Effects of Temperature on Rheology of Olive Oils

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Abstract:
In this study, the rheological properties of different samples of olive oils purchased from the same producer were investigated in a wide range of temperature. In addition, at constant temperatures, the shear rate was varied to obtain heating effects. It was found that all samples reach a minimum viscosity in the temperature range of 120 – 150°C before thickening to higher viscosities. The viscosity remained almost unchanged in high shear rates regardless of temperature, indicating no shear thinning effects. No thixotropic effects were observed for the olive oils. These findings can provide insight into the microstructural, physiological and sensory changes at frying (high) temperatures.

Zusammenfassung:
In dieser Arbeit wurden die rheologischen Eigenschaften von verschiedenen Proben von Olivenöl desselben Herstellers in einem großen Temperaturbereich untersucht. Darüber hinaus wurde die Schergeschwindigkeit bei konstanter Temperatur variiert, um Dissipationseffekte zu erhalten. Sämtliche Proben erreichten eine minimale Viskosität in dem Temperaturbereich von 120°C – 150°C, bevor eine Erhöhung der Viskosität eintrat. Die Viskosität blieb bei hohen Schergeschwindigkeiten nahezu unabhängig von der Temperatur, d. h. strukturviskoses Verhalten trat nicht ein. Für die Olivenöle wurde ebenfalls kein thixotropes Verhalten festgestellt. Diese Ergebnisse können Einblick in die mikrostrukturellen, physiologischen und sensorischen Eigenschaften bei Brenntemperaturen geben.

Résumé:
Dans cette étude, les propriétés rhéologiques d'échantillons d'huile d'olive différents achetés au même producteur ont étés testés dans une large gamme de températures. De plus, pour des températures constantes, la vitesse de cisaillement a été variée afin d'obtenir des effets d'échauffement. On a trouvé que tous les échantillons atteignent un minimum de viscosité dans une gamme de température de 120 à 150 °C, avant de devenir plus épais atteignant des viscosités plus grandes. La viscosité reste pratiquement inchangée aux grandes vitesses de cisaillement, indépendamment de la température, ce qui indique qu'il n'y a pas d'effets rhéo-amincissant. Aucun effet thixotropique n'a été observé pour les huiles d'olive. Ces découvertes peuvent fournir des indices sur la microstructure, et sur les changements physiologiques et sensoriels aux hautes températures (friture).

Key words: rheology, olive oils, temperature effects, activation energy, shear thinning, temperature thickening

1 INTRODUCTION

Rheology, the science of deformation and flow, when used for food products paves the way to a better understanding of structural changes during the processing of these products. A major rheological parameter needed in the selection of pumps and pipes for handling vegetable oils is the viscosity. Despite abundance of studies on microstructure of olive oils, their rheology has been rarely investigated. Among very few articles however, rather historically, studies on rheology of liquid foods by Rao [1] are to be mentioned. Some physical properties of edible oils, such as dynamic viscosity of triglycerides [2] as well as rheology of vegetable oils [3] are also reported. The research on the topic of edible oils also covers more detailed topics such as elasticity and extensional viscosity [4].

Viscosity is a measure of resistance of fluid layers to slip when subject to shear stress. More microscopically speaking, it is therefore related to the molecules dimensions and orientation. It is well known that the viscosity of vegetable oils increases with chain lengths of triglyceride fatty acids and decreases with unsaturation, in other words, it increases with hydrogenation [5]. Changes in the rheological properties are also attributed to the physiochemical alterations in edible oils. The viscosity change of oils can, therefore be indicative of possible degradation, which is the subject of this study. Viscosity can also be a determining parameter for heat transfer [6].

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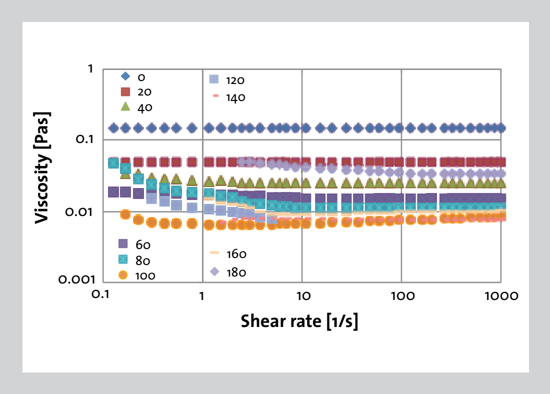

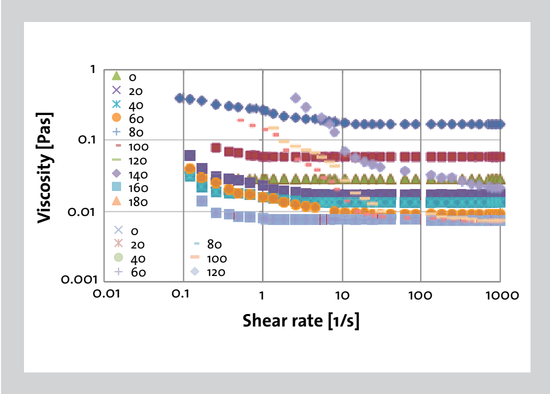

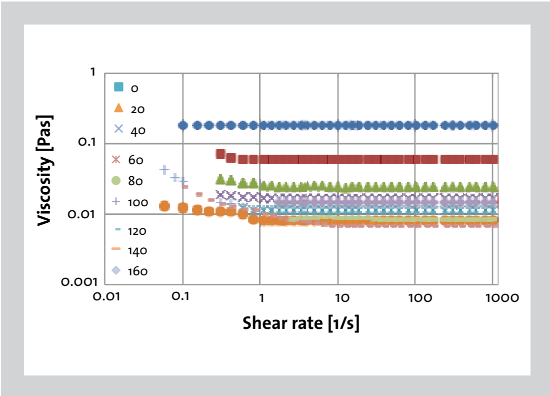

Figure 5 (left above): Viscosity versus shear rate experiment for olive oil with garlic. Temperature is varied within the range of 0 – 180°C with a 20°C increment.

Figure 6 (right): Viscosity versus shear rate experiment for "Olive oil". Temperature is varied within the range of 0 – 180°C with a 20°C increment.

Figure 7 (left below): Viscosity versus shear rate experiment for "Picual" olive oil. Temperature is varied within the range of 0 – 180°C with a 20°C increment.

confirmed by the shear rate experiment. Compared to extra light olive oil, the extra virgin olive oil has resulted in more thinning effects in low shear. However the thinning part, due to the low torque, requires extra sensitive equipment for it to be reported. As the purpose of the shear rate experiment is to obtain constant viscosity regions, it is therefore intended to report the viscosity at high shear rate. Figure 5 shows the viscosities of olive oil with garlic as the shear rate is increased at different temperatures. Here, initial thinning in viscosities at lower shear rates are minimal and there is essentially no change in viscosity beyond the shear rate of 1 s^{-1}, regardless of the temperature. From Table 1, the minimum viscosity of olive oil with garlic is recorded at a temperature of 133.2°C which is also confirmed by the shear rate experiment. Figure 6 shows the viscosities of "Olive oil" as the shear rate is increased at different temperatures. As it can be seen, variations of viscosity, especially in low shear rates and higher temperatures are more evident for the "Olive oil" sample. Again, this is related to the fact that the olive oil sample is composed of refined olive oil and virgin olive oil. The refining process therefore has made the oil more "non-Newtonian". At high temperatures, even in the highest shear rate, it was not possible to obtain constant viscosity readings (see for instance, the curves for temperatures 140, 160, and 180°C in Figure 6). From Table 1, the minimum viscosity of "Olive oil" is given at a temperature of 147.0°C, which is also confirmed by the shear rate experiment. Finally, Figure 7 shows the viscosities of Picual olive oil as the shear rate is increased at different temperatures. No major difficulty in viscosity readings was encountered with exception of the curve for 180°C. From Table 1, the minimum viscosity of Picual olive oil is recorded at a temperature of 130°C, which is also confirmed by the shear rate experiment. In the thixotropy experiment, no particular behavior, worth mentioning, was observed. Therefore, it was concluded that thixotropic effects for olive oils can be disregarded.

5 CONCLUSIONS

Rheology of olive oils, expressed by their viscosities at different temperatures and/or shear rates was studied. While all the samples show temperature thinning effects at lower temperatures, they become temperature thickening as they are heated beyond a critical temperature. All samples exhibit Newtonian behavior at a wide range of shear rates. Since no time effect was observed, thixotropy was not of concern. The temperature-dependent viscosity of the olive oils can be attributed to microstructural changes in the samples. It may be concluded that high temperatures together with shear stress result in unsaturation of olive oils manifested by a decrease of viscosity up to a critical temperature beyond which the viscosity is increased. This (high) temperature thickening implyies a microstructure change, rendering some olive oils not suitable for frying. A claim which calls for more research to prove definitely. Finally, the refining process was found to directly affect the rheology of the olive oils shifting oils further into the non-Newtonian region.

REFERENCES

[1] Rao MA: Rheology of liquid foods- a review. J. Texture Studies 8 (1977) 135.

[2] Goodrum JW, Eitman MA: Physical properties of low molecular weight triglycerides for the development of biodiesel fuel models. Bioresources Technology 56 (1996) 55.

[3] Geller DP, Goodrum JW: Rheology of vegetable oil

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analogs and triglycerides. J. American Oil Chemist's Society 77 (2000) 111.
[4] Koliandris AL, Rondeau E, Hewson L, Hort J, Taylor AJ, Cooper-White J, Wolf B: Food grade Boger fluids for sensory studies, Appl. Rheol. 21 (2011) 13777.
[5] Santos JCO, Santos IMG, Conceicao MM, Porto SL, Trindade MFS, Souza AG, Prasad S, Fernandes VJ, Araujo AS: Thermoanalytical, kinetic and rheological parameters of commercial edible vegetable oils. J. Thermal Analysis and Calorimetry 75 (2004) 419.
[6] Venerus DC, Buongiorno J, Christianson R, Townsend J, Bang I, Chen G, Chung S, Chyu M, Chen H, Ding Y, Dubois F, Dzido G, Funfschilling D, Galand Q, Gao J, Hong H, Horton M, Hu L-W, Iorio CS, Jarzebski AB, Jiang Y, Kabelac S, Kedzierski MA, Kim C, Kim J-H, Kim S, McKrell T, Ni R, Philip J, Prabhat N, Song P, VanVaerenbergh S, Wen D, Witharana S, Zhao X-Z, Zhou S-Q: Viscosity measurements on colloidal dispersions (nanofluids) for heat transfer applications, Appl. Rheol. 20 (2010) 44582.
[7] Angerosa F, Mostallino R, Basti C, Vito R: Influence of malaxation temperature and time on the quality of virgin olive oils, Food Chemistry 72 (2001) 19.
[8] Santos JCO, Santos IMG, Souza AG: Effect of heating and cooling on rheological parameters of edible vegetable oils, J. Food Eng. 67 (2005) 401.
[9] Sanchez-Gimeno AC, Negueruela AI, Benito M, Vercet A, Oria R: Some physical changes in Bajo Aragon extra virgin olive oil during the frying process. Food Chemistry 110 (2008) 654.
[10] Barnes HA: A handbook of elementary rheology, Institute of Non-Newtonian Fluid Mechanics, Aberystwyth, UK (2000).
[11] Paraskevopoulou A, Boskou D, Kiosseoglou V: Stabilization of olive oil – lemon juice emulsion with polysaccharides. Food Chemistry 90 (2005) 627.
[12] Mandala IG, Savvas TP, Kostaropoulos AE: Xanthan and locust bean gum influence on the rheology and structure of a white model-sauce. J. Food Eng. 64 (2004) 335.
[13] TA Instruments Advantage, 2007, TA Instruments, Inc., P/N 925710.001, version 4.9.
[14] Animal and vegetable fats and oils, Determination of polymerized triacylglycerols by high-performance size-exclusion chromatography (HPSEC) European Norm, NF EN ISO 16931 (2009).
[15] Dobarganes C: Formation and analysis of high molecular-weight compounds in frying fats and oils. Oleagineux Corps Gras Lipides 5 (1998) 41.
[16] Bonnet JP, Devesvre L, Artaud J, Moulin P: Dynamic viscosity of olive oil as a function of composition and temperature: A first approach, Eur. J. Lipid Sci. Technol. 113 (2011) 1019.
[17] Wolff JP, Modret FX, Dieffenbacher A: Determination of polymerized triglycerides in oils and fats by high performance liquid chromatography: results of a collaborative study and the standardized method Pure & Appl. Chem. 63 (1991) 1163.
[18] Kim J, Kim DN, Lee SH, Yoo SH, Lee S: Correlation of fatty acid composition of vegetable oils with rheological behaviour and oil uptake, Food Chemistry 118 (2010) 398.
[19] Fasina, OO, Hallman H, Craig-Schmidt M, Clements C: Predicting Temperature-Dependence Viscosity of Vegetable Oils from Fatty Acid Composition, J. Am. Oil Chem. Soc. 83 (2006) 899.

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