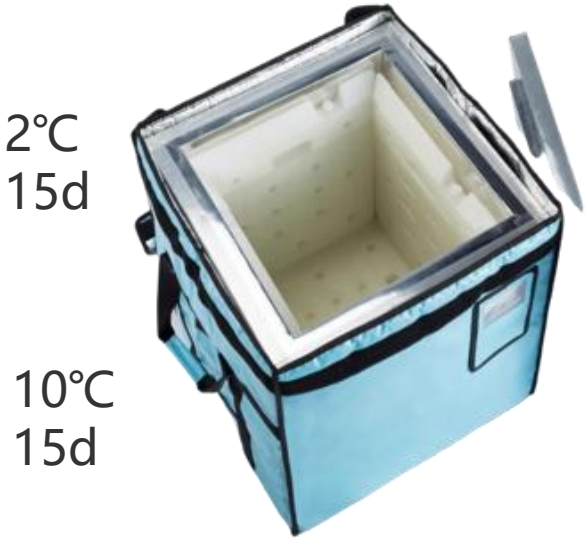
Results and Discussion

05

Conclusions

1 Research Background

- Driven by global economic growth, consumer demand for fresh and high-quality produce is rising with ever-stricter quality standards, making **cold chain logistics** increasingly vital.
- According to the FAO, roughly one-third of global food production is wasted annually; **fruits and vegetables** account for 40–50%, over half of which stems from temperature-induced quality degradation. **Cold chain logistics** addresses this by maintaining stable, continuous **low-temperature** conditions.
- Phase change cold storage technology, which **uses phase change materials (PCMs)** to buffer temperature fluctuations, has become a key technology in this field



2°C
15d

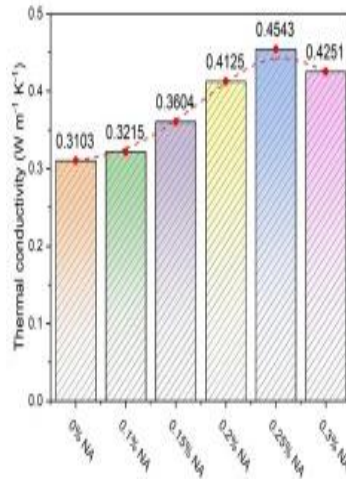
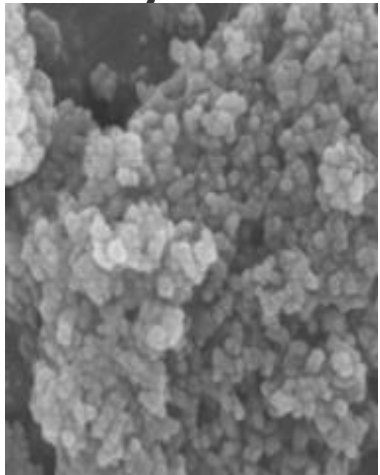
10°C
15d

2 Research Status

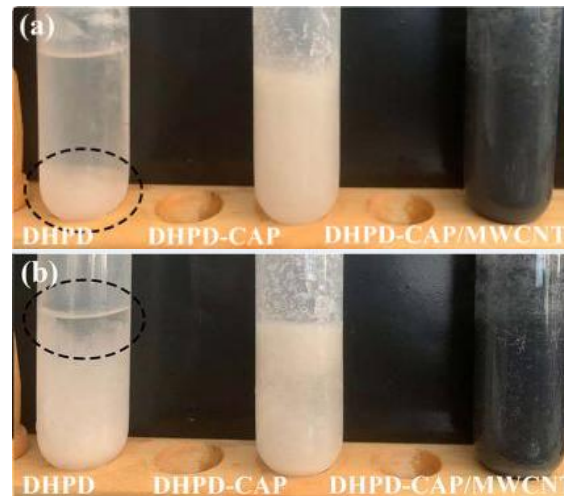
traditional PCMs face limitations such as **high supercooling** and **low thermal conductivity**. Researchers have introduced nucleating agents and thermal conductivity enhancers.

Nanomaterials, due to their small size and high thermal conductivity, offer new optimization pathways.

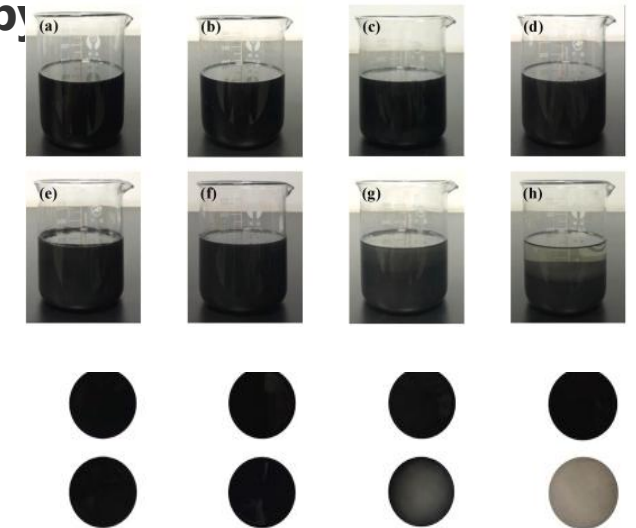
Yang et al. reported a 27% increase (0.357 to 0.4543 W/(m·K)) with 0.25 wt.% **nano- Al_2O_3** in magnesium chloride hexahydrate.



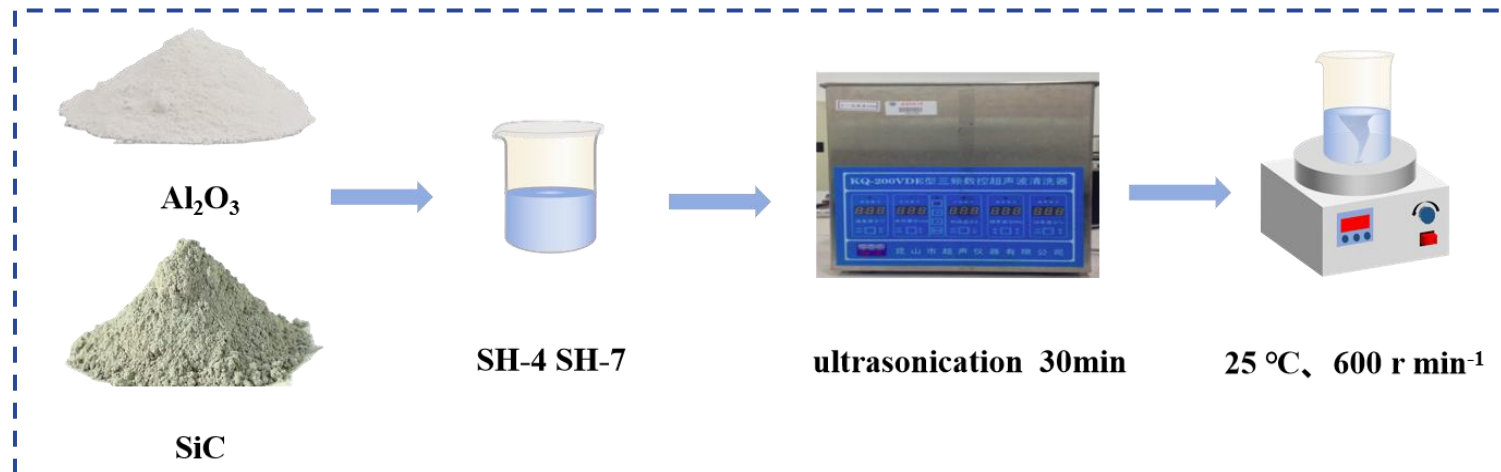
Ding et al. effectively suppressed the supercooling (from 7.4 °C to 0.8 °C) and phase separation of $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ by formulating it with CMC, **Al_2O_3** and PVP,



Lu et al. found that 6% **nano-graphite** reduced supercooling by 64.39% (to 0.47 °C) and increased thermal conductivity by



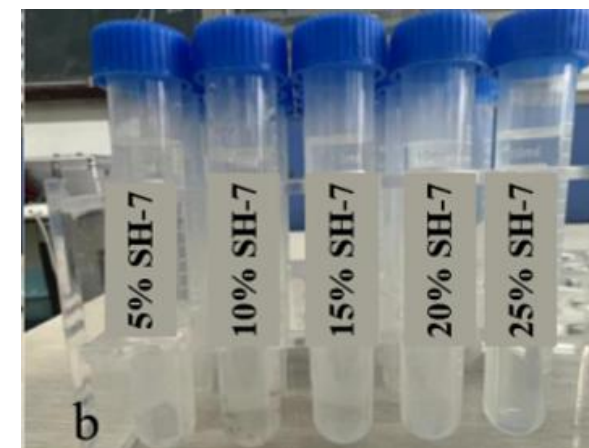
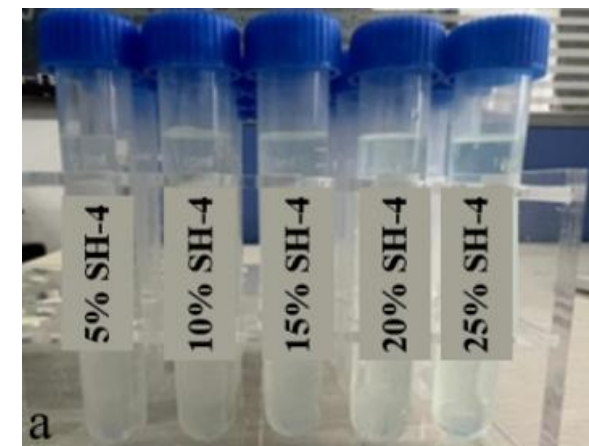
3 Research Contents



Preparation Process of Phase Change Materials

Table 1 Formulation of nanocomposite phase change cold storage

名称	A1	A2	A3	B1	B2	B3	C1	C2	C3
5%SH-4	100%	98%	98%	--	--	--	--	--	--
10%SH-4	--	--	--	100%	98%	98%	--	--	--
5%SH-7	--	--	--	--	--	--	100%	98%	98%
Nano- Al_2O_3	--	1%	--	--	1%	--	--	1%	--
Nano-SiC	--	--	1%	--	--	1%	--	--	1%
SDBS	--	1%	1%	--	1%	1%	--	1%	1%



SH-4 or SH-7 of different mass fractions

3 Research Contents

Performance Parameter Characterization



**Nanoparticle
Tracking
Analyzer(Particle Size)**



**DSC (Phase Change
Temperature/Latent
Heat)**

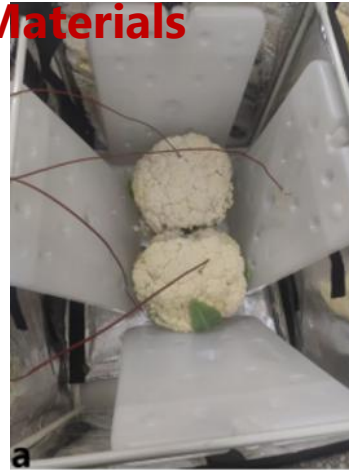


**Low-temperature
constant temperature
water bath
(subcooling)**



**Hot Disk Thermal
Constant
Analyzer(Thermal
Conductivity)**

Applications of Nano-Enhanced Cool Storage Materials

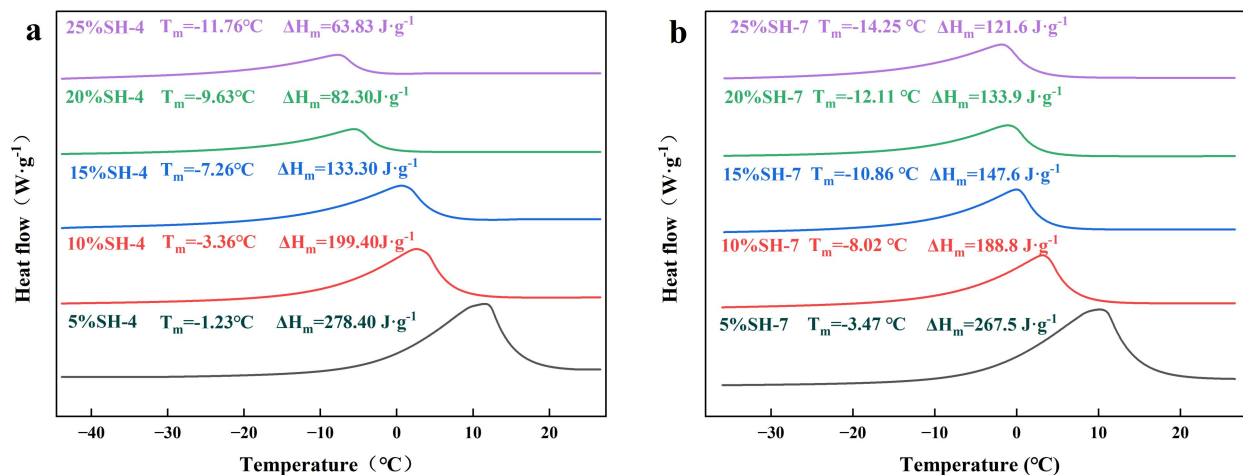


Cauliflower experiment diagram

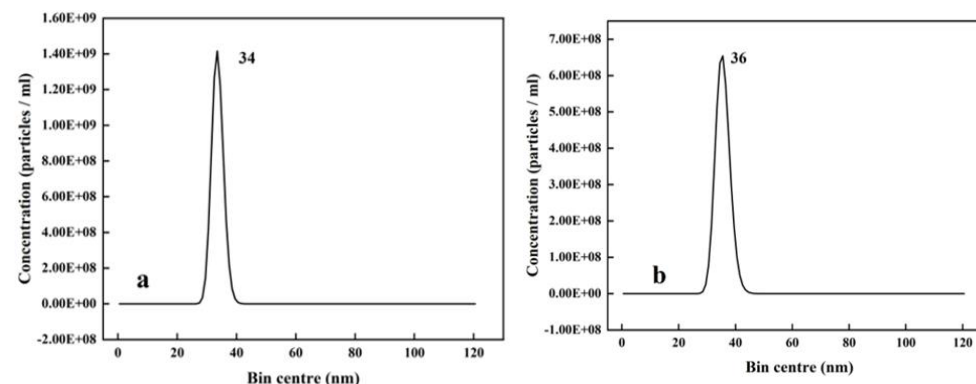
Cauliflower Experiment Plan

Experimental group	Experimental condition	Cauliflower mass (g)	PCM mass (g)
Group a	Pre-cooled cauliflower (2 heads) + PCM + insulated box	834	4000
Group b	Pre-cooled cauliflower (4 heads) + PCM + insulated box	1570	4000
Group d	Non-precooled cauliflower (6 heads) + PCM + insulated box	2586	4000

4 Results and Discussion



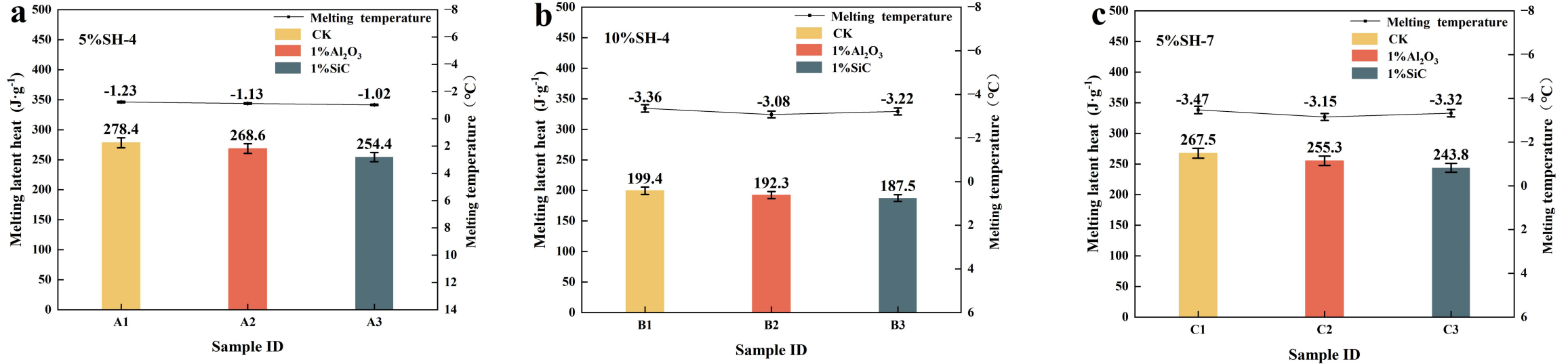
DSC curves of SH-4、SH-7



Particle size distribution a. Al₂O₃ particle size distribution b. SiC particle size

- After adding 30 nm nano-Al₂O₃ and nano-SiC particles, the size peaks all fell within 30 ± 5 nm, indicating good dispersion under the action of the dispersant and ultrasonication, which enabled subsequent experimental research.
- Considering the requirements of fresh produce cold chain logistics, the **5 wt% SH-4**, **10 wt% SH-4**, and **5 wt% SH-7** solutions—with suitable phase change temperatures and relatively high latent heat—were selected for further investigation.

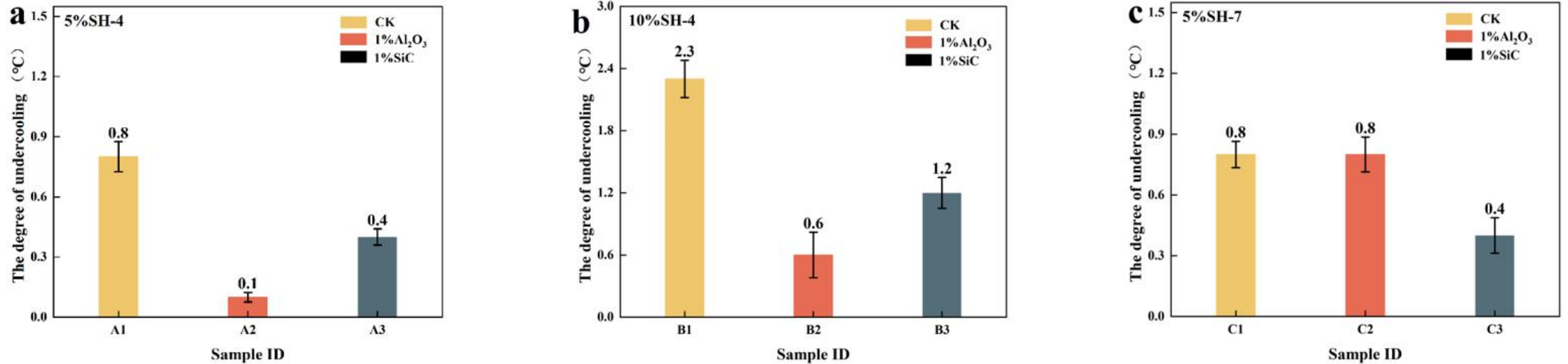
4 Results and Discussion



Phase change temperature and latent heat of phase change of different nanocomposite phase change cold storage materials

- The latent heat decreases with nanoparticle addition: for 5 wt% SH-4, from 278.4 J·g⁻¹ to 268.6 J·g⁻¹ (Al₂O₃, -3.53%) and 254.4 J·g⁻¹ (SiC, -8.62%); for 10 wt% SH-4, from 199.4 J·g⁻¹ to 192.3 and 187.5 J·g⁻¹ (-3.56% and -5.97%); for 5 wt% SH-7, from 267.5 J·g⁻¹ to 255.3 and 243.8 J·g⁻¹ (-4.56% and -8.85%). The reduction is consistently smaller in the Al₂O₃ system than in the SiC system.
- This is because nanoparticles do not participate in the solid-liquid phase change, reducing the effective base-fluid mass per unit composite ; the lower density of SiC leads to a higher volume fraction and thus a stronger dilution effect . Accordingly, the phase change temperature remains essentially unaffected.

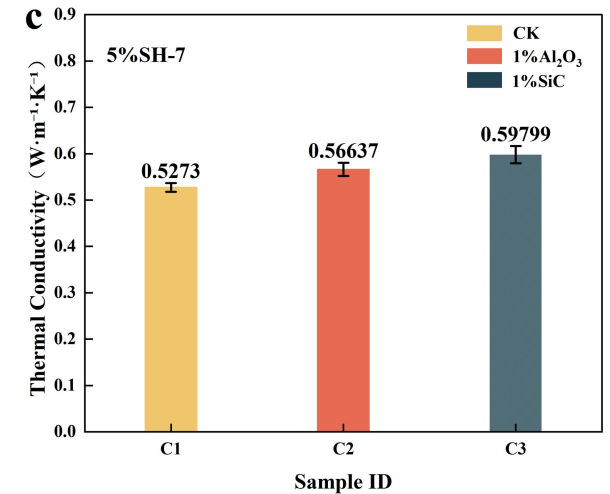
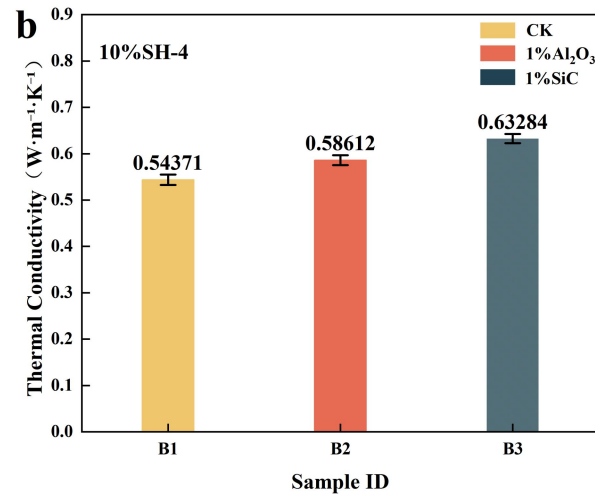
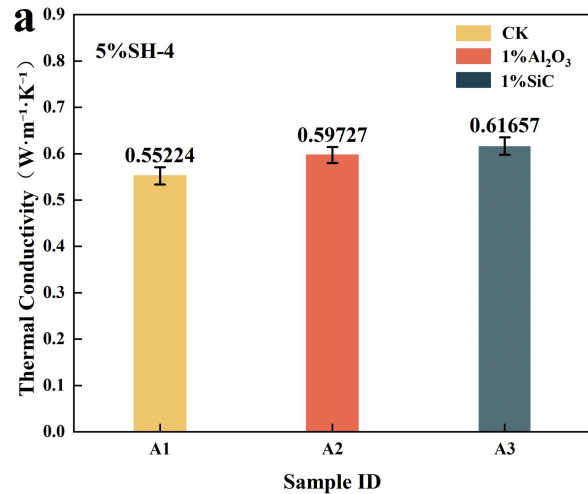
4 Results and Discussion



The supercooling degrees of different nanocomposite phase change materials

- Nano-Al₂O₃ and nano-SiC suppress supercooling via heterogeneous nucleation: Al₂O₃ is more effective in SH-4 (ΔT reduced by **73.9–87.5%** vs. **47.8–50%** for SiC), while SiC is superior in 5 wt% SH-7 (**50%** reduction vs. none for Al₂O₃).
- hydroxyl groups on Al₂O₃ surfaces hydrogen-bond with the alcohols in SH-4, promoting molecular ordering and nucleation, whereas in **SH-7 the strong interaction between Al₂O₃ hydroxyls and salt ions causes agglomeration that reduces nucleation efficacy**, making SiC the better nucleating agent in salt-based systems.

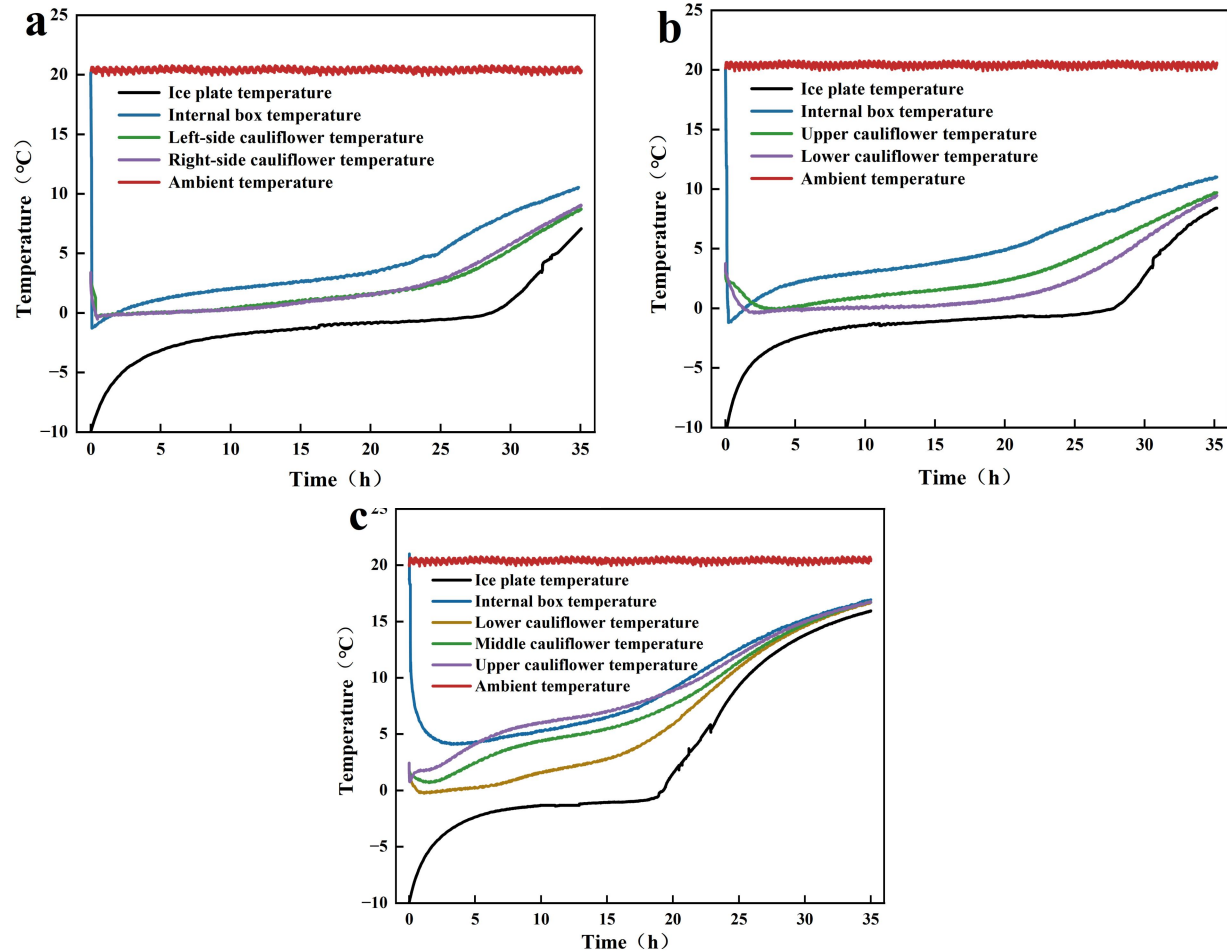
4 Results and Discussion



Thermal conductivity of different nanocomposite phase change cold storage materials

- Adding nano- Al_2O_3 or nano-SiC enhances the thermal conductivity of all base fluids (by **7.4–8.2% for Al_2O_3** and **11.7–16.4% for SiC** across 5 wt% SH-4, 10 wt% SH-4, and 5 wt% SH-7), with SiC-based composites consistently outperforming Al_2O_3 -based ones.
- The enhancement stems from the nanoparticles' higher intrinsic thermal conductivity and their high specific surface area, which induces micro-convection and particle-liquid collisions; SiC's much higher intrinsic conductivity (270–490 $\text{W}/\text{m}\cdot\text{K}$ vs. 40 $\text{W}/\text{m}\cdot\text{K}$ for Al_2O_3) explains its consistently superior performance.

4 Results and Discussion



Experimental Diagram (a) One layer of pre-cooled cauliflower (b) Two layers of pre-cooled cauliflower (c) Three layers of pre-cooled cauliflower

Cauliflower cold storage

Layer	Position	Cooling duration	Preservation Time (0–5°C)
First layer	Left side		29.5h
	Right side		29.5h
Second layer	Upper layer		26.5h
	Lower layer		29h
Third layer	Upper layer		6.5h
	Middle layer		13.5h
	Lower layer		19h

- The **ice plate rose**, plateaued (PCM melting) then rose again, while the cauliflower cooled, stabilized, then warmed. Symmetric samples matched at 29.5 h (0–5 °C), so one side represented the whole.
- **Upper and lower layers** stayed uniform and followed the plate trend; the top was only marginally warmer/colder-retention-shorter. Two layers gave the most even field.
- Clear gradient: 19 h (bottom) → 13.5 h (middle) → 6.5 h (top), due to lid-side ambient heat, sinking cooled air, and wall heat ingress.

5 Conclusions

- The **5 wt% and 10 wt% SH-4** aqueous solutions and the **5 wt% SH-7** aqueous solution exhibit suitable phase change temperatures and relatively high latent heats, making them applicable for fruit and vegetable preservation.
- Adding Al_2O_3 and SiC nanoparticles influences the latent heat of the three base solutions, with Al_2O_3 causing a smaller reduction. Both nanoparticle types effectively reduce supercooling and enhance thermal conductivity. Adding 1% Al_2O_3 **reduces supercooling by 87.5%, 73.91%, and 0%**, and **increases thermal conductivity by 8.15%, 7.80%, and 7.41%**, respectively. Adding 1% SiC **reduces supercooling by 50%, 47.83%, and 50%**, and **increases thermal conductivity by 11.65%, 16.39%, and 13.4%**.
- The 5% SH-4 + 1% Al_2O_3 nanocomposite performs best overall. At a holding temperature of 0–5 °C, **a single cauliflower layer keeps fresh for 29.5 h. With two layers, temperatures stay uniform, lasting 26.5 h (top) and 29 h (bottom). With three layers, a clear temperature gradient forms, and the duration drops from 19 h (bottom) to 6.5 h (top)..**



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Thank you

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