Viscosity of a selection of edible oils and blends of oils at different temperatures.

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ABSTRACT

The viscosity of edible oils is a parameter used to describe quality. Liquid viscosity is also important regarding design of process equipment for the edible fat- and oil industry. Rheological data are required for process piping design, pressure drop determination and in design of heat transfer equipment. Rheological properties are also of interest when modifying fats and oils, either the method used is fractionation, chemical, hydrogenation, enzymatic, blending or combinations of the mentioned methods. Blending can as an example be used in industrial applications to provide oils with improved composition related to stability, nutrition and functionality endowed with the characteristics requested by consumer preferences. Another aspect is related to authenticity of edible oils and fats, and methods available to detect or verify food authenticity. This is of course important both from a nutritional- and economical point of view. Fats and oils have a huge contribution in our diet as cooking or frying oils, salad oils or in food products formulations.

The viscosity of a selection of oils and their blends was measured in an MCR301 rheometer between 4 °C and 20 °C at varying shear rates. The results show expected general temperature effects. The viscosity generally decrease with increase in temperature. There are also differences in viscosity of the investigated oils due to the fatty acid composition between the different oils.

INTRODUCTION

Fats and oils are important as raw materials in food, feed, cosmetics, pharmaceuticals and as ingredients in paintings and other technical applications.

Regarding human nutrition, fats and oils are essential as source of energy, fatty acids and fat soluble vitamins like A, D, E and K. Knowledge of physical properties of fats and oils as a function of temperature and reliable predictive models, is of great practical interest for food, pharmaceutical and chemical engineering. One challenge is the demand of computational tools in the design and evaluation of processes[1]. So far, density- and viscosity measurements have been the most commonly used.

Other aspects in relation to fats and oils is linked to quality, nutrition and storage stability. This was also focused as one of the objectives in the study of Gulla et al. in 2010[2]. They tried to determine the optimal fatty acid composition in blends of edible oils to achieve a balance between the storage stability, frying property and health. They observed a gradual increase in saturated fats and a decrease in unsaturated fats over time using pure oils. In contrast, blends of oils could be stored for a period of 12 months without any adverse changes in their peroxide values. In addition, blending could

also be designed to achieve an ideal fatty acid combination regarding nutrition.

Data for viscosity as a function of temperature have been reported by several studies [3,4,5]. In general, the studies concluded that the viscosity in edible vegetable oils and their blends, like all Newtonian fluids, decreased with increase in temperature.

Investigation of thermal behavior of emulsion systems are essential for the food- and feed industry. It might be in order to understand changes when fats and oils are exposed to different temperature cycles during storage and use. In fat emulsions, like butter and margarine, the amount of crystallized fat is greatly dependent on temperature, and so is the firmness. Even at constant temperature, a slow recrystallization may occur since the fat crystals in such products seldom are in thermodynamic equilibrium. A slight temperature increase often causes some melting of the fat crystals. Upon subsequent slight cooling, newly formed crystals will deposit on existing crystals, often referred to as "sintering". Consequently, the fat product may markedly increase in firmness due to small temperature fluctuations during storage[6].

When investigation blends of edible oils, adulteration may be a challenge. Edible oils are important from nutritional and economical points of views. Their authenticity is a serious issue since old time. Some edible oils and fats such as olive oil, cocoa butter and milk fats are quite expensive, which makes tempting to adulterate them with other low price vegetable oils and fats to achieve more profit. Therefore, it is necessary to use and further develop suitable and fast low-cost methods to detect adulteration[7,8].

Since adulterations are becoming more and more sophisticated, it is necessary to use advanced methods to detect this phenomenon. Generally, physical properties like refractive index, viscosity, melting point, saponification and iodine value are not anymore practical to detect adulteration[7]. Instead, it is possible to use both major and minor components as detection tools and/or in combination with spectral characteristics[9].

The objectives of the studies reported in this paper was to:

- investigate- and compare the viscosity of a selection of edible oils and some blends[10] of the oils
- compare the viscosity of some fresh- and some stored edible oils

MATERIALS AND METHODS

Edible oils

The six different edible oils and blends of oils tested given in Fig. 1, were purchased fresh from Norwegian food shops.

Figure 1: The different edible oils tested, from right to left – soy bean oil, corn oil, rapeseed oil, olive oil , extra virgin olive oil and cod liver oil (fresh and stored).

Table 1. Approximate fatty acid composition (%ww) of the different edible oils investigated [10, 11].

Oil	Fat Cont.	SFA	MUFA	PUFA
Corn oil	100	13.0	31.0	56.0
Rapeseed	100	7.0	65.0	28.0
Soybean	100	14.0	24.0	62.0
Olive	100	14.0	77.0	9.0
Olive Virgin	91.6	13.8	68.5	9.3
Cod liver	100	22.0	44.0	34.0

Instrumental analysis and experimental set-up

The Physica MCR301 rheometer (Paar Physica, Anton Paar, Stuttgart, Germany, 2010) fitted with a Titanium CC27 bob/cup measuring system was used for viscosity measurements. The viscosity of the oils was measured by rotational viscometry.

Rotational shear rate sweeps from 1 1/s to 500 1/s were recorded at +20 °C and at +4 °C. Temperature-sweeps from +20 °C to +4 °C were recorded at a shear rate of 50 1/s.

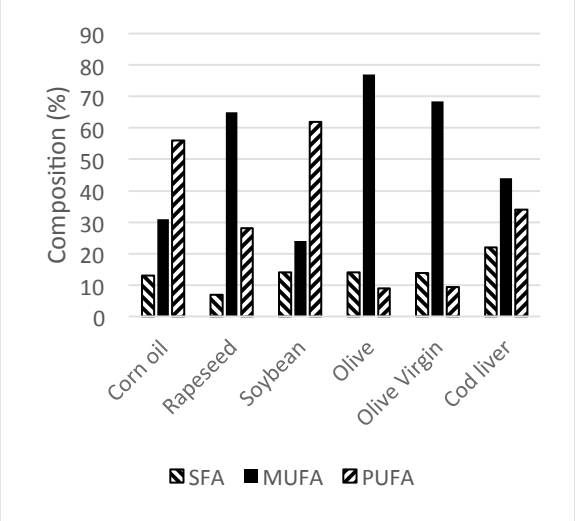

Figure 2: Composition of investigated oils regarding fatty acid composition; SFA, MFA and PUFA.

RESULTS

Typical results of the viscosity determination with the Paar Physica rheometer for the oil samples are shown in Figure 3 and Figure 4. All the oils behaved as Newtonian fluids. The blended viscosity results are visualized in Figure 5.

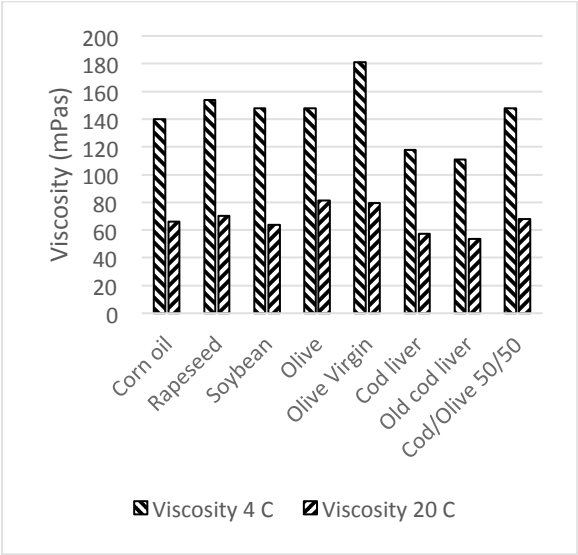

Figure 3: Viscosity of oils at 4°C and 20 °C, measured by a Physica MCR301 rheometer fitted with a CC27 Bob/ Cup.

A normalized viscosity is calculated from the relationship:

$$\eta_{Normalized} = 2\frac{(\eta - \eta_{min})}{(\eta_{max} - \eta_{min})} - 1 \qquad (1)$$

The normalized viscosity values are illustrated in Figure 4.

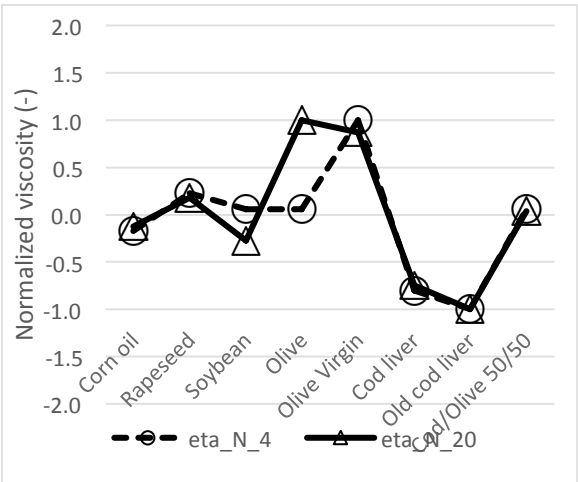

Figure 4: Normalized viscosities at 4 and 20 °C of 6 different edible oils and one blend, measured by a Physica MCR301 rheometer fitted with a CC27 Bob/ Cup.

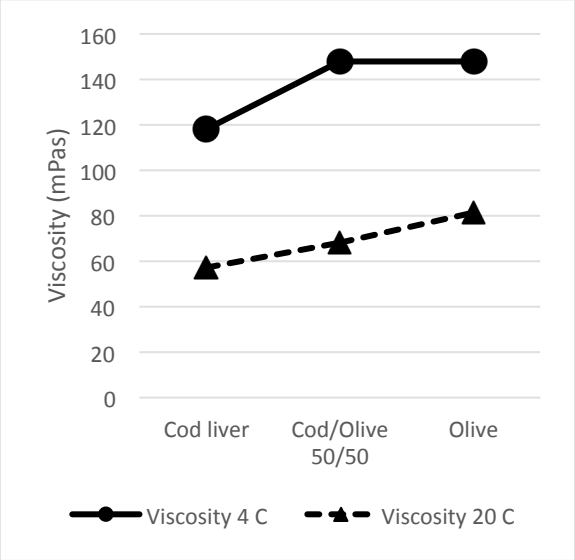

Figure 5: Viscosity of 50/50 blend of Cod/Olive oil, measured by a Physica MCR301 rheometer fitted with a CC27 Bob/ Cup.

DISCUSSION

The viscosity of the different edible oils investigated in this screening test, are strongly influenced by the two temperatures 20 °C and 4 °C. The viscosity decreased for all oils when the temperature raised from 4 °C to 20 °C. The highest relative viscosity among the tested oils was measured in olive oil at 20 °C. Among the olive oils, the virgin olive oil showed highest relative viscosity at 4 °C; Fig. 3 and Fig. 4.

This phenomenon may be addressed to the content of some plant materials in the virgin olive oil, since this oil miss the refining process. The mentioned plant materials include classes of compounds not related chemically to the fatty acids; hydrocarbons, chlorophylls, aliphatic alcohols, free sterols, tocopherols and polar compounds such as tyrosol and hydroxytyrosol[12].

Regarding the 50:50 blend of cod liver- and olive oil, it seems that the viscosity of the blend at 20 °C achieved the mean value between the values for each of the blended oils; Fig. 5. At 4 °C however, it seems that the viscosity of the blend achieved the same value as the olive oil. This phenomenon may be related to the fact that the fatty acid composition in olive oil is very uniform since it contains almost 80 % MUFA which again mostly consists of cis C18:1; oleic acid.

Both the corn- and soybean oil have a relative high content of PUFA; 56% and 62% respectively. Looking at Fig 3, it might be expected a lower viscosity of these oils at 4°C, compared to the viscosity of for example rape seed oil or olive oil at the same temperature. But the results show almost the same viscosity. This may be explained by the fact that each oil consists of many different fatty acids, which make a huge blend of fatty acids with their many different melting points. Looking just at one single oil – stearic acids C18 and its derivates C18:1 (oleic acid), C18:2 (linoleic acid) and C18:3 (linolenic acid) the melting point of these cis forms are about 70, 16, -5 and -11°C[9].

Knowledge about melting points are of course important, when using different oils and blends as raw materials in food products. One example is production of margarine regarding crystallisation during processing. Knowledge of thermal behavior of emulsion systems is essential in order to understand changes when fats and oils are exposed to different temperature cycles during processing, storage and use.

Looking at Fig. 4 regarding normalized viscosity at 4 and 20 °C of the different edible oils, it is observed that only olive oil has a fairly different relative viscosity at the two temperatures. This applies also to a certain extent for soybean oil. Regarding the cod liver oil, surprisingly small relative normalized viscosity values were observed between the stored (>10 year at about 20°C) and the fresh oil. Just some lower values were observed for the stored cod liver oil.

In a future perspective, it would be interesting to further investigate rheological properties both in more edible oils, and in different blends. In addition, it is of course interesting to measure viscosity of the oils at temperatures above 100 °C, since a lot of food processing use hot edible oils. Frying, typically at 150-195°C, include simultaneous transfer of heat from oil to food, mass transfer of moisture from the food and subsequent oil absorption by the food.

CONCLUSIONS

The conclusions of this screening study can be summarized as follows:

- The viscosity of edible oils is a function due to the fatty acid composition of the different oils.
- The relative viscosity between the edible oils and their blends is a function of temperature in the range 4 to 20°C.
- "Surprisingly" small relative normalized viscosity values were observed between stored- (>10 year at about 20°C) and fresh cod liver oil.

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