Optical Parameters of Adipose Tissue During Phase Transition

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Motivation

There is convincing evidence that diseases, such as atherosclerosis and coronary heart disease, hypertension, type 2 diabetes, liver diseases, orthopaedic diseases, some cancers (lipoma, liposarcoma, etc.), are associated with excessive accumulation of body fat, i.e. obesity. In this context, there has been a growing interest in studying the function of adipose tissue and its role in health and disease.

The healthy adipose tissue expansion is largely linked to adipocyte hyperplasia, indicative of increased de novo adipogenesis, as well as a relatively lower degree of inflammation and fibrosis. In fact, fibrosis has emerged as a key factor that distinguishes metabolically healthy versus metabolically unhealthy obesity of humans. Due to the growth of connective tissue fibers, adipose tissue becomes more refractory, which can be assessed by measuring phase transitions. Thus, the temperature dependence of phase transitions can be used as a diagnostic tool to identify pathological tissue.

The aim of the work was to study the optical properties of adipose tissue during the phase transition upon heating.

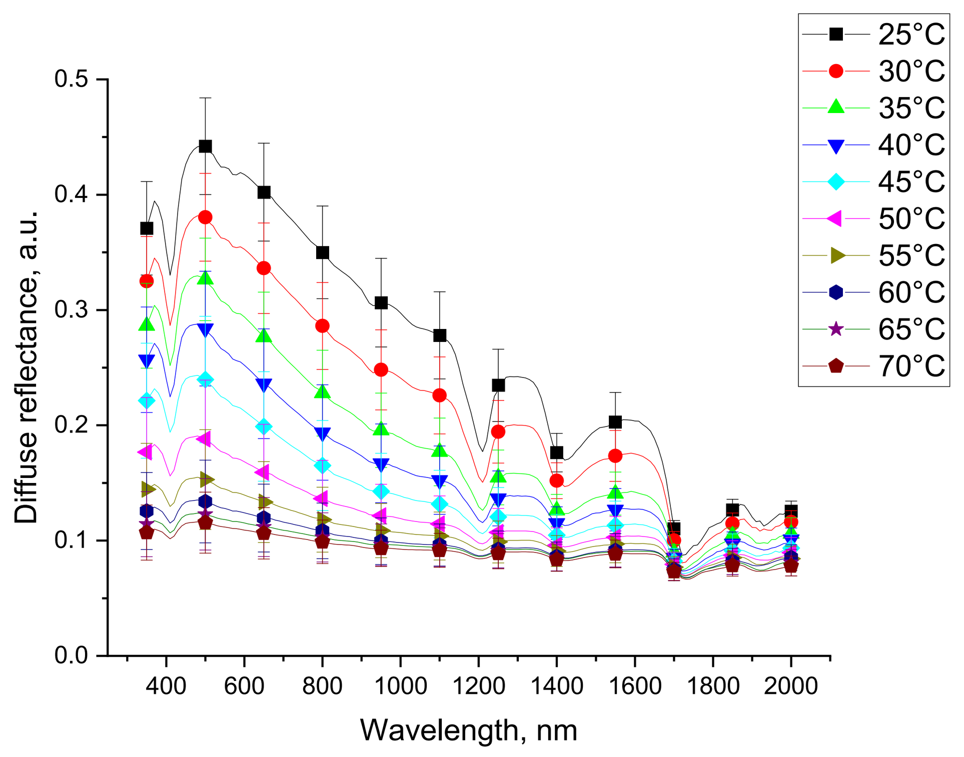
Materials and Methods

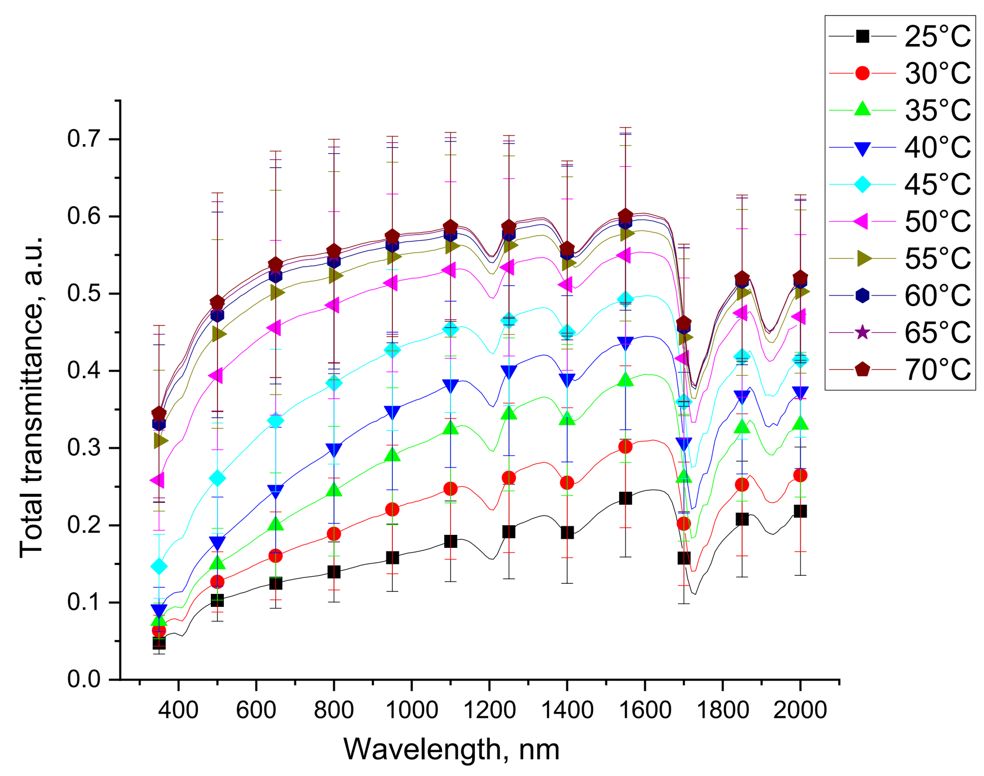
- Material: 20 samples of fresh porcine abdominal adipose tissue.
- Optical parameters detection: diffuse reflection (R_d) and total transmission (T_t) of the samples were measured during heating from ~25 to 70°C in the wavelength range of 350–2500 nm using a spectrophotometer UV-3600 with an integrating sphere LISR-3100 (Shimadzu, Japan).
- Optical parameters calculating: the absorption (μ_a) and reduced scattering (μ_s') coefficients of the samples were calculated from diffuse reflection and total transmission values using the inverse addition-doubling method [1].
- Meta-samples: to calculate such optical parameters as μ_a and μ_s', samples with measured R_d were matched to samples with measured T_t based on the similarity of sample thicknesses. Thus, the obtained values of μ_a and μ_s' correspond not to actually existed samples, but to certain "meta-samples" that combined the properties of two samples of similar thickness.

[1] *Prahl, S. A.: The Adding-Doubling Method. In Optical-thermal response of laser-irradiated tissue, Welch A.J., van Gemert, M.J.C., Eds.; Plenum Press: New York, UK, 1995, pp. 101-129.*

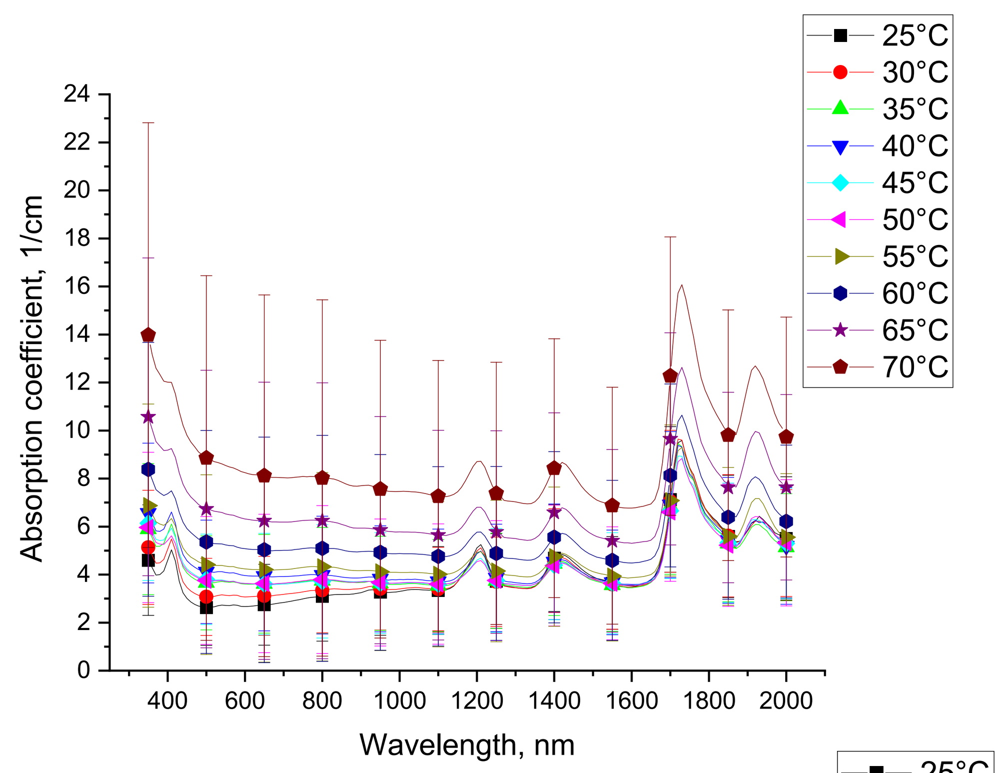
Results

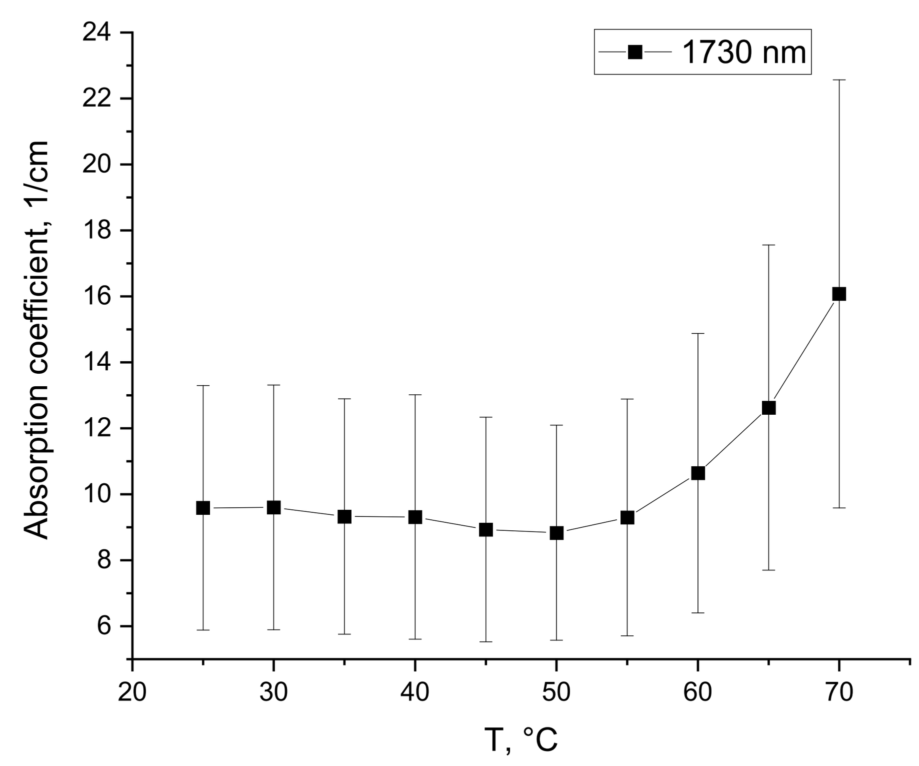
Detected parameters

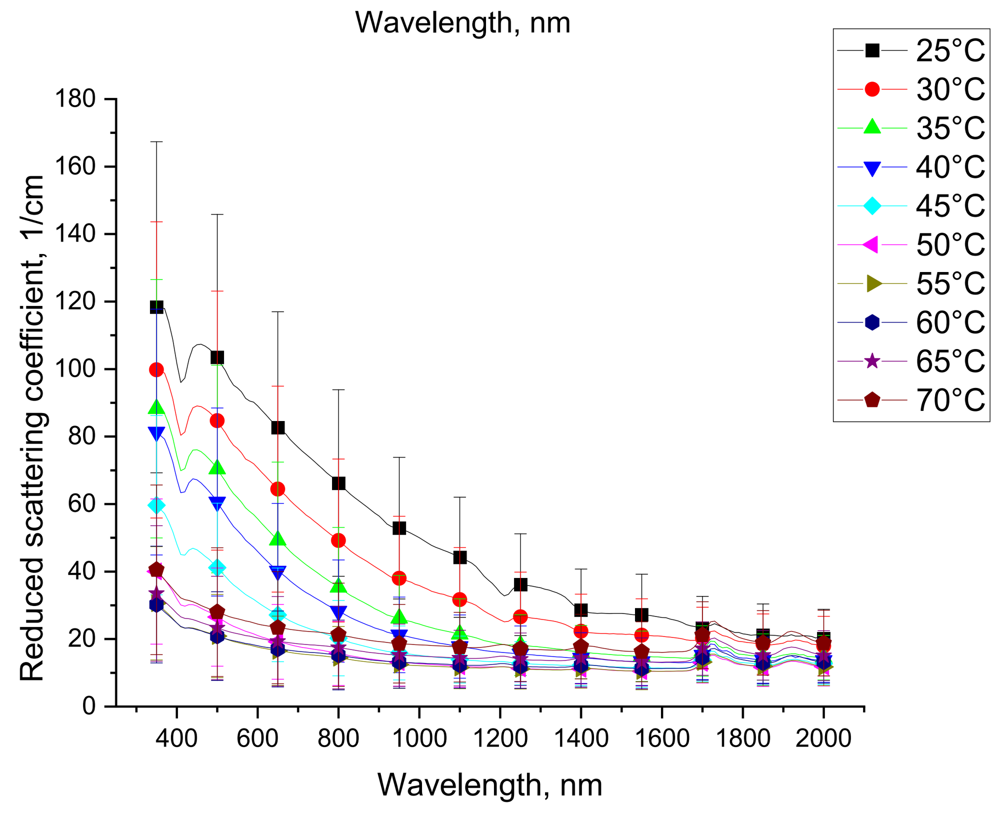


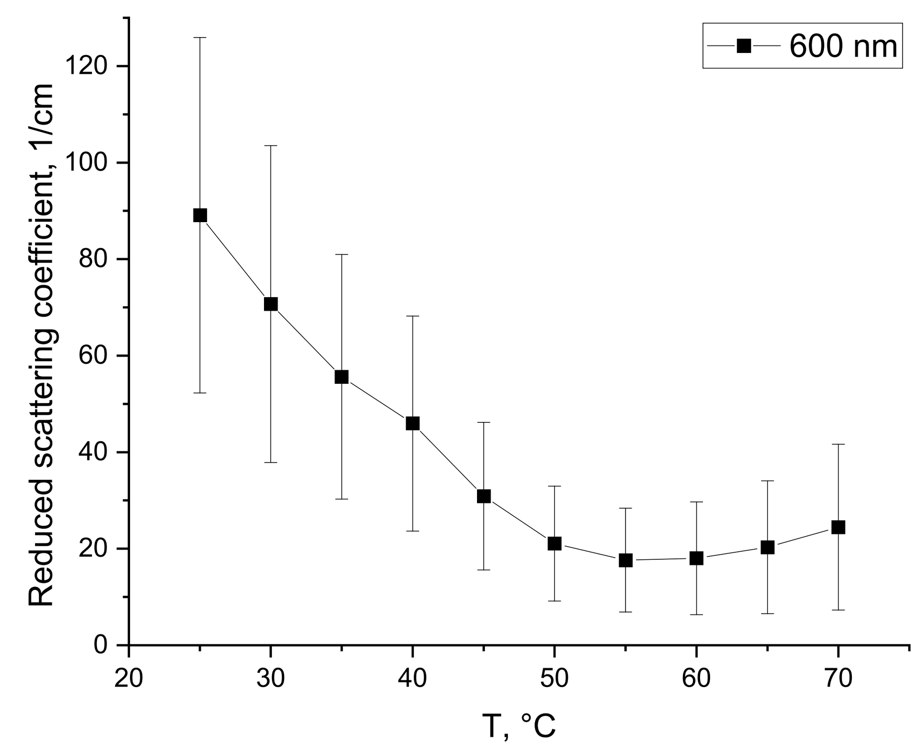


Calculated parameters









Discussion

The detected parameters spectra shapes are determined by the capillary blood hemoglobin absorption bands and the scattering coefficient spectral dependence in the visible range and by the water, lipids and proteins absorption bands in the IR spectral range. It is clearly seen that with increasing temperature there is a decrease in diffuse scattering and an increase in total transmission. This is especially noticeable at the initial stages of heating.

In figure with the calculated parameters spectra, the hemoglobin absorption band at 410 nm (Soret band) is evident. With increasing temperature, it becomes significantly smoother. On the black graph corresponding to a temperature of 25°C two peaks at 540 and 570 nm can be seen, but they also smooth out as the temperature increases. These three absorption bands are characteristic of oxygenated hemoglobin, while deoxygenated hemoglobin is characterized by two peaks near 425 and 555 nm. The absorption bands of water can be seen at 1210, 1420 and 1920 nm and at 1730 nm there is a lipid absorption band. Another lipid absorption band can be seen at 1760 nm in the graphs corresponding to temperatures of 25-55°C, but at higher temperatures this band is smoothed out.

This may be due to a phase transition of the lipids that make up the adipose tissue. This assumption is confirmed by figures, which demonstrates a sharp change in the direction of growth of optical parameters upon reaching a temperature of 50-55°C.

Hemoglobin absorption bands smoothing indicates that with increasing temperature, hemoglobin in adipose tissue is destroyed. With increasing tissue temperature, the amplitude of the absorption peaks of the main chromophores (hemoglobin and water) in the visible and near infrared spectral regions change. It can be seen that the absorption coefficient, after a slight decrease when heated to 50°C, then increases sharply when heated to 70°C. The reduced scattering coefficient decreases significantly when heated to 55°C, and then increases slightly when heated to 70°C. These changes may be associated with a phase transition of the sample substance.

Conclusion

The work demonstrates the changes of the adipose tissue optical parameters during the temperature-mediated phase transitions. During the work, changes in the optical properties of adipose tissue caused by a phase transition during heating were identified. Knowledge of optical properties can help in developing methods for diagnosing and treating many diseases.

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