Preliminary experiments for the rheological study of oleogels

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Introduction

Due to deforestation to expand the area of oil palm plantations and the many negative health effects of palm oil, the food industry needs other alternative fat sources. In our research, we investigated blends of fully hydrogenated rapeseed oil and non-hydrogenated high oleic sunflower oil, as well as beeswax and high oleic sunflower oil as possible oleogel for palm oil alternatives. The rheological properties of these oleogels were compared with the rheological properties of palm oil and a commercially available confectionery fat containing palm oil.

Materials and methods

The rheological measurements were performed on the following materials:

- Unfractionated palm oil
- Chocofill confectionery fat
- Blends of fully hydrogenated rapeseed oil (R) and non-hydrogenated high oleic sunflower oil (H)
    - R25H75 – 25 m/m% rapeseed oil + 75 m/m% sunflower oil
    - R30H70 – 30 m/m% rapeseed oil + 70 m/m% sunflower oil
    - R35H65 – 35 m/m% rapeseed oil + 65 m/m% sunflower oil
- Beeswax (BW) and high oleic sunflower oil (H) mixture
    - H85BW15 – 85 m/m% sunflower oil + 15 m/m% beeswax

The flow curve in the shear rate range 0,1 to 100 1/s, as well storage (G') and loss (G") modules of oleogels, palm oil and confectionery fat were determined with an Anton-Paar MCR302 oscillatory rheometer. The flow curves were approximated with the Hershel-Bulkley and Casson model using the Excel Solver program. The linear viscoelastic limit was determined from the curves obtained by amplitude sweeping.

The addition of the samples to the measuring surface significantly influenced the results. The sample smear was standardized with a coffee spoon, a wire frame and a self-made plastic circular template. The use of the plastic frame resulted in the smallest deviation (Figure 1).

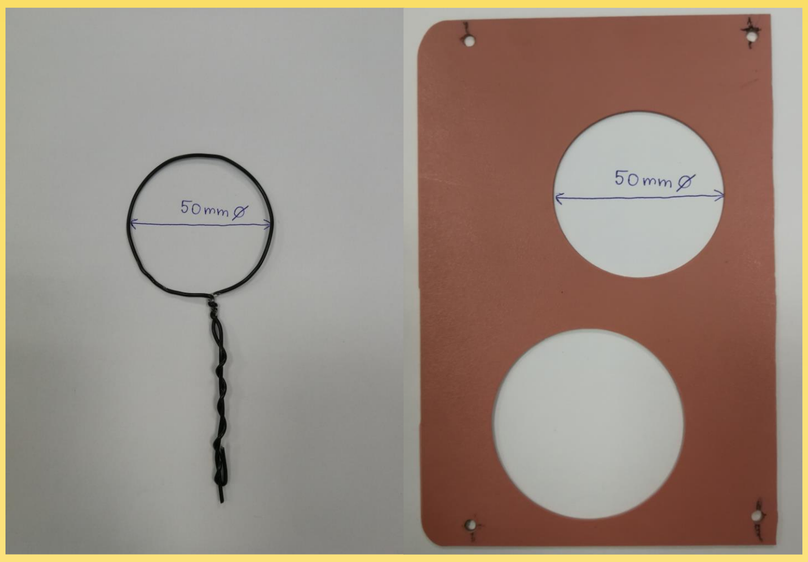

Figure 1. Sample loading tools

Results

Palm oil, chocofill, and H85BW15 had LVER limits and flow points, while oleogels containing hydrogenated rapeseed oil had only flow points. In the amplitude scanning, the confectionery fat („Chocofill") showed a rheological similarity to palm fat, but at the same time, this type of sample was farthest from the properties of the rapeseed oil-sunflower oil and beeswax-sunflower oil mixtures in its rheological properties. The beeswax oleogel was closest to the characteristics of the palm oil and chocofill samples. While rapeseed oil blends showed different behavior (Figure 2).

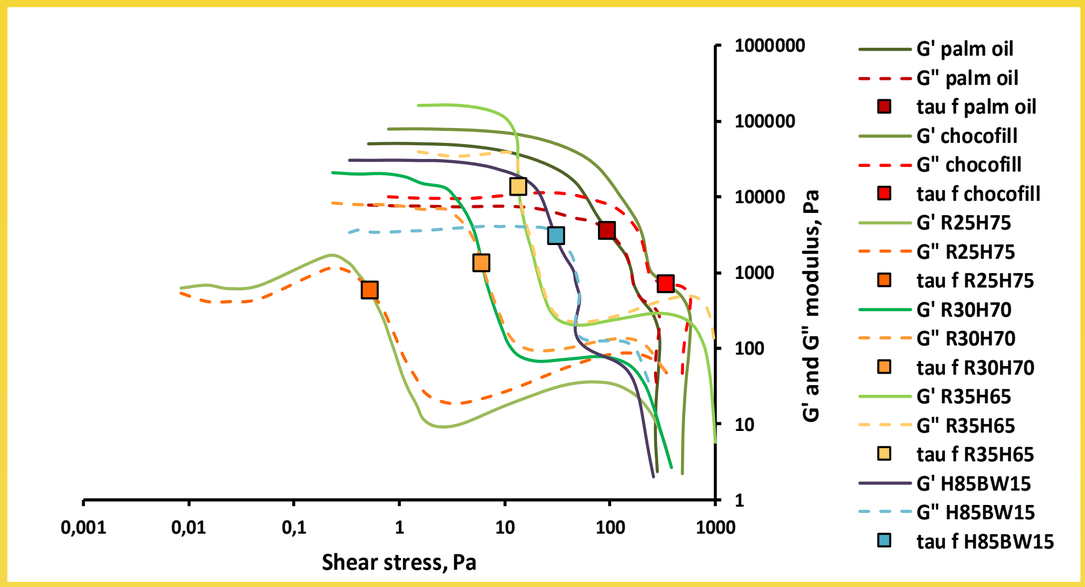

Figure 2. G' and G'' curves of the samples as a function of the shear stress, as well as the shear stress values of the flow points

During recording of the flow curves, along with the increasing shear rate, the shear stress increased, as a result of which the material began to flow. This phenomenon is called pseudoplastic flow. The flow curve of palm oil was best approximated by the sample containing 35% fully hydrogenated rapeseed oil and by the beeswax oleogel, which can be seen better in Figure 3.

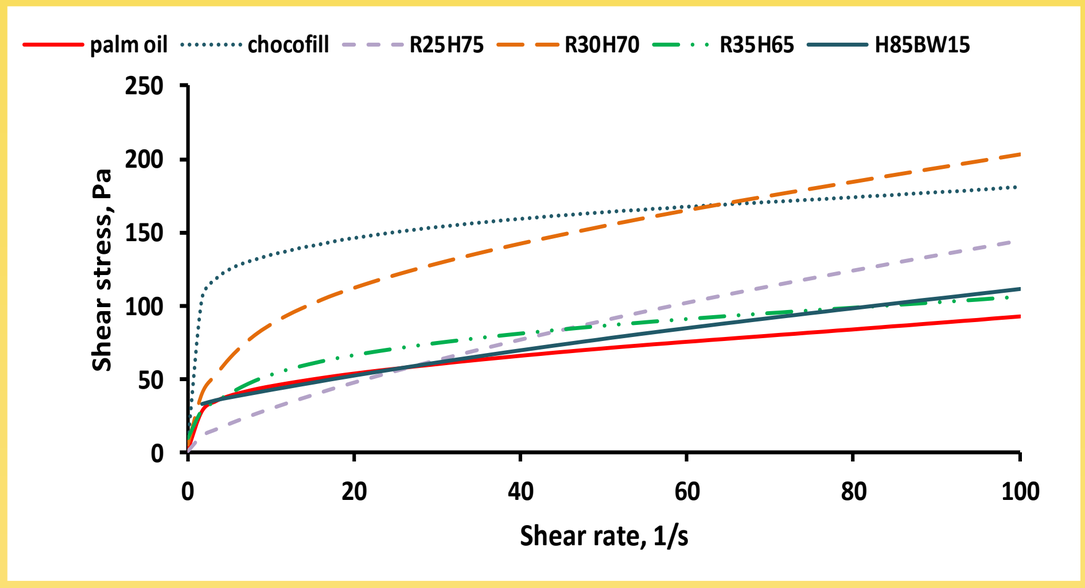

Figure 3. Shear stress - shear rate diagrams of the samples

During model fitting, based on the R^2 and RMSE values, it was decided which model fits the flow curves better. In the case of all six samples, it can be said that the Herschel-Bulkley model fitted the measured curves better.

Herschel-Bulkley: $\tau = \tau_0 + \eta_{pl} \cdot (\dot{\gamma})^n$
R2 = 0,9917 – 0,9999; RMSE = 0,2137 – 2,5248

Casson: $\tau^{0,5} = {\tau_0}^{0,5} + {\eta_{pl}}^{0,5} \cdot (\dot{\gamma})^{0,5}$
R2 = 0,7228 – 0,9995; RMSE = 0,7283 – 13,383

Conclusion

By summarizing the experimental results, it can be stated that it was possible to develop a test method that gave applicable and well-reproducible results, and it was possible to determine the characteristics and rheological properties of the samples. The error resulting from sample preparation was eliminated with a self-made tool. Based on the data analysis and the characteristics of the mixtures, the oleogel containing 35 m/m% fully hydrogenated rapeseed oil and the beeswax oleogel could perhaps be suitable for replacing palm oil, but further tests are required to decide this.