DEVELOPMENT AND OPTICAL REFLECTANCE CHARACTERIZATION OF PHANTOMS MIMICKING BIOLOGICAL TISSUES FOR STUDIES OF LIGHT PENETRATION IN THE BRAIN

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The search for materials that accurately mimic the optical properties of biological tissues is essential, particularly for research in transcranial photobiomodulation, where it is necessary to comprehend how light propagates through the head tissues. Particularly, there is a lack of information in literature on the reflectance spectra of these materials, which is a property of relevance when determining how light interacts with tissues. Thus, the first objective of this study was to characterize the reflectance spectra of different porcine tissues, which show similar properties to those of human tissues, to serve as reference. The second objective was to understand and evaluate if it is possible to mimic the reflectance spectra of those tissues. Finally, the third objective was to determine the best materials and concentrations for future studies with multilayer phantoms, that accurately mimic the reflection of light in the head, up to the brain.

In this research, we characterized, in the 500 - 1200 nm range, the reflectance spectra of porcine tissues (skin, fat, cranium, muscle, brain, cerebellum) and different agarose-based phantoms. These phantoms were developed using different combinations of titanium dioxide (TiO_2), India ink, organometallic compounds and laser-sintered gold and zinc oxide nanoparticles. The reflectance measurements were performed using an integrating sphere (1-nm sampling interval, 20-nm slit, at a medium scan speed).

The results showed that increasing TiO_2 concentration increased the optical reflectance of the phantoms. Additionally, when TiO_2 was added to the India ink and laser-sintered nanoparticles' phantoms, not only it increased reflectance amplitude, but it also accentuated the fluctuations in the spectral curves. Comparing the phantoms and biological tissues' results, the spectral profiles of TiO_2 samples appeared similar to that of muscle, skin and brain/cerebellum; organometallic compounds replicated the skin and muscle curves; India Ink emulated the skin; while laser-sintered nanoparticles with the addition of TiO_2 showed similarities to the spectra of muscle and brain/cerebellum, but only after 750-nm.

Although it was possible to establish qualitative similarities between the phantoms and the biological tissues' optical reflectance spectra, there is a need for further studies with different components' combinations, to ascertain curves that more closely mimic the biological tissues spectra.

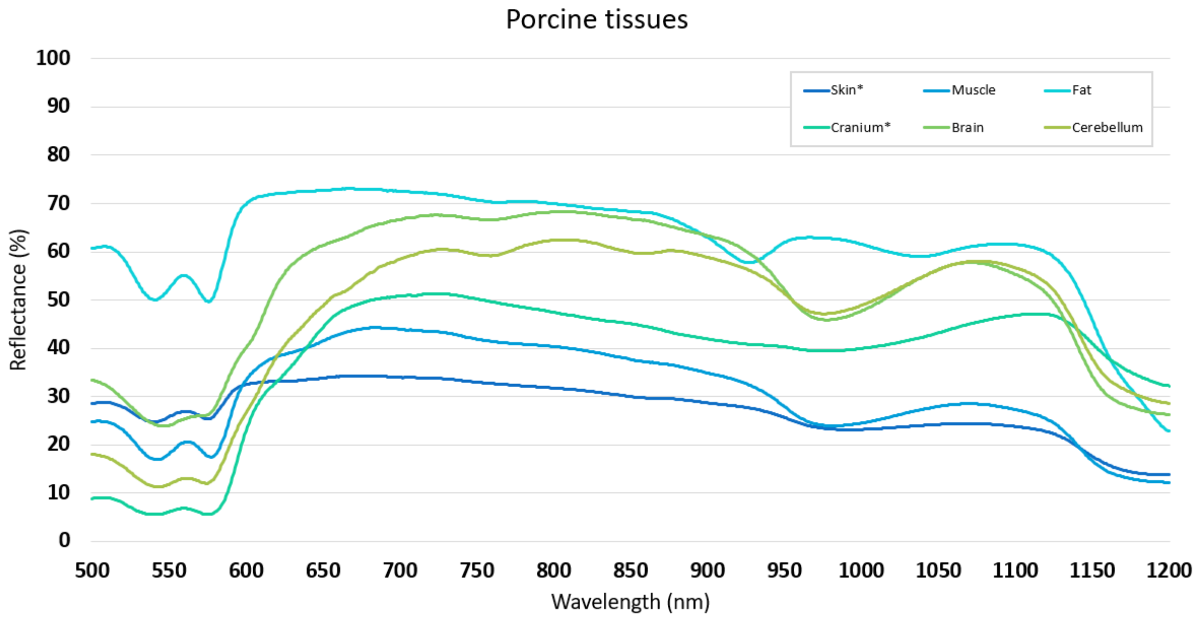

Figure 1 – Reflectance spectra (%) of the porcine tissues, in the 500 – 1200 nm optical range. *Skin (2.5 mm) and cranium (4 mm) samples have different thickness from the other samples (5.5 mm).

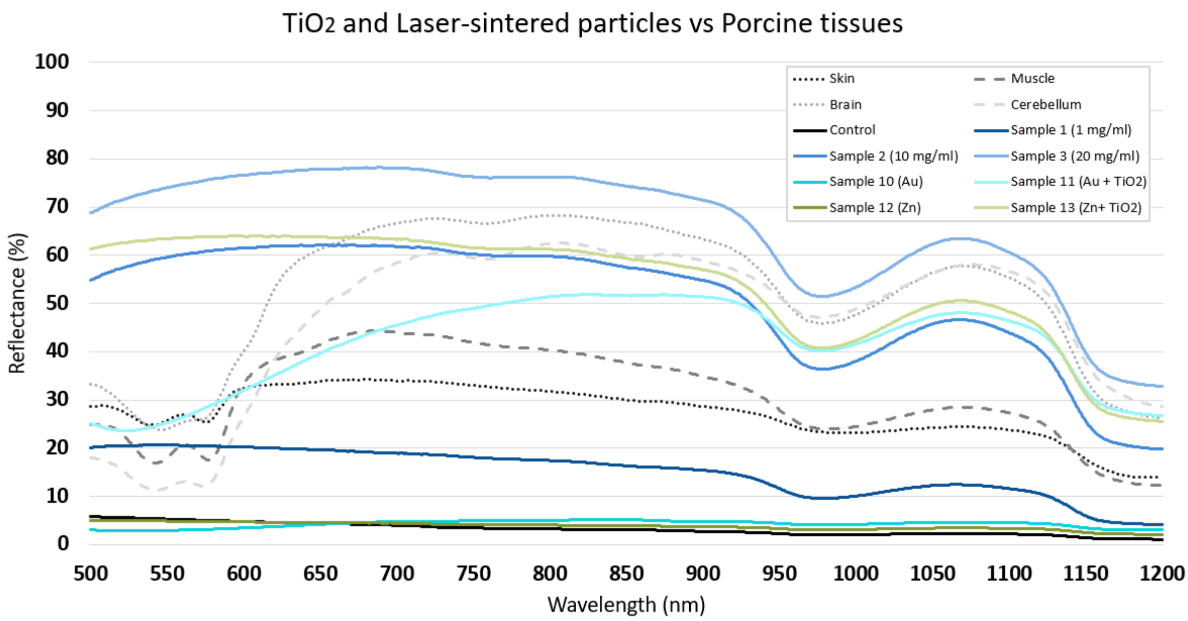

Figure 2 - Reflectance spectra (%) of the TiO_2 (samples 1, 2 and 3) and Laser-sintered particles (samples 10, 11, 12 and 13) the 500 – 1200 nm optical range. The dashed lines represent some of the biological porcine tissues and how they are portrayed close to the phantoms' spectral curves.

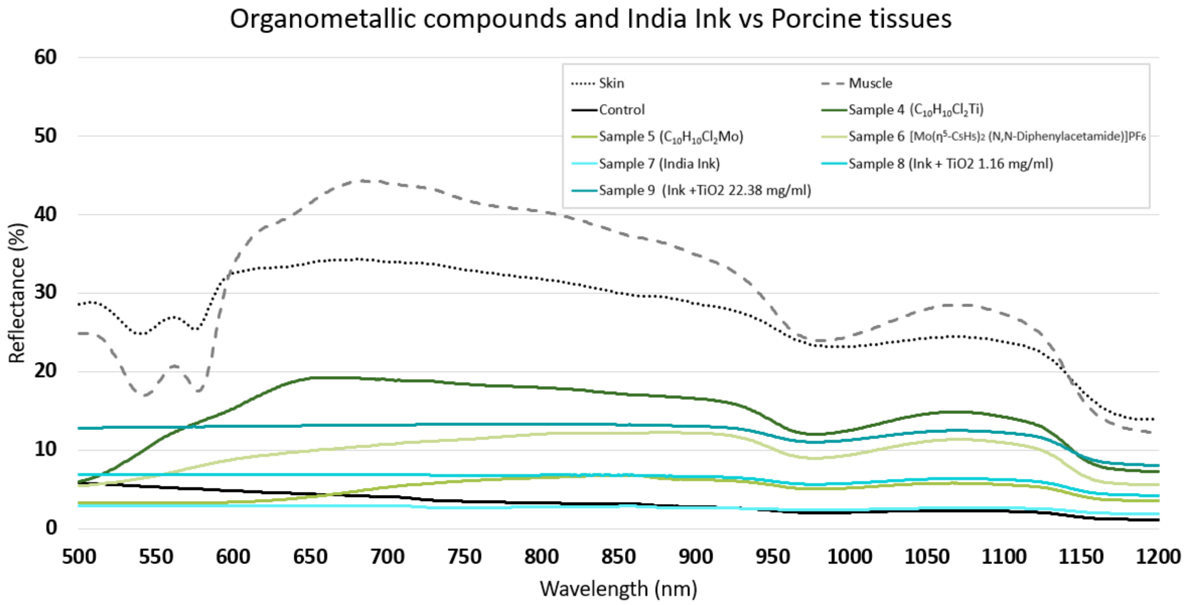

Figure 3 - Reflectance spectra (%) of the organometallic compounds (samples 4, 5 and 6) and India Ink (samples 7, 8 and 9) in the 500 – 1200 nm optical range. The dashed lines represent some of the biological porcine tissues and how they are portrayed close to the phantoms' spectral curves.

Acknowledgments

This work was supported by the project PTDC/EME-EME/1681/2021 – BrainStimMap, with DOI: 10.54499/PTDC/EME-EME/1681/2021, and by the FCT (Fundação para a Ciência e Tecnologia), under the reference projects UIDB/04436/2020 and UIDP/04436/2020. Susana Catarino thanks FCT for her contract funding provided through 2020.00215.CEECIND, with DOI: 10.54499/2020.00215.CEECIND/CP1600/CT0009.