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Microfluidized hydrogels and emulgels structured with dietary fiber: influence of processing on physical properties

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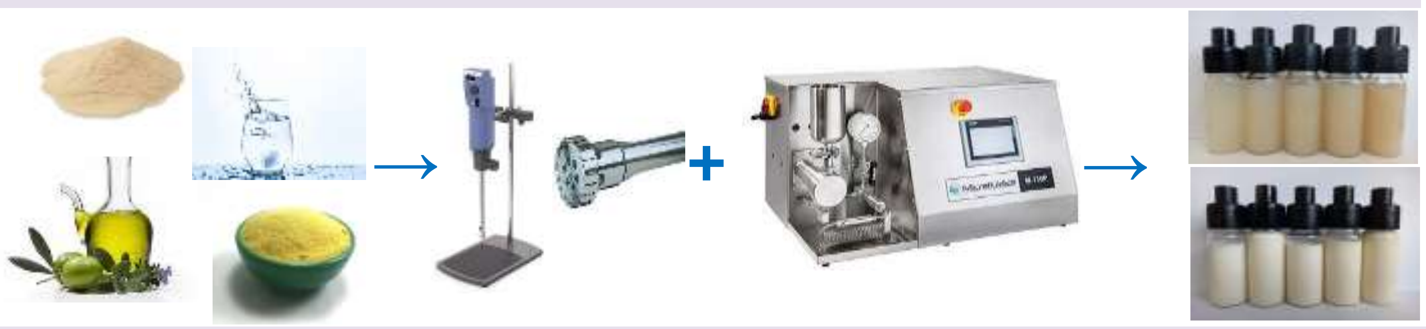
INTRODUCTION & AIM

The usage of dietary fibers from food processing by-products is receiving a growing interest because of its health benefits, texturing and stabilization ability [1]. Under mechanical shear stress, citrus fiber aqueous suspension typically gives rise to (particle) hydrogel or emulgel, if oil phase is present [2]. Technology and process condition affects rheology, microstructure and stability of such system [2]. Microfluidization is a very attractive and effective homogenization technique for processing food systems. The effects of microfluidization channel types (Z-z chamber series and y-Z chamber series) and number of cycles (1 and 2) on rheology and microstructure of both hydrogel and emulgels was faced. In particular, rheological properties connected to strength, deformation and consistency were evaluated by dynamic oscillatory shear tests and particle and droplets size distribution were determined by laser diffraction. Morphology was investigated by optical and confocal microcopies. Finally, physical stability was assessed by multiple light scattering.

METHOD

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



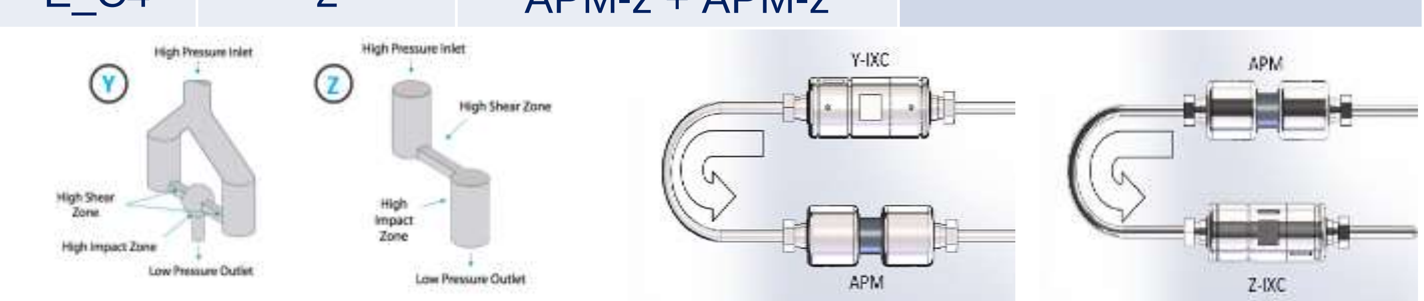
Rotational rheology - Haake Mars 40 (Thermo Scientific, USA):

- Stress sweep test (0.01 – 100 Pa, 1 Hz);
- Frequency sweep test (0.01 – 10 Hz, LVR).

Microstructure:

- Laser diffraction-Mastersizer 2000 (Malvern, USA);
- Optical microscopy - Axio Scope A1 (Carl Zeiss, Germany);
- CLSM - Stellaris 8 (Leica microsystem, Germany).

Sample ID	n° of cycles	Channel configuration	Channel diameters (µm)
H_C1	1	APM-z	200-87
H_C2	2	APM-z + APM-z	
H_C3	1	APM-z	75-200
H_C4	2	APM-z + APM-z	
E_C1	1	APM-z	200-87
E_C2	2	APM-z + APM-z	
E_C3	1	APM-z	75-200
E_C4	2	APM-z + APM-z	



$\tau_L = \tau\big|_{G'=0.95\,G'_{LIN}}$ Limit stress (Pa)

$\gamma_L = \gamma\big|_{G'=0.95\,G'_{LI}}$ Limit strain (-)

$\tau_c = \tau\big|_{G'=G''}$ Critical stress (Pa)

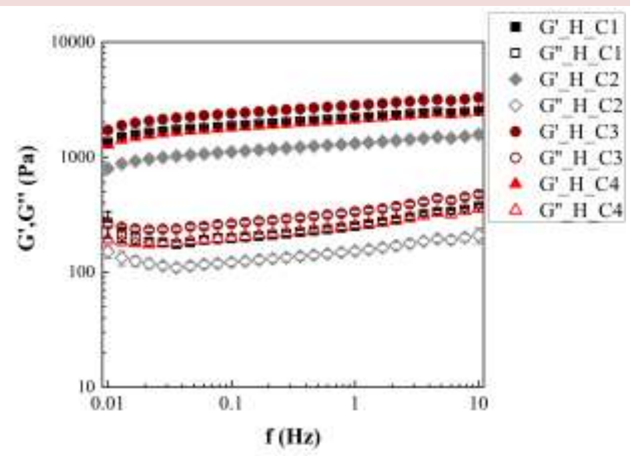
$\gamma_c = \gamma\big|_{G'=G''}$ Critical strain (-)

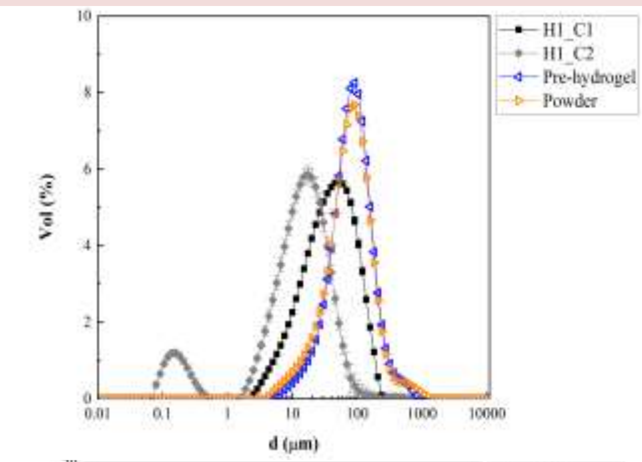
$G_N^0 = G'\big|_{G''_{min}}$ Plateau modulus (Pa)

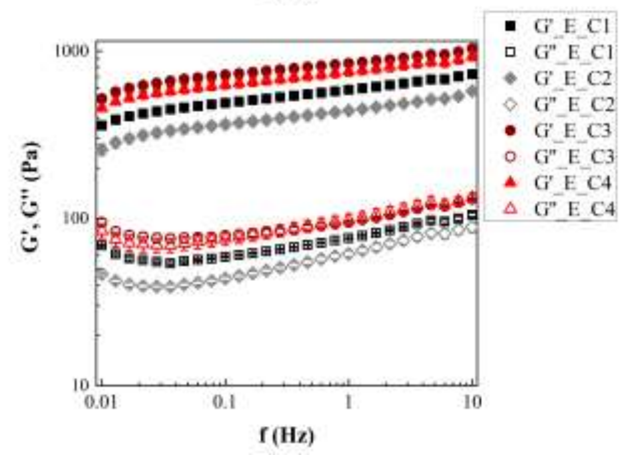
G''_{min} Minimum viscous modulus (Pa)

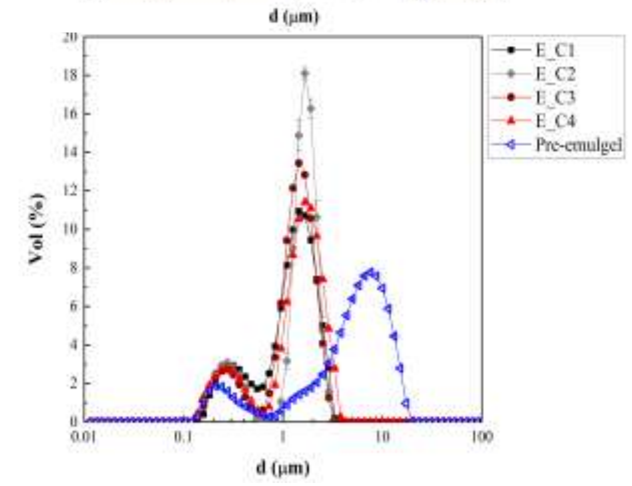
RESULTS & DISCUSSION

- Hydrogels and emulgels showed weak gel behavior.
- The plateau condition is located at approximately 0.315 Hz;
- Particle size distribution is notably affected by processing cycles whereas droplets size distribution is scarcely affected.



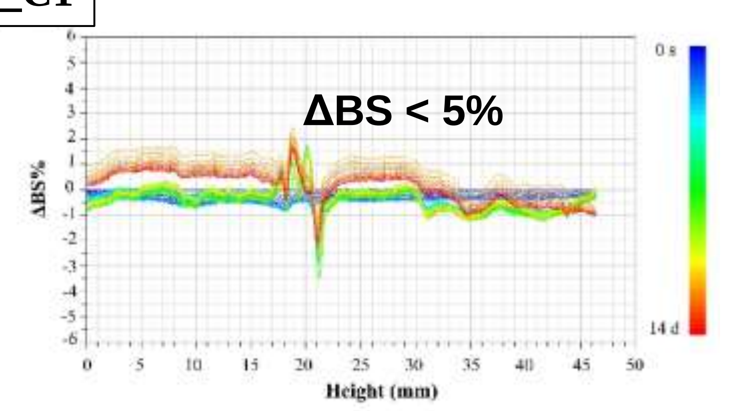


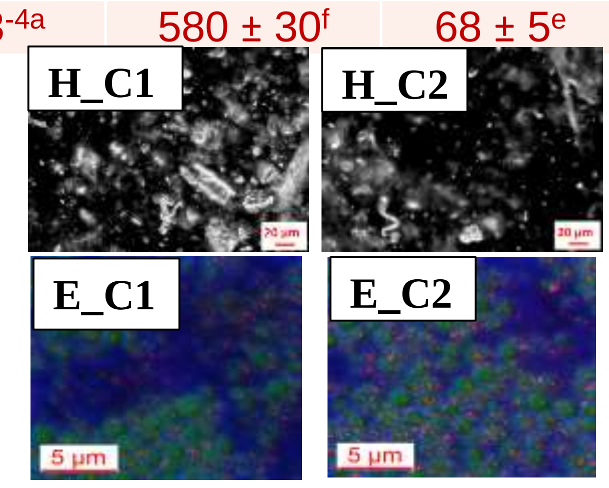




Sample ID	τ_L (Pa)	γ_L (-)	G_N^0 (Pa)	G''_{min} (Pa)
H_C1	22.1 ± 0.5[a]	0.01138 ± 0.00001[a]	1720 ± 20[a]	178 ± 9[a]
H_C2	14 ± 1[b]	0.012 ± 0.001[a]	1020 ± 40[b]	110 ± 9[b]
H_C3	30.33 ± 0.02[c]	0.0120 ± 0.0004[a]	2060 ± 90[c]	230 ± 10[c]
H_C4	11 ± 2[b]	0.010 ± 0.001[a]	1550 ± 50[d]	176 ± 7[a]
E_C1	5 ± 1[de]	0.010 ± 0.002[a]	403 ± 10[e]	46 ± 1[d]
E_C2	2.5 ± 0.2[e]	0.0092 ± 0.0007[a]	330 ± 20[e]	39 ± 1[d]
E_C3	6.889 ± 0.002[d]	0.009 ± 0.003[a]	670 ± 30[f]	77 ± 2[e]
E_C4	3.6 ± 0.2[e]	0.010 ± 0.0003[-4a]	580 ± 30[f]	68 ± 5[e]

E_C1





CONCLUSION

- A second cycle generates a second population of small fiber particles (microfibrils) in both hydrogel and emulgel.
- τ_L, G_N^0 and G''_{min} decrease with a second cycle.
- γ_L is independent from process conditions and type of systems.
- For all sample, the second cycle yields to weaker systems but with the same limit strain.
- The decrease in strength (τ_L) and elasticity (G_N^0) found for hydrogel and emulgel can be associated to the hindering action of microfibrils and fragments of microfibrils toward fiber network.

REFERENCES

[1] Pathania S.; Kaur N. , Utilization of fruits and vegetable by-products for isolation of dietary fibres and its potential application as functional ingredients, Bioactive Carbohydrates and Dietary Fibre 27 (2022) 100295.

[2] Bruno, E.; Lupi, F.R.; Mammolenti, D.; Baldino, N.; Gabriele, D. Development and Rheological Modeling of Dietary Fiber and Policosanol Plant-Based Bigels for Potential Food Applications. Food Hydrocoll. 2024, 150, 109733