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Rheological modeling of food emulgels: the role of interfacial contribution and droplets radius in designing biphasic food systems

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INTRODUCTION & AIM

In recent years, the development of rheological models for the description of biphasic food systems is receiving a growing attention [1,2]. Due to the complexity of the systems, theoretical, semi-empirical and empirical approaches are used for the description and, modelling can even take into account rheological properties of the interface and the droplets size, in addition to the rheological properties of the bulk phases. In the present work emulgel samples were produced, characterized and modelled. Emulgels with healthy and sustainable ingredients (plant-based) were produced. Several techniques were used for the characterization of sample properties, spacing from bulk rheology tests to interfacial measures, passing through laser diffraction for the microstructural investigation. Two semi-empirical models were used to describe the sample's rheology and compared to the theoretical ones. The most suitable model was then used for the prediction of the consistency of emulgel sample prototypes with the same consistency of commercial benchmarks.

METHOD

High Shear Homogenization (4000 rpm, 1 min)
+ **Microfluidization (172 MPa)**

Bulk Rheology (G_C^*, G_E^*):

- Frequency sweep test (Haake Mars 40, Thermo Scientific, USA).

Interfacial Rheology (γ, G_i, E_i):

- Static Interfacial Tension Measurements (FTA 200 tensiometer, First ten angstrom, USA);
- Interfacial Dilatational Relaxation Tests (FTA 200 tensiometer, First ten angstrom, USA);
- Interfacial Shear Frequency Sweep Tests (ISR400, KSV Instruments, Finland);

Quantitative microstructure (R):

- Laser diffraction-Mastersizer 2000 (Malvern, USA);

Qualitative microstructure:

- CLSM - Stellaris 8 (Leica microsystem, Germany).

Rheological Modeling

«Modified Kerner Model»

$$G_r^* = \frac{1+\frac{3}{2}H\varphi}{1-AH\varphi} \qquad H = \frac{2(M-1)}{2M+3} \qquad M = \frac{G_D^*}{G_C^*} \qquad G_r^* = \frac{G_E^*}{G_C^*}$$

«Modified Palierne Model»

$$G_r^* = \frac{1+\frac{3}{2}H\varphi}{1-AH\varphi} \qquad H = \frac{E}{D}$$

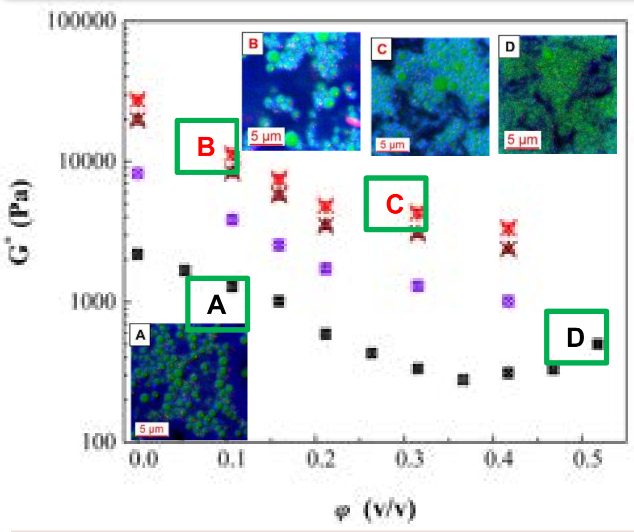
$$\mathrm{E} = \mathrm{E}(\mathrm{M}, G_C^*, R, \gamma, E_i, G_i)$$

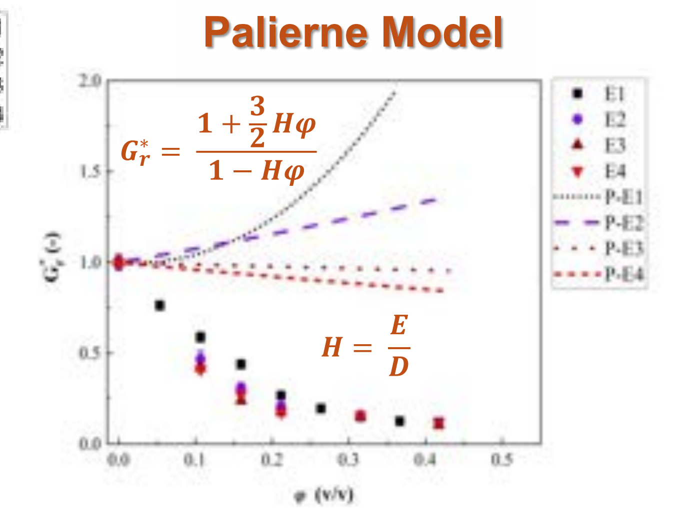
$$\mathrm{D} = \mathrm{D}(\mathrm{M}, G_C^*, R, \gamma, E_i, G_i)$$

$$R = D_{3,2}/2$$

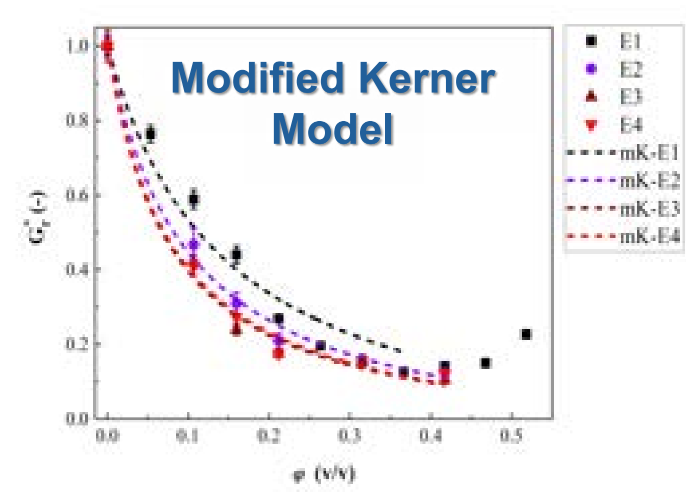
G_E^* = emulgel complex modulus
G_C^* = hydrogel complex modulus
R = droplets radius
γ = interfacial tension
E_i = interface dilatational modulus
G_i = interface shear modulus
A = corrective parameter
$D_{3,2}$ = surface diameter

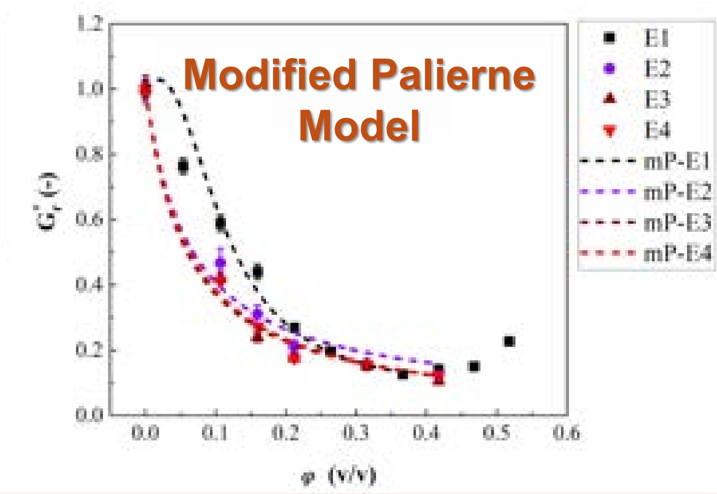
RESULTS & DISCUSSION





- Microscopic and macroscopic properties strictly depends on composition (x_f, φ).





- Modified Kerner model fits the data in a better way.

B1

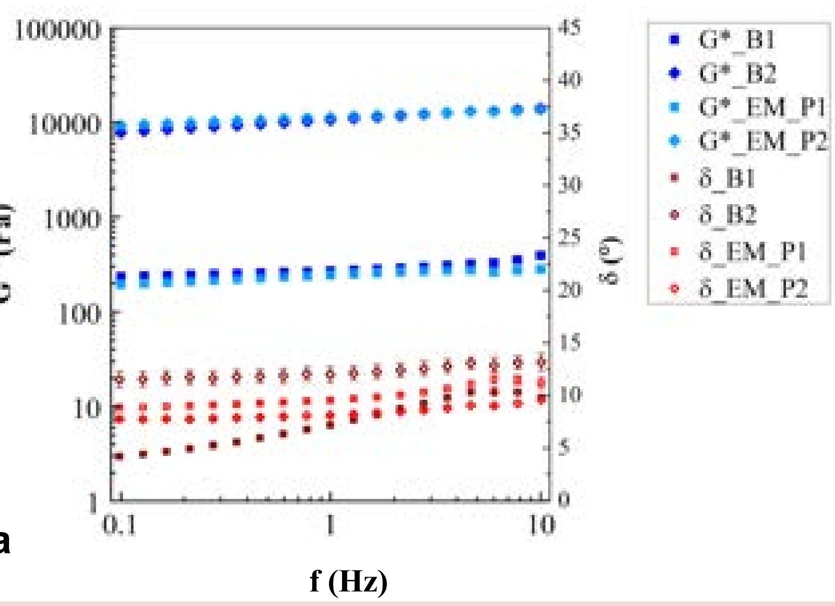
$\varphi = 0.27$

G_E^* = 270 ± 10 Pa

B2

$\varphi = 0.13$

G_E^* = 10600 ± 600 Pa



- The EM_P1 and EM_P2 prototypes with predicted fiber content (x_f) have similar G* to those of benchmarks B1 and B2, respectively.

EM_P1
$\varphi = 0.27$, x_f = 0.0055

EM_P2
$\varphi = 0.13$, x_f = 0.0453

Sample ID	G^*@1Hz (Pa)	δ@1Hz (°)
EM_P1	250 ± 10	9.53 ± 0.09
EM_P2	11300 ± 700	8.10 ± 0.03
B1	270 ± 10	7.19 ± 0.03
B2	10600 ± 600	12.0 ± 0.7

CONCLUSION

- Theoretical Kerner and Palierne model overestimate the consistency of systems and in the case of Palierne even a stiffening effect is predicted.
- The modified Kerner model resulted the most suitable for practical application (better data fitting and simplicity).
- The modified Kerner model can be effectively used to design emulgel formulations similar to reduced-fat (light) mayonnaise and reduced-fat (light) spreadable cheese.

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