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Citrus fiber–soy protein emulgels for plant-based foods: a rheological characterization and modeling

E. Bruno[1], F. R. Lupi[1], O. Mileti[1], N. Baldino[1], D. Gabriele[1]

[1]University of Calabria, Department D.I.M.E.S, Via P. Bucci, Cubo 39C, 87036 Rende (CS)

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INTRODUCTION & AIM

This work aimed at studying oil-in-water systems structured with citrus insoluble dietary fiber (IDF) and enriched with soy protein (SP), to propose rheological models and design plant-based/vegan functional foods. Emulsion gels (emulgels), chosen for their tunable texture and stability[1],were developed as model systems. Emulgels were prepared with high-pressure homogenization, fixing O/W ratio (ϕ = 0.111 w/w) while varying IDF and SP fraction, as a function of fiber/protein ratio (κ). Additional samples were produced by varying ϕ to propose a comprehensive rheological model. This model was then applied to design an emulgel with properties comparable to the benchmark (a spreadable cheese).

METHOD

Samples preparation

Materials:
Water phase: IDF (JRS Silvateam Ingredients srl) and SP Isolate (Bulk Powders, UK)
Oil phase: Sunflower oil (Fabiano, Italy) and soy lecithin (15% w/w, Ivovital, Germany)

Preparation conditions:
Premixing of the sample by magnetic stirring, followed by high-pressure homogenization (Homolab 2.50, FBF Italia S.r.l., Italy) at 150 bar (first stage) and 200 bar (second stage).

- ✓ **Effect of fiber and protein fraction**: O/W emulgels (10/90) prepared by increasing fiber and protein (1:1 mass ratio).
- ✓ **Effect of protein/fiber ratio (κ)**: O/W emulgels (10/90) at fixed fiber fraction (2% and 4% w/w) with variable κ.
- ✓ **Rheological modeling**: Emulgels at different oil fractions, fixing fiber and protein concentration at 4%w/w.

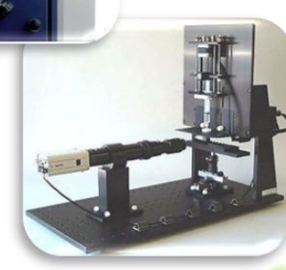
Samples characterization

Rheology
MCR702e, Anton Paar, PP 20 mm SAOS
T=25°C, ω= 0.1÷10 Hz

Microscopy
Cryo-SEM, Flexsem 1000 II, Hitachi, T=-30°C, low vacuum (50 Pa)

Particle size distribution
Mastersizer 2000, Malvern, (UK)

Interfacial characterization
Automated Pendant Drop Tensiometer (FTA200, First Ten Angstroms, Portsmouth, VA, USA).



RESULTS & DISCUSSION

Effect of fiber and protein fraction

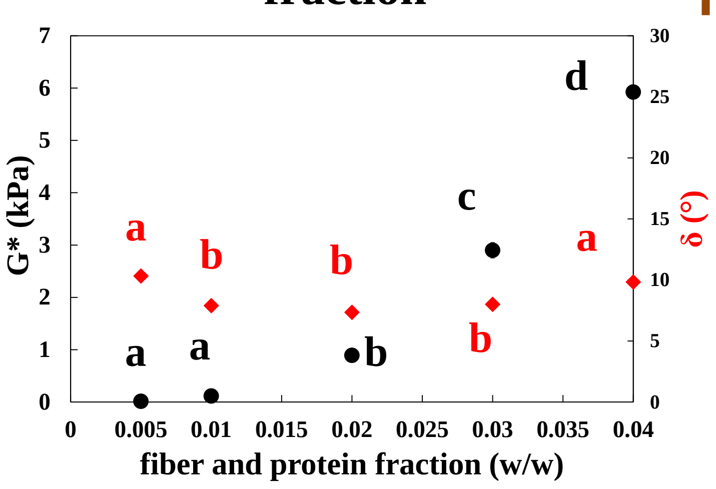


Fig. 1: G* and δ (1Hz) with fiber and protein fraction.

Effect of κ

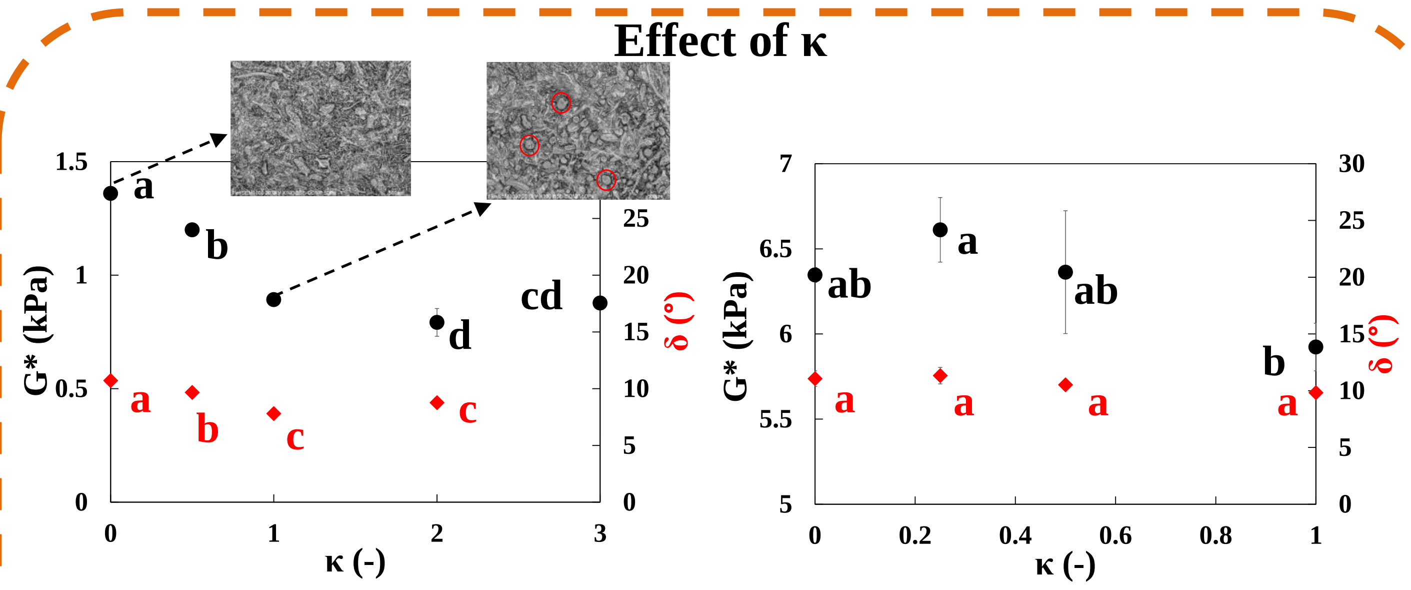


Fig. 2: G* and δ (1Hz) *vs* κ at 2% of fiber (a) and 4% of fiber (b).

For both Fig. 1 and 2, different letters within the same parameter indicate significantly different values ($p < 0.05$).

- ✓ **Greater consistency with increasing fiber and protein concentration**
- ✓ **Increasing κ reduces consistency at low fiber content**
- ✓ **SEM: higher protein fraction gives undissolved globules which disrupt fiber networks and weaken gel consistency**

Rheological modeling[2]

$$G_r = \frac{1 + 3H\phi}{1 - 2H\psi\phi} \qquad M = \frac{G_d}{G_c}$$

$$H = \frac{(M-1)(19M+16) + \left(\frac{4\gamma}{RG_c}\right)(5M+2)}{(2M+3)(19M+16) + \left(\frac{40\gamma}{RG_c}\right)(M+1)}$$

1 ***Interfacial tension (γ)*** at O/W interface under saturation conditions[1]:

$$\gamma = 5.6 \pm 0.2\ mN/m$$

Droplets Radius (R) is described as a function of ϕ

$$D_{3,2} = A \cdot \phi^b \qquad A = 0.594 \pm 0.005\ \mu m \qquad b = -0.813 \pm 0.003\ (-)$$

2 ***Neglecting interfacial properties*** and assuming that the elastic modulus of particles is predominant

$$H = \frac{M-1}{2M+3}$$

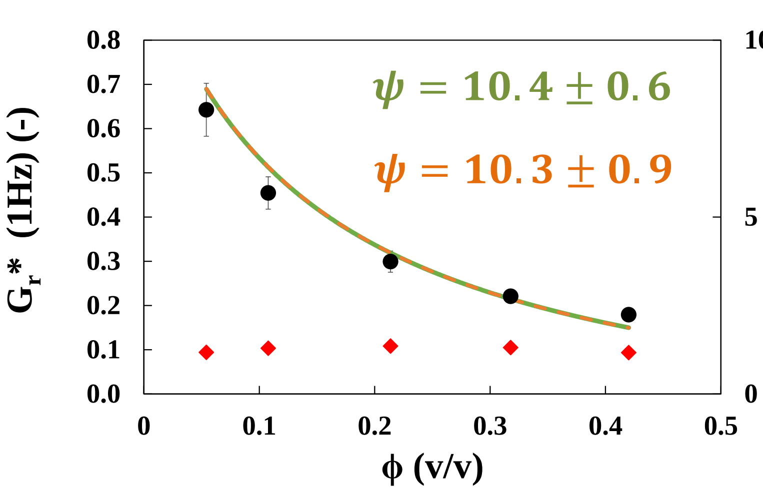


Fig. 3: G_r^* and δ of emulgels as a function of volumetric fraction

- ✓ H was included in the model both in 1 and in 2
- ✓ Both models fit well the experimental data
- ✓ Eq. 2 could be more suitable, for potential use in industrial applications

CONCLUSIONS

Emulgels with κ = 4.5% and ϕ = 0.12 showed benchmark-like rheology, modeled by an industry-suitable equation, and very good nutritional properties.

And validation…

Model 2 was adopted to design a light spreadable cheese, rich in fiber and protein, with rheological properties similar to Philadelphia Light

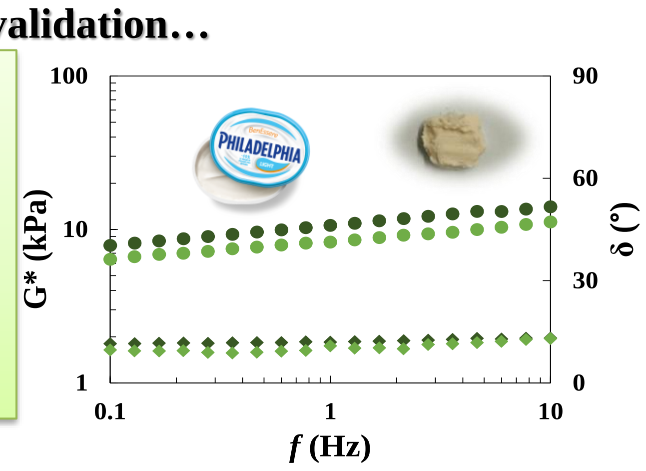


Fig. 4: G* (circles) and δ (diamonds) of philadelphia light (dark green) and emulgel prepared for model validation (light green).

REFERENCES

[1] Bruno et al. 2022. Foods, 11(23).
[2] Van Aken et al. 2015. Food Hydrocolloids, 48, 102-109