Research Article *Open Access*

Journal of Modern Classical Physics & Quantum Neuroscience

ISSN: 3068-4196

DOI: doi.org/10.63721/26JPQN0168

HALOGLAS FIR Glass: Material Characterization, Biocompatibility & Biological Effects

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Citation: *Jeremy Sablon, MaCe, Wang Jinghan (2025) HALOGLAS FIR Glass: Material Characterization, Biocompatibility & Biological Effects. J.of Mod Phy & Quant Neuroscience 2(3), 1-11. WMJ/JPQN-168*

Abstract

This study reports the development and systematic evaluation of a far-infrared (FIR) functional glass material (HALOGLAS). FIR radiation has been widely investigated for its biological interactions, particularly in relation to thermal regulation and cellular activity. The material was characterized using standardized analytical methods and independently tested by accredited laboratories. HALOGLAS exhibits stable FIR emission with a normal total emissivity of 0.88 at 40 °C across a wavelength range of 2.5–25 μm, consistent with biologically relevant infrared regions. Chemical safety testing confirms compliance with international food-contact standards, with minimal heavy-metal migration. Antibacterial assays demonstrate significant activity against Escherichia coli and Staphylococcus aureus. In vitro biological evaluations suggest modulation of inflammatory markers (TNF-α, IL-6), enhanced ATP production, and increased collagen synthesis, which are associated with cellular metabolic activity. These findings indicate that HALOGLAS is a promising multifunctional material for applications in functional consumer products and healthcare-related materials. Further in vivo validation is required to establish clinical relevance.

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Submitted: 30.04.2026 **Accepted**: 05.05.2026 **Published**: 20.05.2026

Keywords: Haloglas, Far-Infrared Glass, Biocompatibility, Antibacterial Activity, Water Structure, Biological Effects

Introduction

Far-infrared (FIR) radiation has attracted considerable attention due to its potential interactions with biological systems, particularly in the wavelength range of 4–14 μm, which overlaps with the peak emission spectrum of the human body. Previous studies have demonstrated that FIR exposure may influence microcirculation, tissue oxygenation, and cellular metabolism. The biological effects of FIR radiation are often attributed to vibrational energy transfer mechanisms involving water molecules and biomolecular structures. These interactions may contribute to changes in enzymatic activity, cell signaling, and thermal regulation.

Functional materials capable of emitting FIR radiation have been explored in ceramics, coatings, and nanomaterials; however, these systems often exhibit limitations in durability, scalability, or transparency. Glass materials, by contrast, offer excellent chemical stability, mechanical strength, and manufacturability, yet remain underexplored as FIR-emitting platforms. This study introduces HALOGLAS, a FIR-emitting functional glass material, and aims to evaluate its physicochemical properties, safety profile, and biological interactions. The work integrates material science and biophysical analysis to provide a foundation for future applications.

Materials and Methods

All experiments were conducted in accordance with relevant international standards, and laboratory analyses were performed in accredited testing facilities.

Far-Infrared Measurement

FIR emissivity was measured using infrared spectroradiometry at 40 °Cover the wavelength range of 2.5–25 μm. Radiative heat transfer principles were considered in data interpretation.

Antibacterial Testing

Antibacterial activity was evaluated using colony counting methods against *Escherichia coli* and *Staphylococcus aureus*, following standardized protocols.

In Vitro Biological Assays

Cell-based assays were conducted using macrophages, fibroblasts, and neuronal cell lines. Key biomarkers included TNF-α and IL-6 (inflammation markers), ATP production (cellular metabolism indicator), collagen synthesis (tissue repair marker), and GABA secretion (neuroactive response). Cellular responses were interpreted in the context of established inflammatory and metabolic pathways.

Water Interaction Analysis

Water structure and solute release behavior were evaluated using spectroscopic methods.

Statistical Analysis

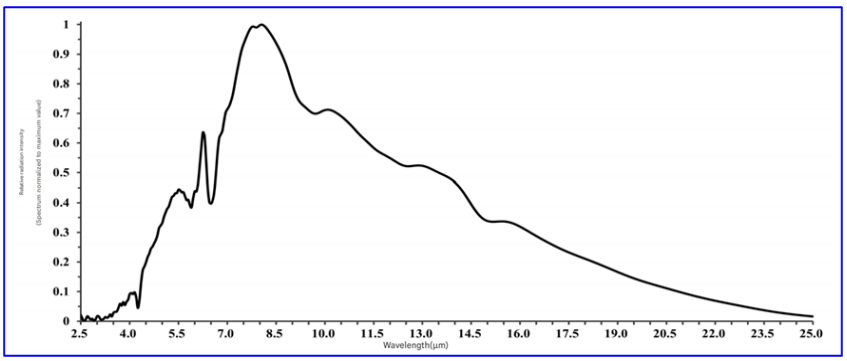
Statistical significance was defined at $p < 0.01$.

Results

FIR Radiative Properties

HALOGLAS exhibited a normal total emissivity of 0.88 at 40 °C, with emission spanning 2.5–25 μm. This range overlaps with biologically active FIR wavelengths reported in previous studies.

Serial Number	Inspection Items	Unit	Inspection Method	Standard Requirements	Sample Test Results	Individual Assessment	Remark
1	Normal total emissivity	/	GB/T 18497.2-2019 (6.15)	/	0.88	/	40°C



Chemical Safety

All parameters complied with international food-contact standards including US FDA CPG, EU 1935/2004, LFGB, and DIN 51032. Migration levels of lead and cadmium were significantly below regulatory limits.

	Leachable Lead (μg/mL)	Leachable Cadmium (μg/mL)
1	<0.05	<0.01
2	<0.05	<0.01
3	<0.05	<0.01
4	<0.05	<0.01
5	<0.05	<0.01
6	<0.05	<0.01
Avg	<0.05	<0.01
Limit	3.0	0.5

US FDA CPG Sec.545.400 and CPG Sec 545.450 - Leachable Lead and Cadmium

	Leachable Lead (mg/dm²)	Leachable Cadmium (mg/dm²)
1	<0.1	<0.01
Limit	0.8	0.07

Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004, German Food, Articles of Daily Use and Feed Code of September 1, 2005 (LFGB), Section 30 with amendments, DIN 51032:2017 - Leachable Lead and Cadmium

	Leachable Cobalt (mg/dm²)
1	<0.01
Limit	0.02

Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004, ALS

Antibacterial Activity

The material demonstrated:

Test Organism	The number of bacteria on the inoculated treated samples at "0" contact time of control group (cfu/piece)	Under bright conditions the number of bacteria on the inoculated treated samples of control group (cfu/piece)	Under bright conditions the number of bacteria on the inoculated treated samples of test group (cfu/piece)	Under the dark conditions the number of bacteria on the inoculated treated samples of control group (cfu/piece)	The number of viable bacteria after the sample for photocatalysis was cultured under dark conditions (cfu/piece)	Antibacterial value under fluorescen (%)	Antibacterial rate R_{total} (%)
Escherichia coli AS1.90	9.6×10^4	7.0×10^6	1.8×10^2	7.8×10^6	5.6×10^6	99	99

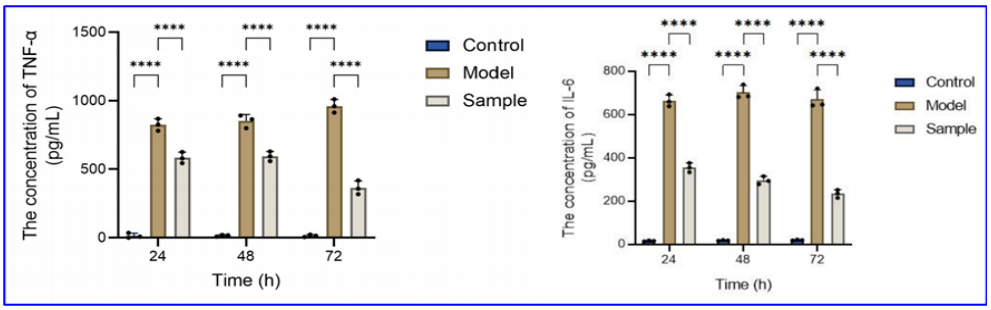
99% reduction of E. coli

Test Organism	The number of bacteria on the inoculated treated samples at "0" contact time of control group (cfu/piece)	Under bright conditions the number of bacteria on the inoculated treated samples of control group (cfu/piece)	Under bright conditions the number of bacteria on the inoculated treated samples of test group (cfu/piece)	Under the dark conditions the number of bacteria on the inoculated treated samples of control group (cfu/piece)	The number of viable bacteria after the sample for photocatalysis was cultured under dark conditions (cfu/piece)	Antibacterial value under fluorescen (%)	Antibacterial rate R_{total} (%)
Staphylococcus aureus AS1.89	1.3×10^5	8.6×10^6	2.4×10^5	9.0×10^6	9.6×10^5	75	97

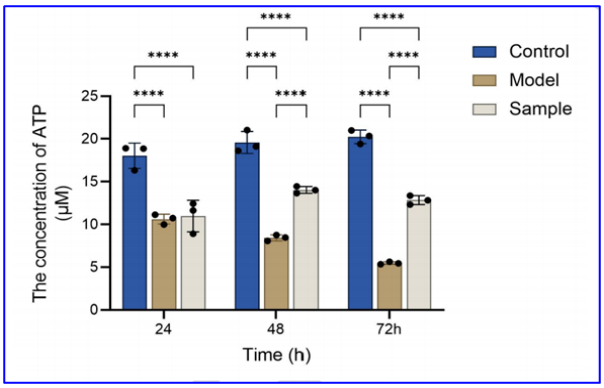
97% reduction of S. *aureus*

In Vitro Biological Effects

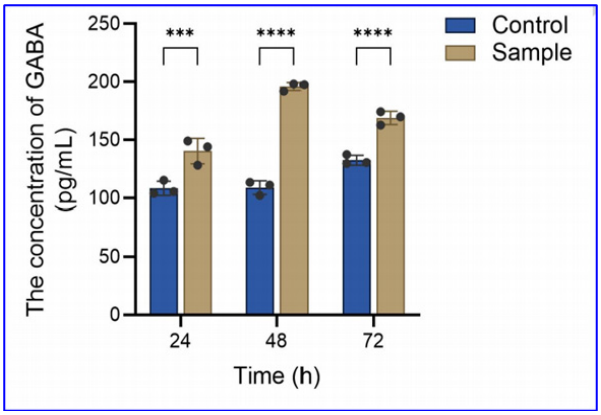
- Significant reduction in TNF-α and IL-6 expression ($p < 0.01$)



- Increased ATP production

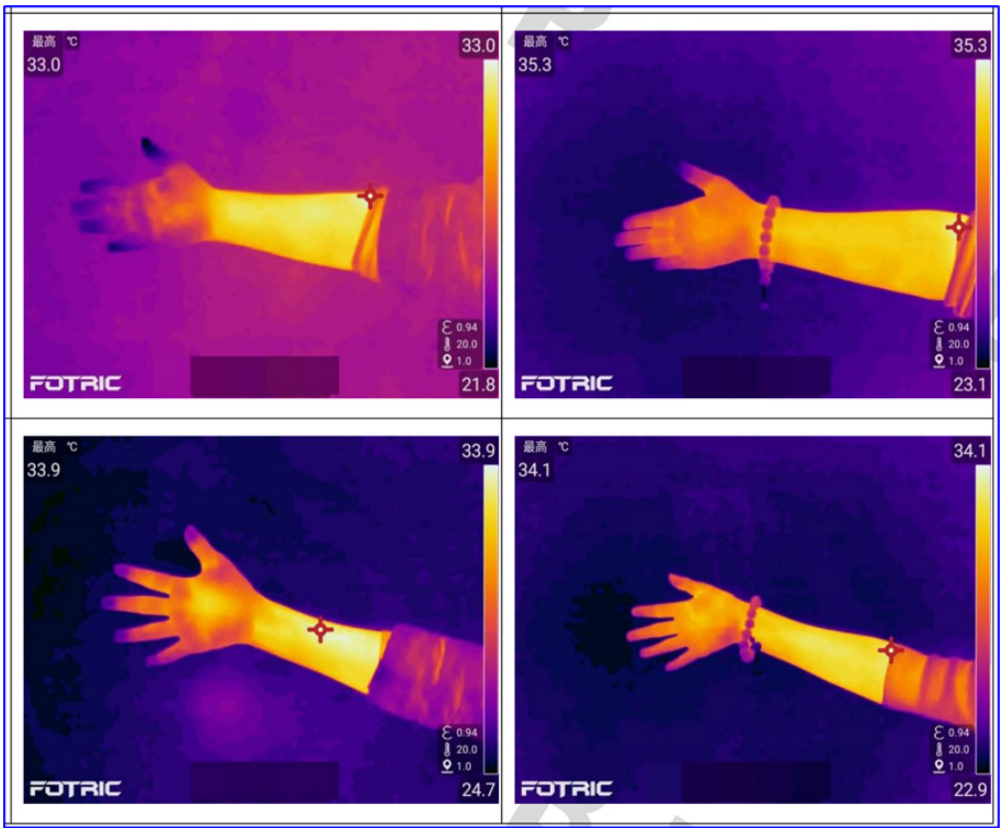


- Increased GABA content

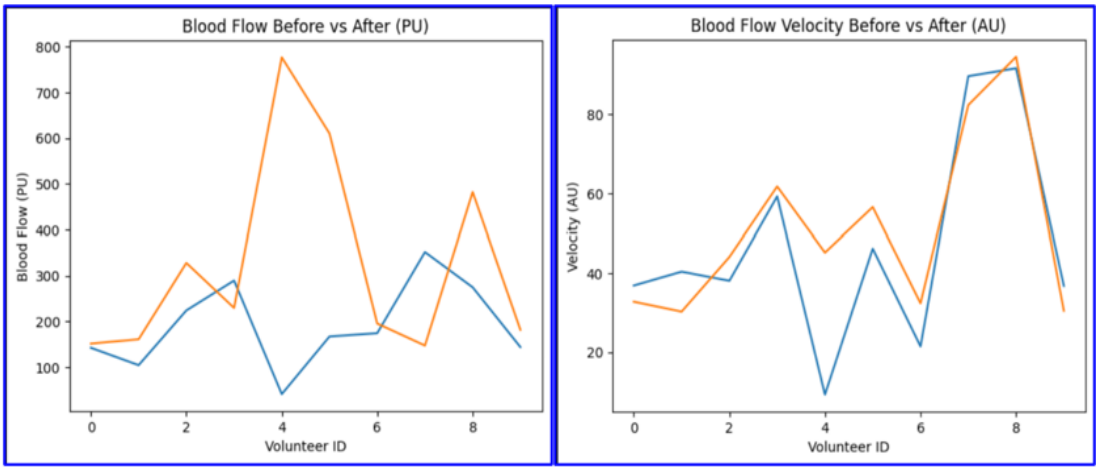


- Increased wrist surface temperature in volunteers

Through thermal infrared imaging, it can be seen that the wrist temperature of the volunteers increased to varying degrees after using the bracelet made from Haloglas material.



- Improved blood flow and velocity after 7 days of using HALOGLAS bracelets

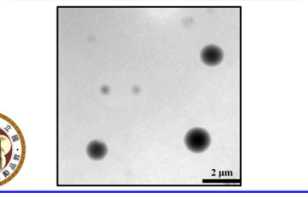
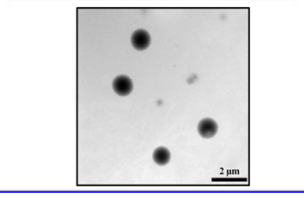


Water Interaction Effects

Particle size and Raman spectroscopy analyses showed modified water hydrogen bonding and reduced water cluster size, indicating altered molecular interactions in treated water.

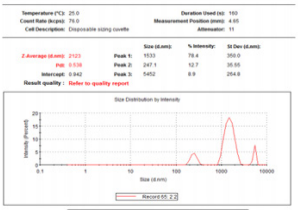
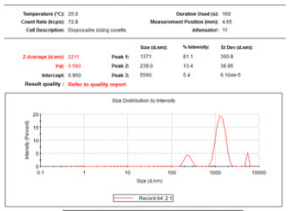
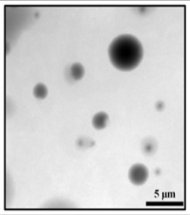
Particle size analysis: drinking water mixing with olive oil

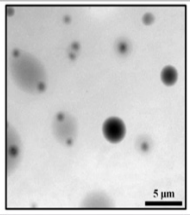
0 min	120 min
1893 nm (93.9%) 222.1 nm (6.1%)	1140 nm (94.6%) 177.4 nm (5.4%)

Particle size analysis: drinking water mixing with lard

0 min	120 min
1533 nm (78.4%) 247.1 nm (12.7%) 5425 nm (8.9%)	1371 nm (81.1%) 239.0 nm (13.4%) 5560 nm (5.4%)



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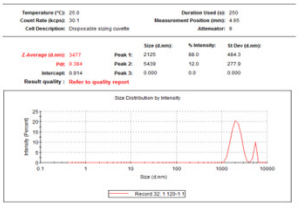
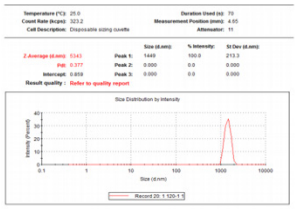
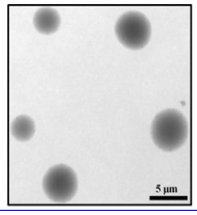
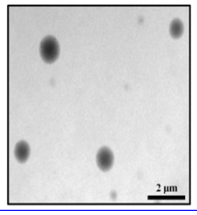
Particle size analysis: RO water mixing with olive oil

0 min	120 min
2125 nm (88.0%) 5439 nm (12.0%)	1449 nm (100%)



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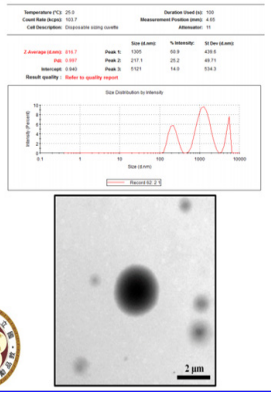
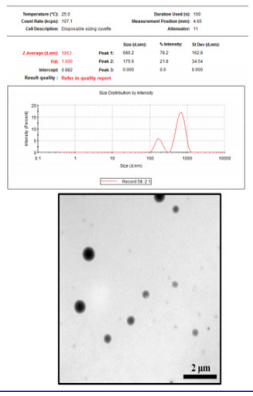
Particle size analysis: RO water mixing with lard

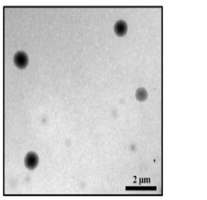
0 min	120 min
1305 nm (60.9%) 217.1 nm (25.2%) 5121 nm (14.0%)	680.2 nm (78.2%) 175.6 nm (21.8%)

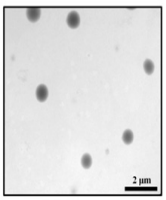




Particle size analysis: DI water mixing with olive oil

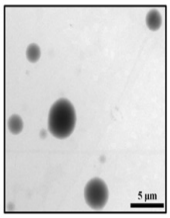
0 min	120 min
1490 nm (100%)	1310 nm (100%)

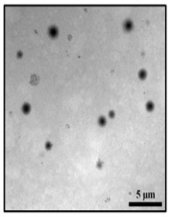




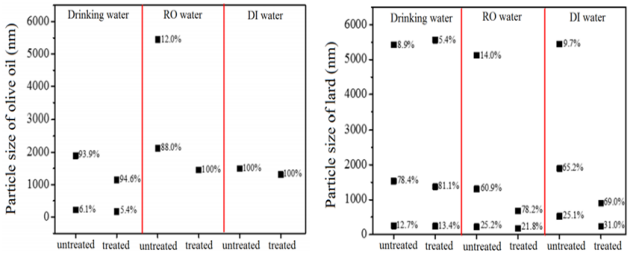
Particle size analysis: DI water mixing with lard

0 min	120 min
1897 nm (65.2%) 521.1 nm (25.1%) 5448 nm (9.7%)	896.9 nm (69.0%) 238.5 nm (31.0%)

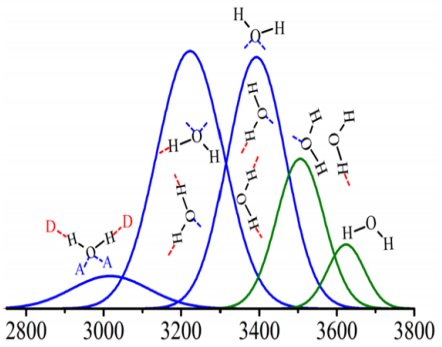




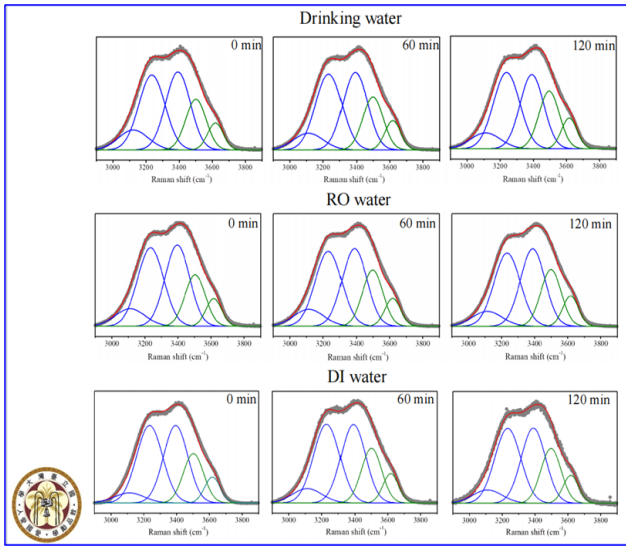
Particle size analysis

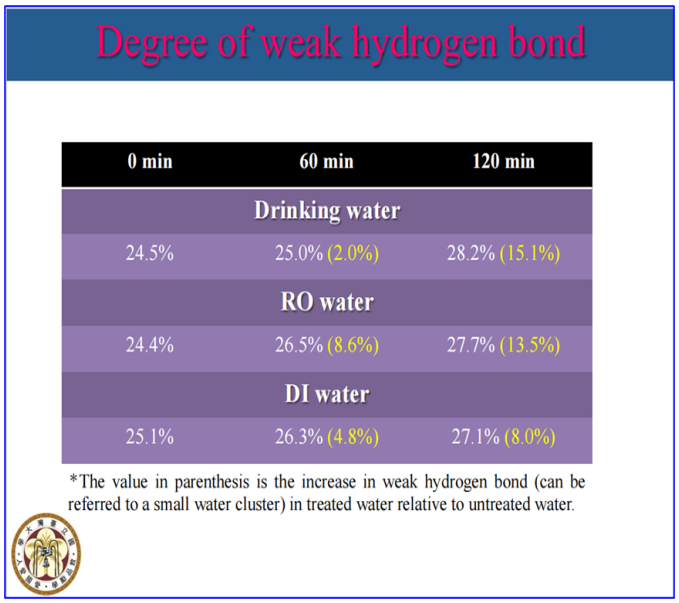


Raman spectra analysis



The OH stretching vibration of water in Raman spectrum can be deconvoluted into five Gaussian components. The former three peaks (blue line) are attributed to the stronger hydrogen bond and the latter two peaks (green line) are assigned to the weaker hydrogen bond. The degree of weak hydrogen bond in water is defined as the ratio of the green areas to the total blue and green areas.





Discussion

The FIR emission properties of HALOGLAS suggest that it can act as a passive infrared-emitting material. FIR radiation has been reported to influence biological systems through thermal and non-thermal mechanisms, including molecular vibration and energy transfer. The antibacterial activity observed may be associated with physicochemical surface interactions or indirect environmental effects, consistent with prior antimicrobial material research.

In vitro biological responses indicate potential interactions with cellular metabolic and inflammatory pathways. However, these findings should be interpreted cautiously, as in vitro results do not necessarily translate to in vivo outcomes. The observed water interaction effects may be related to changes in hydrogen bonding and molecular organization, although further investigation is required to clarify the mechanisms [1-40].

Conclusion

HALOGLAS demonstrates stable FIR emission, compliance with food-contact safety standards, and measurable antibacterial and in vitro biological effects. These findings support its potential as a multifunctional material for applications in consumer products and functional materials. Further studies, including long-term in vivo and clinical validation, are required to confirm its biological efficacy and practical applications.

Declarations

Funding

This research received no specific grant from any funding agency.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

Human volunteer tests were approved by the Institutional Ethics Committee (Approval No.: BJY251231-9180501-01).

Author Contributions

Conceptualization: Author 1, Author 2; Methodology: Author 2, Author 3; Validation: Author 1, Author 3; Formal analysis: Author 2; Investigation: Author 1, Author 3; Resources: Author 2; Data curation: Author 1; Writing – original draft: Author 1; Writing – review & editing: Author 2, Author 3; Visualization: Author 3;

Supervision: Author 2.

Data Availability Statement

Data are available upon reasonable request from the corresponding author.

AI Usage Statement

Generative AI tools were used only for language editing and formatting; no AI was used for data generation or analysis.

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