

Soybean Oil-Based Oleogels: Analysis of Rheological, Structural, and Thermal Properties

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In this study, oleogels based on soybean oil were developed, structured with carnauba wax at concentrations ranging from 2 to 10% (w/w), used as a lipid gelation agent. The results demonstrated that increasing the concentration of carnauba wax significantly enhances the structuring capacity of the oil phase, leading to the formation of a denser three-dimensional crystalline network, characterized by increased consistency and superior mechanical stability. Microstructural and thermal analyses indicated the progressive development of a more ordered crystalline network with increasing wax content, which promotes the efficient immobilization of the oil phase and confers high physicochemical stability to the obtained systems. Differential scanning calorimetry (DSC) results, conducted over the temperature range of -60 to 100 °C using a DSC 25 calorimeter (TA Instruments, USA), revealed an increase in melting and crystallization temperatures with increasing wax concentration, suggesting improved crystalline organization and intensified intermolecular interactions between the wax and the lipid matrix. Additionally, rheological analysis was performed using a Haake Mars dynamic rheometer equipped with a parallel plate geometry, highlighting the viscoelastic behavior of the systems under controlled shear and temperature conditions. From a rheological perspective, all systems exhibited pseudoplastic behavior, characterized by a decrease in viscosity with increasing shear rate and temperature. Viscoelastic analysis showed the predominance of the storage modulus ($G' > G''$), indicating solid-like behavior, more pronounced at higher wax concentrations, where the internal network exhibits increased rigidity and mechanical strength. Temperature-dependent tests demonstrated a significant influence of wax concentration on the stability of the oleogel network, through the intensification of crystalline interactions and modification of thermal transitions. Frequency sweep analyses indicated a reduced viscoelastic dependence at higher wax concentrations, suggesting the formation of more stable and better interconnected colloidal structures. Overall, the results demonstrate that soybean oil can be effectively structured into stable oleogels using carnauba wax, yielding lipid systems with controllable rheological and thermal properties. These systems exhibit high application potential in the food sector, offering functional alternatives to conventional solid fats, with thermal stability confirmed by DSC analyses.

Keywords:

Oleogels, soybean oil, carnauba wax, rheological properties, thermal properties

References:

- [1]. Biswajit Sena, Somali Dhal, Deblu Sahu, Preetam Sarkar, Biswaranjan Mohanty, Maciej Jarzębski, Marek Wieruszewski, Haladhar Behera and Kunal Pal. (2022). Variations in microstructural and physicochemical properties of soy wax/soybean oil-derived oleogels using soy lecithin. *Polymers*, 14 (19), 3928.
- [2]. Zou, Y., Xi, Y., Pan, J., Ahmad, M. I., Zhang, A., Zhang, C., & Zhang, H. (2022). Soy oil and SPI based-oleogels structuring with glycerol monolaurate by emulsion-templated approach: Preparation, characterization and potential application. *Food Chemistry*, 397, 133767.
- [3]. Chen, X., Zhu, J., Tian, D., & Li, Z. (2024). Preparation of soybean protein isolate-ester emulsifier oleogels and comparative study of their structure and properties. *Food Chemistry*, 461, 140927.
- [4]. Dhal, S., Alhamidi, A., Al-Zahrani, S. M., Anis, A., & Pal, K. (2023). The influence of emulsifiers on the physiochemical behavior of soy wax/rice bran oil-based oleogels and their application in nutraceutical delivery. *Gels*, 9(1), 47.
- [5]. Bayomy, H. M., & Almasoudi, S. E. (2025). Physicochemical Properties of Oleogels Based on Sunflower or Soybean Oil Structured with Rice Bran Wax. *LWT*, 118845.

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