Optical clearing of skin using enhancers of tissue permeability in a wide spectral range

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The goal of the study was to measure total transmission and diffuse reflectance spectra of skin samples and to obtain spectra of the reduced scattering and absorption of samples before and after immersion in glycerol solution. The study shows comparison of optical clearing (OC) effect at application of DMSO, ultrasound separately, in their combination and without them.

MATERIALS AND METHODS

Samples: *ex vivo* skin samples of white outbred rats

Optical clearing agents:

1. Aqueous 70% glycerol solution (n=1.4279 at 589 nm)
2. Aqueous 70% glycerol solution with the addition of 10% dimethyl sulfoxide (DMSO) (n=1.4450 at 589 nm)

Equipment: UV-3600 spectrophotometer with an integrating sphere (Shimadzu, Japan), spectral range of 350-1500 nm, step width of 2 nm

Ultrasound system Dynatron 125 US (Dynatronics, USA), frequency 1 MHz, power 1 W, continuous mode

UV-3600 spectrophotometer (Shimadzu, Japan)

Ultrasound system Dynatron 125 US (Dynatronics, USA)

Spectral measurements were performs before and after 30 minutes of immersion in glycerol solutions without or after application of US.

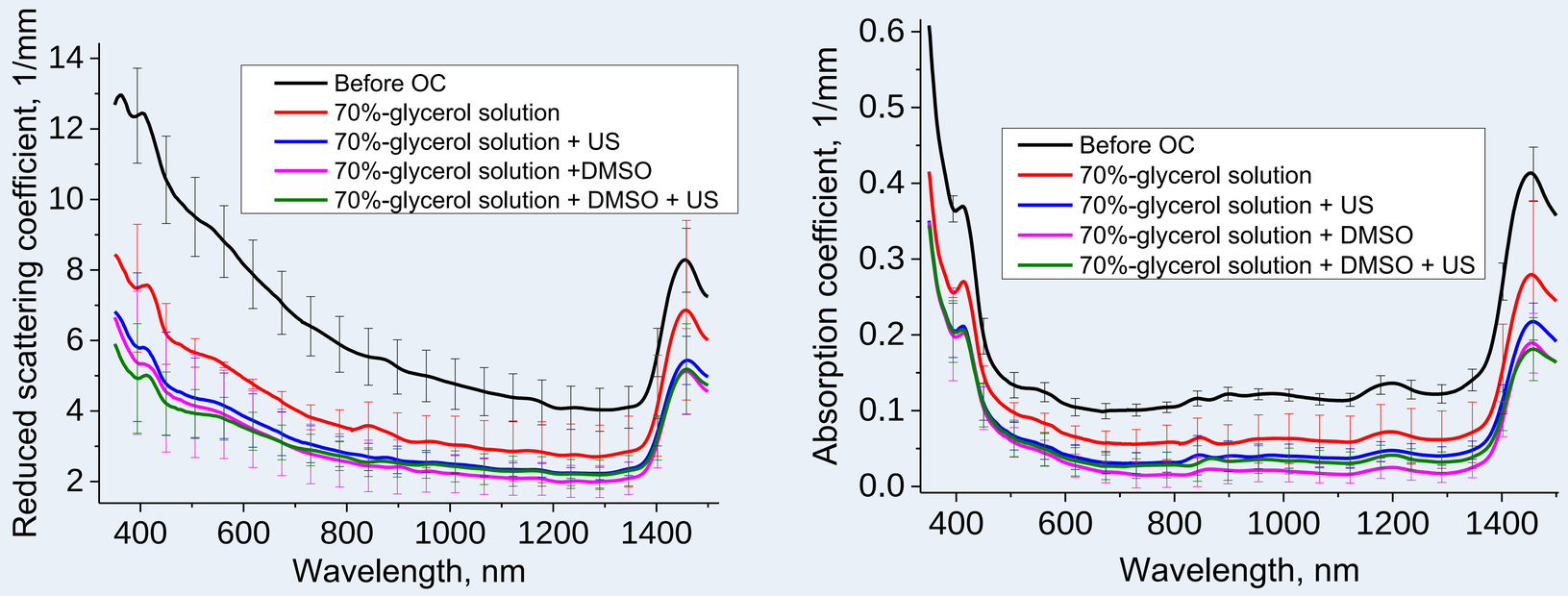
Groups of samples
Aqueous 70% glycerol solution
Aqueous 70% glycerol solution + US
Aqueous 70% glycerol solution with DMSO
Aqueous 70% glycerol solution with DMSO + US

RESULTS

The measured total transmission and diffuse reflectance spectra of samples were used in calculating the spectral dependences of the reduced scattering and absorption coefficient of the samples using the algorithm [1] described in [2].

References:

1. Inverse Adding-Doubling https://omlc.org/software/iad/index.html
2. S. Prahl, Everything I think you should know about Inverse Adding-Doubling. *Oregon Medical Laser Center, St. Vincent Hospital*, 1-74 (2011).



a b

Reduced scattering (a) and absorption (b) coefficient of the samples groups before and after immersion in glycerol solutions

The efficiency of optical clearing of the samples was calculated as the ratio of the difference between the values of the reduced scattering coefficient of the samples, obtained before μ'_{s_0} and after μ'_{s_oc} immersion in glycerol solution, to the initial μ'_{s_0} value:

$$OC_{eff} = \frac{\mu'_{s\_0} - \mu'_{s\_oc}}{\mu'_{s\_0}} \times 100\%$$

Wavelength, nm	Efficiency of OC, %			
	70% -glycerol solution	70% -glycerol solution + US	70% -glycerol solution + DMSO	70% -glycerol solution + DMSO +US
415	58±14	58±13	61±13	61±10
548	51±9	57±5	61±13	58±3
700	46±5	56±3	61±12	51±11
1000	43±13	50±5	57±13	51±9
1460	41±31	37±7	43±15	45±2

Group	Thickness before OC, mm	Thickness after OC, mm
70% -glycerol solution	0.84±0.06	0.84±0.10
70% -glycerol solution + US	0.77±0.09	0.85±0.11
70% -glycerol solution + DMSO	0.87±0.20	0.82±0.17
70% -glycerol solution + DMSO +US	0.82±0.13	0.81±0.13

CONCLUSION

The values of the transport scattering coefficient and absorption coefficient of rat skin *ex vivo* decreased after optical clearing in the studied spectral range in each group of samples.

The reduced scattering coefficient of samples decreased by an average of 1.5 times, and the absorption coefficient – by 1.7 times, at immersing the samples in a aqueous 70% glycerol solution.

The decrease in the transport scattering coefficient and absorption coefficient was more significant (2.2 and 4.4 times, respectively) at adding permeability enhancers to the optical clearing by glycerol solution.

A tendency toward an increase in the efficiency of optical clearing of the skin was observed at adding DMSO and ultrasound to the glycerol solution.

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