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Influence of ultrasonication parameters and NaCl on the stability of olive oil model emulsions containing xanthan.

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Introduction

Ultrasonic emulsification is attracting interest for the production of products such as mayonnaise and dressings. When comparing to conventional methods, ultrasonics offer several improvements such as color uniformity, oil droplet size reduction, increased emulsion stability with only small amounts of emulsifier and overall energy efficiency. When applied to a liquid system of polymers, ultrasounds can modify their viscosity through the phenomenon of cavitation that causes depolymerization and decrease of molecular weight. Viscosity alteration can be either temporary or permanent depending on the intensity of sonication. [1,2,3]

Aim

The purpose of this study was to investigate the effect of ultrasound parameters such as time and amplitude on the stability of emulsions containing a commonly used biopolymer stabilizer and provide useful information about process optimization and over-processing conditions. Finally the influence of NaCL addition (100, 200, 300, 400 mM) on emulsion stability is presented.

Materials & Methods

Whey protein isolate (WPI, 92%wt in protein, Arla) was used as an emulsifier for the preparation of coarse emulsions (pH 3.8) containing 20 %wt extra virgin olive oil (Elais) and xanthan gum (XG, Sigma Aldrich) 0.25wt% as a stabilizer. Coarse emulsions were prepared with a high-shear mixer (13.500rpm-2min) and were subjected to different sonication treatments (20kHz) by varying time (1, 2, 3 and 4 min) at a constant amplitude of 70%, or by varying amplitude (40, 60, 80 and 100%) for constant time of 1min to form the final emulsions. The same conditions were used to estimate the effect of sonication on the viscosity of 1wt% XG solutions.

A multiple light scattering (MLS) device (Turbiscan 2000MA) was used to collect daily creaming –phase separation profiles of emulsions during cold storage (10 days, 5^{o}C) and the creaming index (CI %) evolution was estimated. Micrographs of dissolved emulsions were obtained from an optical microscope (40x magnification) and an image analysis software (ImagePro v.1.6) was used for the oil droplet size measurements. A stress-controlled rheometer with a plate-plate geometry provided viscosity profiles of ultrasonically treated 1%wt XG solutions. The linear sections of the flow curves were fitted to a power law model and consistency coefficient (K) and flow behavior index (n) were calculated.

Results & Discussion

Figure 1 shows emulsification temperature rise derived by sonication energy applied on the emulsions according to time and amplitude modifications. Energy release followed a linear regression over time and amplitude, while temperature rise was exponentially influenced.

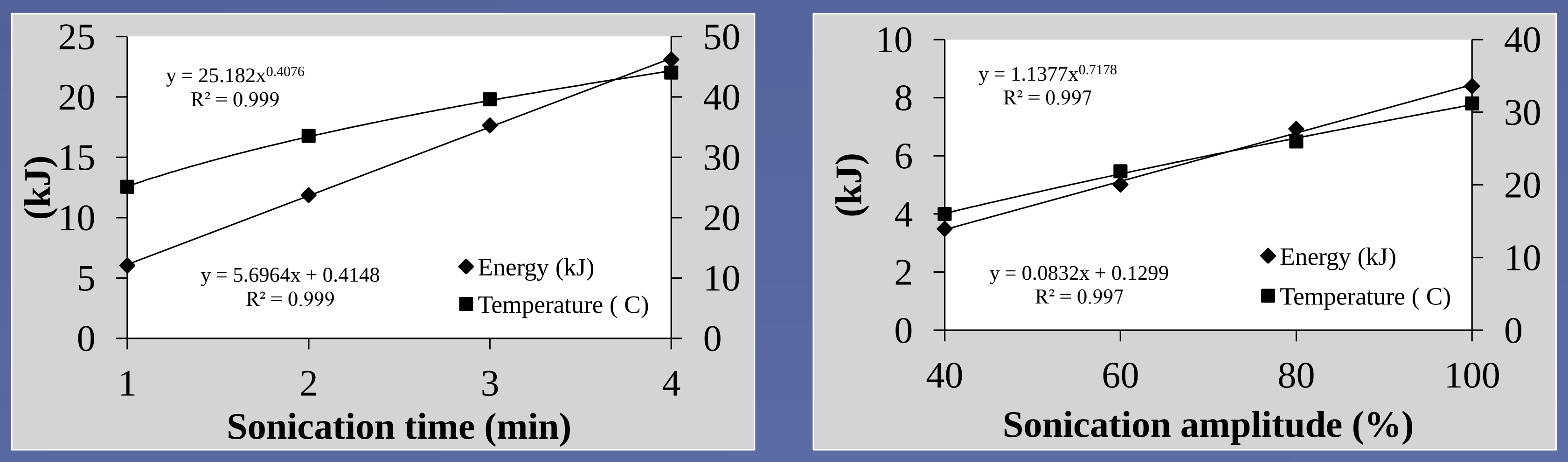

Figure 1: Energy release and temperature rise as a function of sonication time (left) and amplitude (right).

Increase of sonication time and amplitude decreased apparent viscosity (data not shown), k and n indices (Table 1) of 1wt% XG and emulsion droplet size (Figure 2). The power-law model was not applicable in the case of 70%-4min treatment. The increase of CI occurring (4min, 70% amplitude) seems to be more related to the decrease of viscosity of the continuous phase, since the oil droplet size was decreased.

Table 1: Viscosity properties as affected by sonication time and amplitude

% amplitude-time	k (Pa-s^n)	n (-)
No Ultra	24.00	0.181
40%-1min	11.16	0.196
60%-1min	4.37	0.309
80%-1min	3.18	0.331
100%-1min	2.58	0.354
70%-1min	4.12	0.308
70%-2min	2.38	0.359
70%-3min	1.49	0.420
70%-4min	-	-

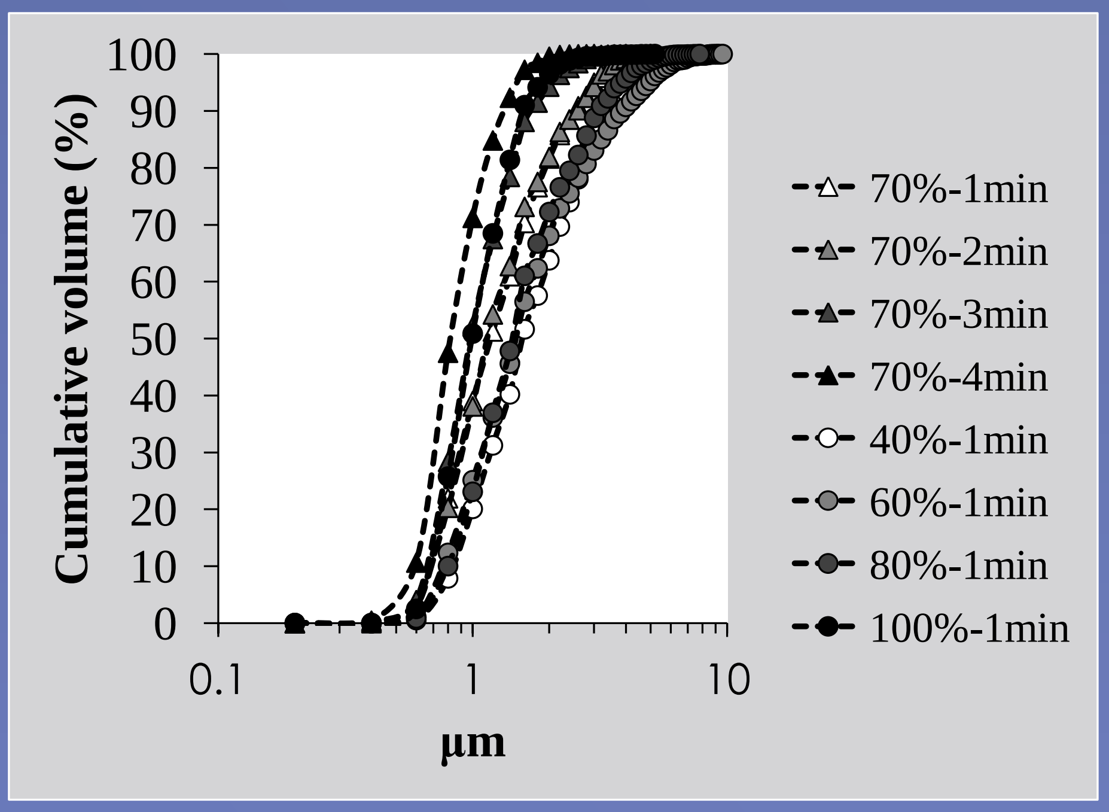

Figure 2: Droplet size distribution as affected by sonication time and amplitude.

The creaming index of final emulsions (day 10) was strongly affected by sonication duration and amplitude as seen in Figure 3(a, b). In the case of amplitude there was an improvement of emulsion stability expressed by the reduction of the CI from 13.07% (40% amplitude) to 7.20% (100% amplitude). Emulsions prepared with duration (3min, 70% amplitude) presented an even more pronounced stability. Extended sonication time (4min, 70%) seems to have an adverse influence over stability and this suggests an over-processing limitation. Emulsion stability was improved upon addition of low concentrations of NaCl (100mM). The addition of higher concentrations significantly increased the CI and this destabilization followed an exponential regression (Figure 4).

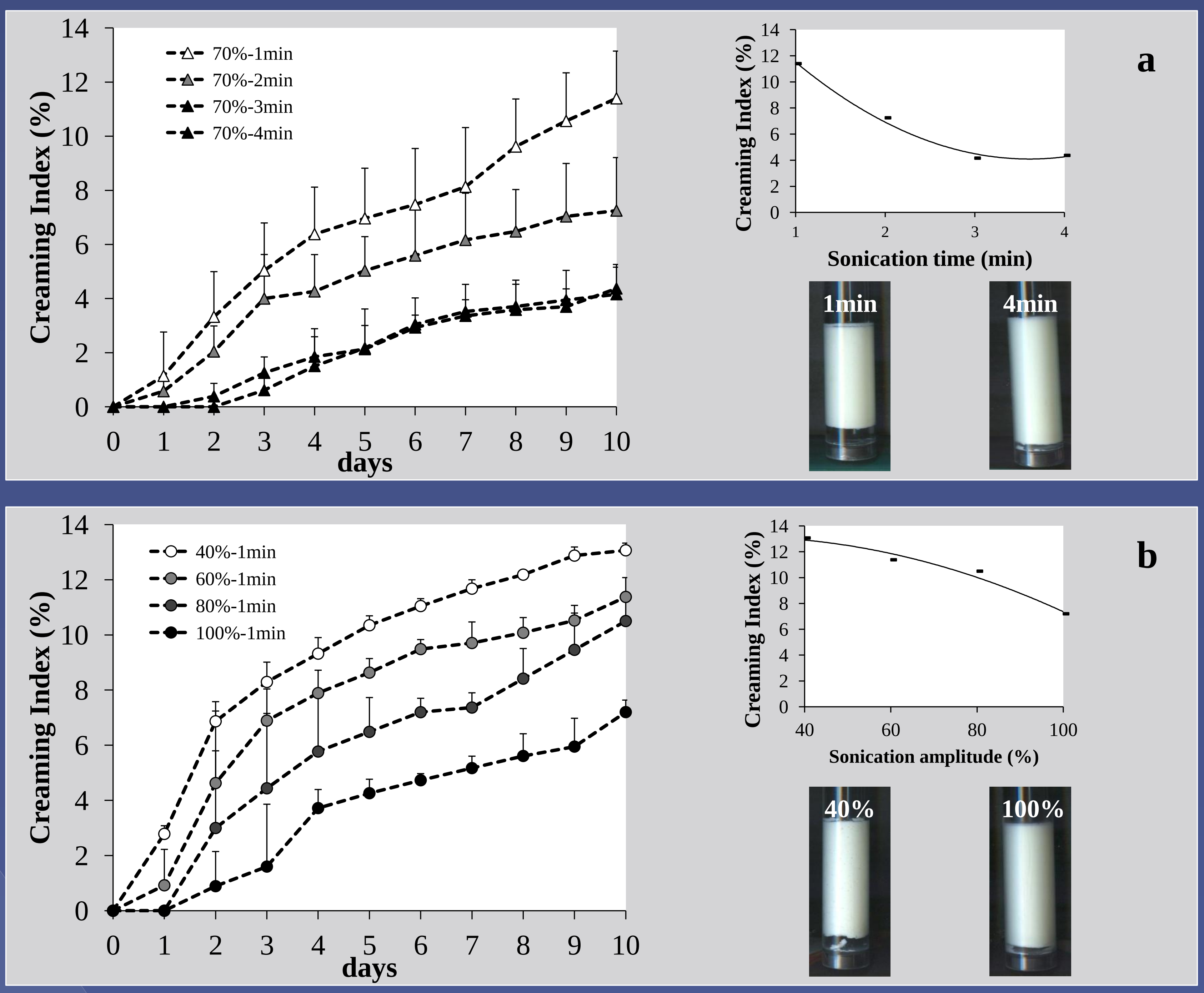

Figure 3: Stability of emulsions prepared by varying (a) time and (b) amplitude, during cold storage. On the right side: CI (on day 10) as a function of sonication time and amplitude.

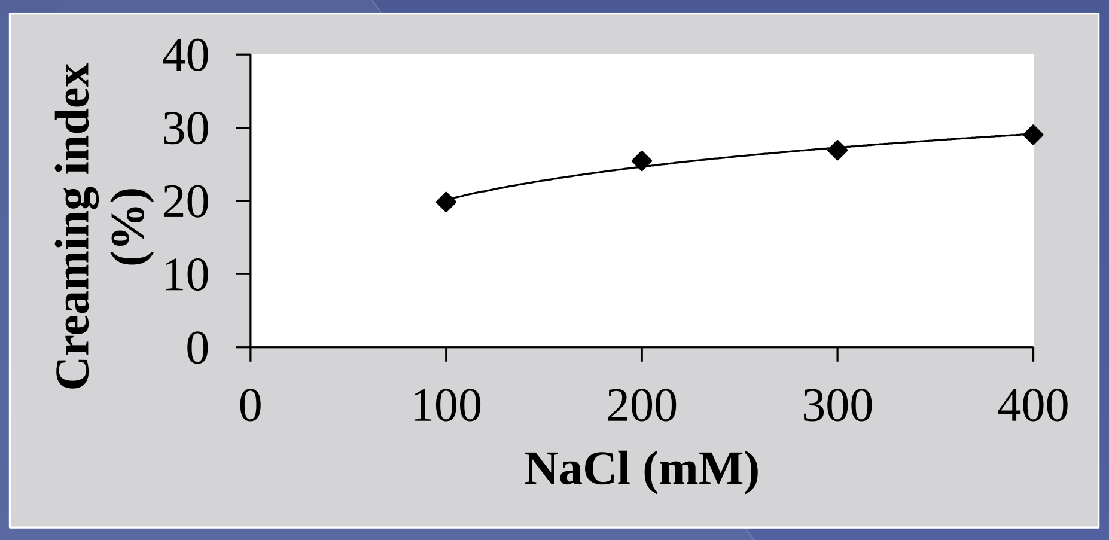

Figure 4: Influence of NaCl concentration on the stability (CI at day 10) of 0.25wt% XG emulsions (sonication conditions, 70% amplitude-3min+90%-1min).

Current and Future work

The CI of whey emulsions will need to be further decreased to ensure long term stability of emulsions during storage.

-Parameters such as pH and olive oil concentration could be adjusted to generate emulsions with smaller droplet and different electrical charge to facilitate a layer-by-layer emulsion formation technique.

-Future work will include the incorporation of small molecular weight emulsifiers combined with whey proteins as an emulsifying system and different high-energy emulsification systems.

References

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Acknowledgements

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.