Modeling small strain behavior of subcutaneous fat

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Introduction

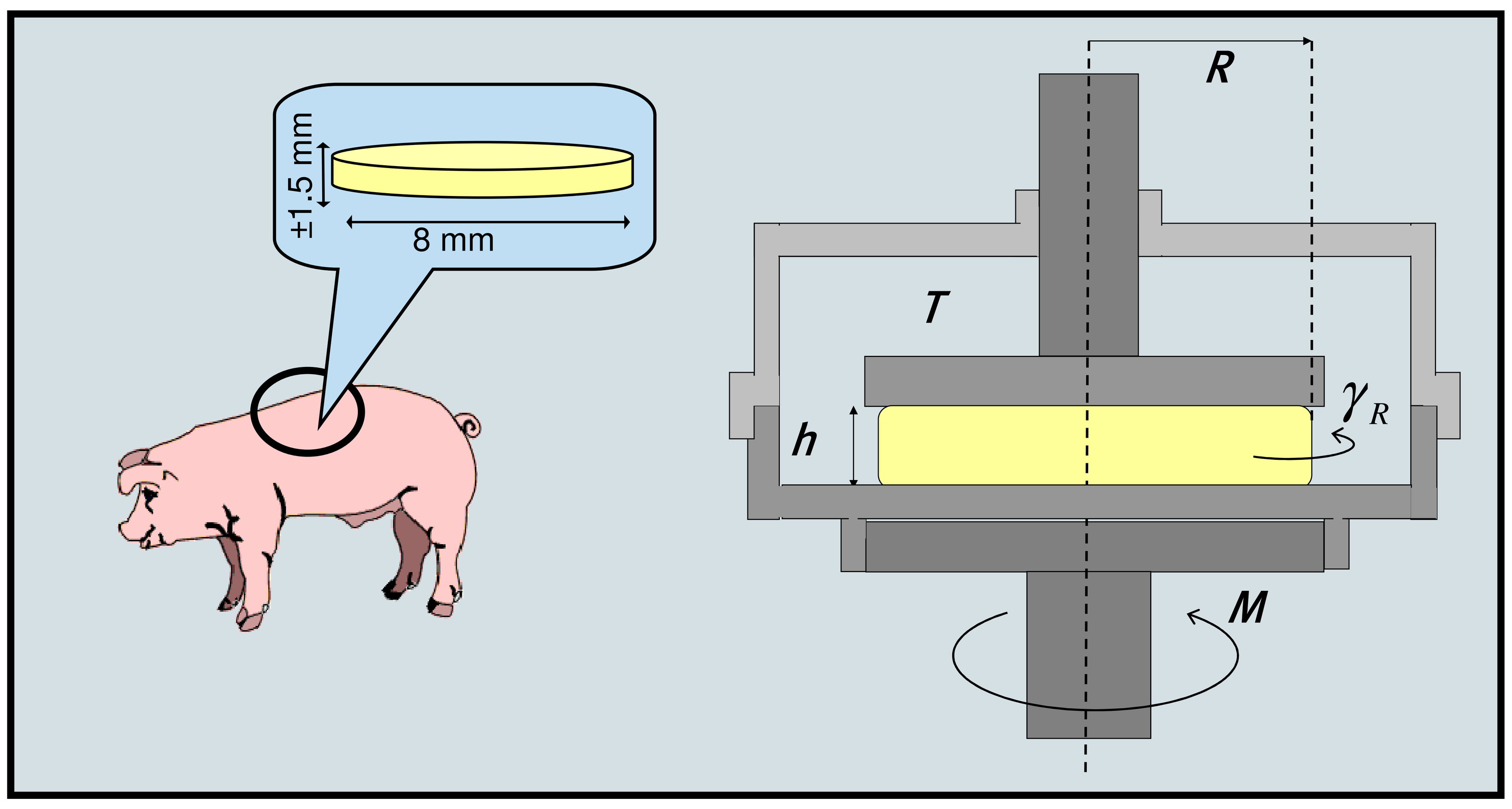
Until today mechanical properties of the subcutaneous fat layer have been hardly considered as important and hence, a constitutive model describing its behavior is lacking. However, numerical models including the subcutaneous fat layer are needed in a wide field of applications such as skin device contact, needle insertion procedures, and the removal of skin adhesives.

Objective

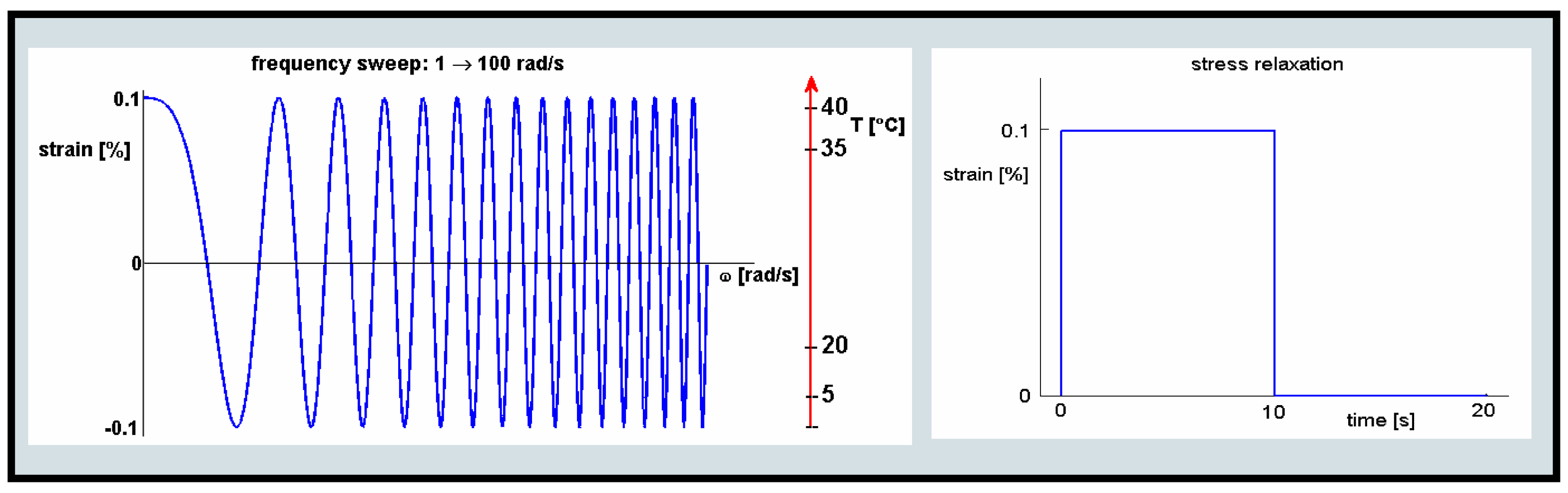
Implementing models that cover the small strain-behavior of the subcutaneous fat layer.

Experimental testing

Experimental set-up

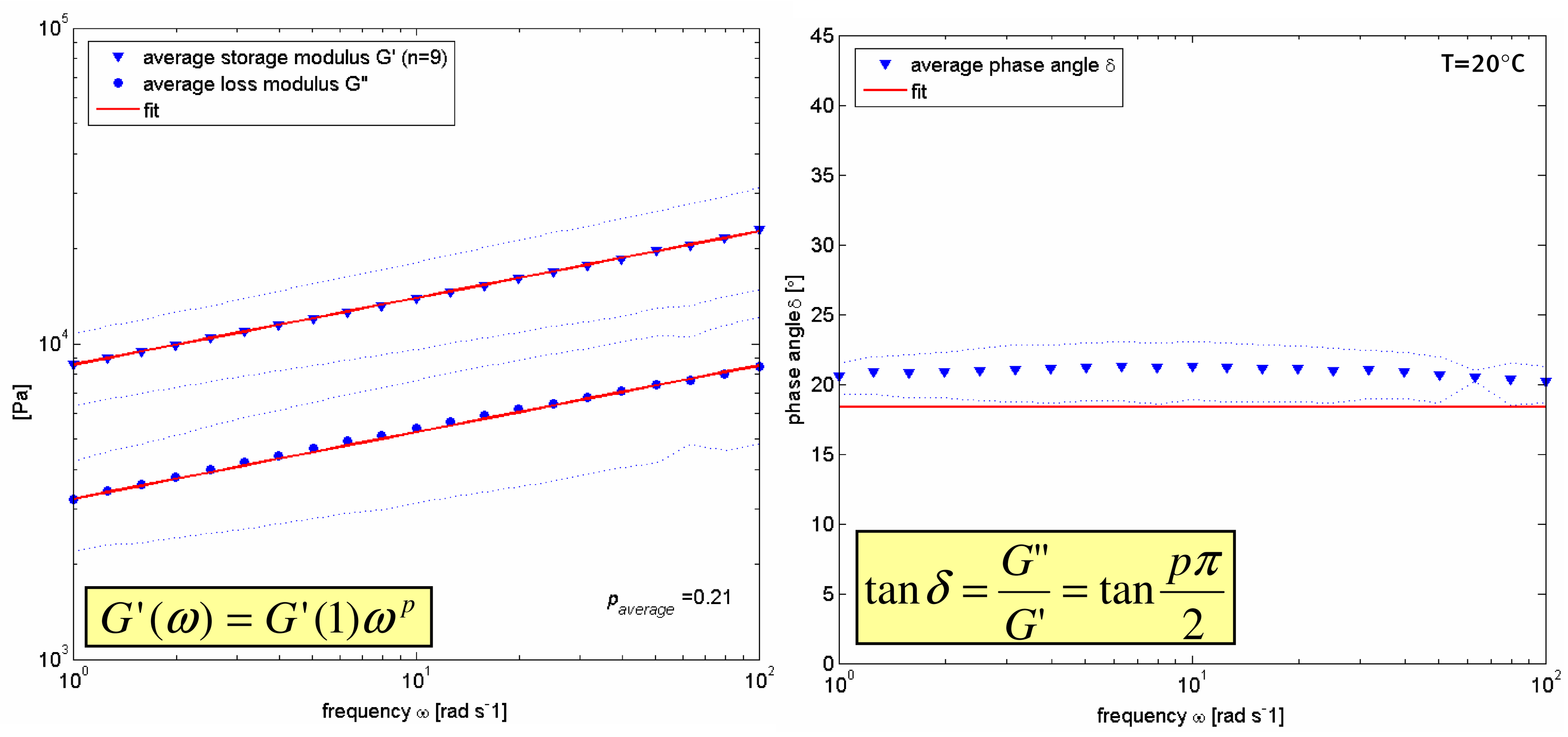


Testing protocol

- Presetting: 2 frequency sweeps (T=20°C)
- 

Model application

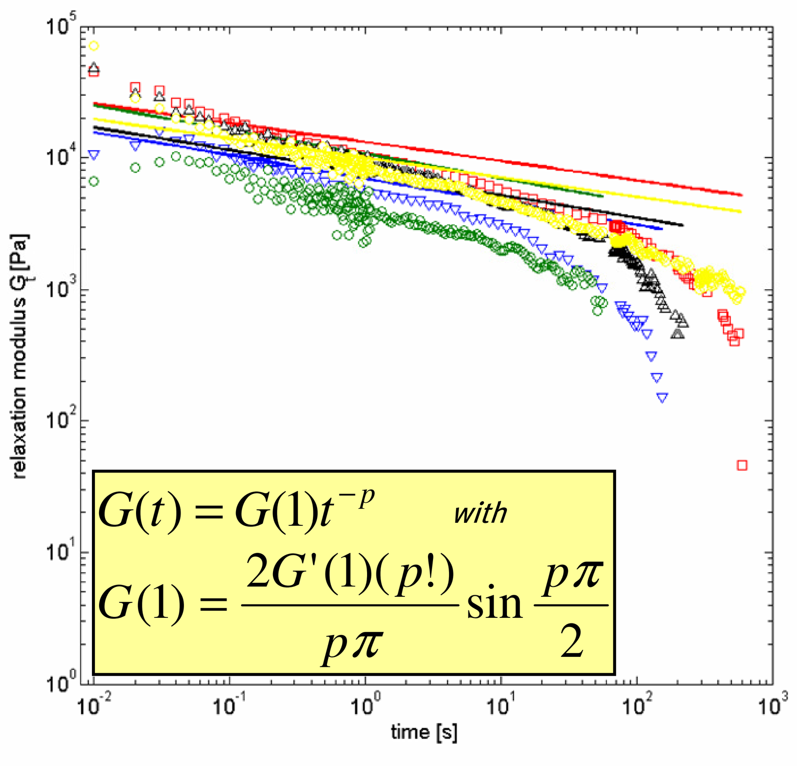
Small-oscillatory strain behavior



The experimental data for the storage modulus *G'*, the loss modulus *G"*, and the phase angle δ are adequately described by a power-law relation with only two constants: *G'(1)* and an exponential *p*-value[1].

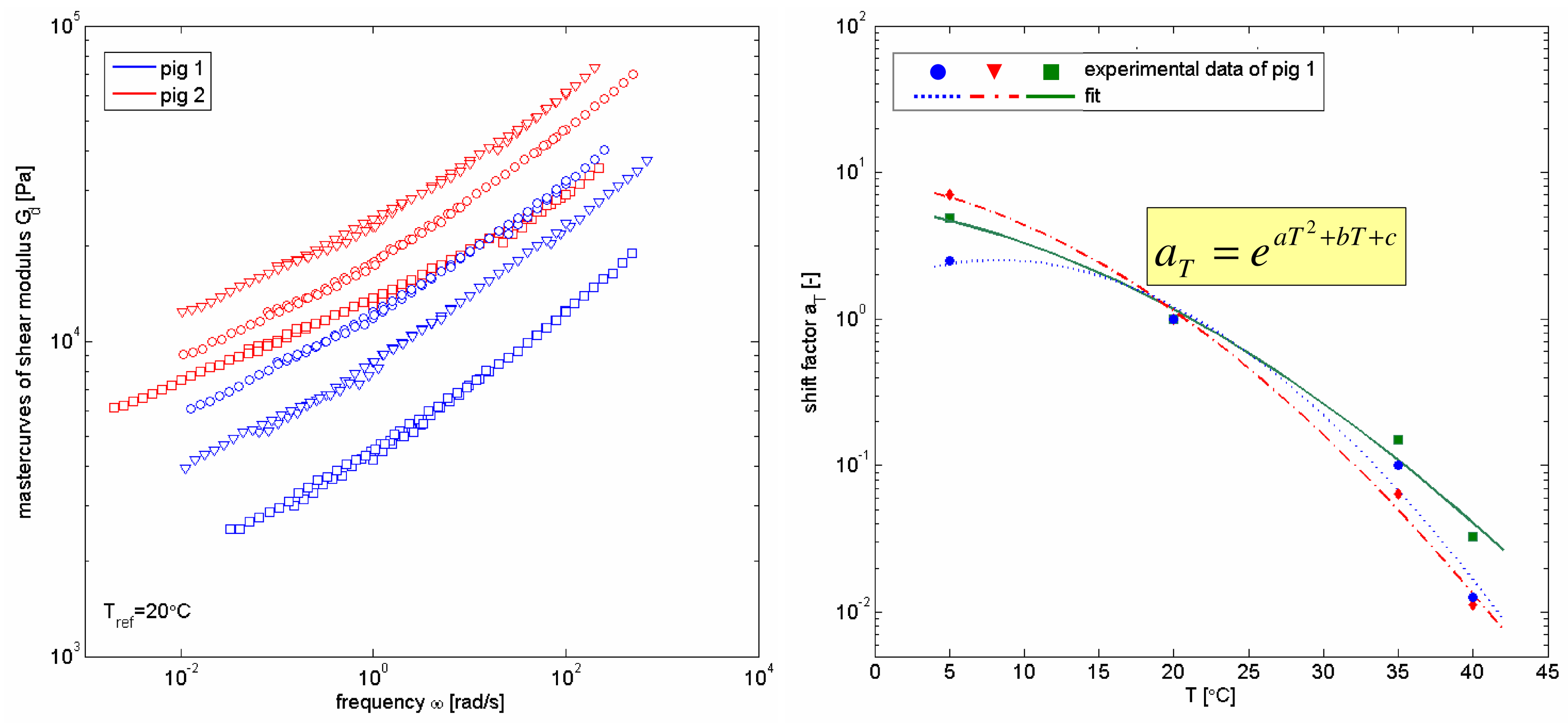
Stress relaxation

Frequency sweeps were followed by a stress relaxation test. By expressing the obtained relaxation function *G(t)* as a function of *G'(1)* and the *p*-value[2], the power-law model also captures these experimental data.



Time-Temperature Superposition

During consecutively applied frequency sweeps the phase angle remained constant over the temperature range. Therefore only horizontal shifting of the shear modulus G_d to a reference temperature T_{ref} was performed to obtain a mastercurve. The relation between the shift factor a_T and the temperature T is fitted by an exponential function.



Conclusions

- A common rheological model with only 2 constants, *G'(1)* and *p*, is successfully introduced to describe the small strain behavior.
- Time-Temperature Superposition is applicable, meaning that the frequency domain can be widened to outside the experimental limits.
- The power-law function model forms a good basis for a constitutive model describing small and large strain behavior during all kinds of loading, which can be implemented into numerical models.

References

[1] R.I. Tanner, Engineering Rheology, second ed., Oxford University Press, 2000.

[2] A.C. Pipkin, Lectures on Viscoelasticity Theory, second ed., Springer-Verlag, New York, 1986.