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Investigation of the Chemical Applicability of Used Cooking Oils

Rebeka BEJCZI,[1] Roland NAGY[2]

[1] *Pannon University, Faculty of Engineering, Bio-, Environmental and Chemical Engineering Research and Development Center, Department of MOL, Veszprém, Hungary, bejczi.rebeka@mk.uni-pannon.hu*

[2] *Pannon University, Faculty of Engineering, Bio-, Environmental and Chemical Engineering Research and Development Center, Department of MOL, Veszprém, Hungary, nagy.roland.dr@mk.uni-pannon.hu*

Abstract

Cooking oils play a crucial role in the food industry; however, during the cooking process, they undergo significant physical and chemical transformations that affect their subsequent usability and environmental impact. Our results show that oxidized rapeseed oil exhibits similar properties to industrial raw rapeseed oil, suggesting that used cooking oils at a certain oxidation state could potentially be suitable for surfactant synthesis. Since surfactants are widely used across various industries, this recycling approach offers a sustainable alternative to synthetic raw materials.

Keywords: *used cooking oil, oxidation, rapeseed oil, sustainability.*

1. Introduction

Used cooking oils (UCOs) play a significant role in the food industry; however, during the frying process, they undergo chemical and physical transformations that affect their subsequent usability and environmental impact [1].

Fresh cooking oils are typically derived from vegetable or animal fats, with triglycerides as their main components. Commonly used vegetable oils include palm, sunflower, rapeseed, and soybean oils, while among animal-derived fats, lard is the most frequently mentioned. The oxidative stability and fatty acid composition of cooking oils are key factors in their selection, as they influence the chemical reactions occurring under heat exposure [2, 3]. High temperatures lead to the formation of free fatty acids, aldehydes, ketones, and polymers, which degrade oil quality, increase viscosity, and pose health risks [4, 5]. Improperly managed waste oil can contribute to environmental pollution, highlighting the importance of sustainable recycling strategies [6, 7, 8].

The recycling of UCOs offers environmental and economic benefits, supporting a sustainable, circular economy. One of the most common methods is biodiesel production via transesterification, which reduces carbon dioxide emissions and dependence on fossil fuels. Life cycle assessments confirm that UCO-based biodiesel is more environmentally friendly, and triglycerides can also serve as raw materials for surfactants and construction additives. Surfactants derived from UCOs present a sustainable alternative to synthetic materials, reducing waste generation and the demand for new raw materials [9, 10, 11].

Our research was aimed at modeling the physical and chemical changes occurring during the frying process of rapeseed oil, with particular focus on oxidative stability, total acid number, saponification number, iodine-bromine number, and kinematic viscosity. Additionally, efforts were made to expand the range of raw materials suitable for surfactant synthesis by determining whether oxidized rapeseed oil from frying could potentially be applied for synthesis purposes.

2. Materials

For the experiments, cooking oil, rapeseed oil was utilized as the raw material. Its properties are summarized in **Table 1.** As a reference, the properties of crude, unrefined rapeseed oil typically used in industrial surfactant synthesis were also examined.

Table 1. *Properties of used materials*

Properties	RO-cook	RO-crude
Physical state (20 °C)	liquid	liquid
Density, d_{420} (kg/m³)	0.882	0.91
Boiling point (°C)	347	341
Flash point (°C)	225	214
Pour point (°C)	-9	-8
Molecular weight (g/mol)	900	900
Dynamic viscosity (40 °C mPas)	32.69	30.14

The rapeseed oils used in the experiments were supplied byBunge Zrt.

3. Methods

Edible rapeseed oil was subjected to oxidation to simulate the frying processes and the associated chemical changes occurring during various applications. Following the aging procedures, the physical and chemical properties of the oils were analyzed in detail to identify potential changes and assess their impact on future applicability.

3.1. Oxidative stability

The resistance of oils to air (oxygen) is characterized by their oxidative stability, which was determined according to the IP 157 [12] standard. The oxidation parameters are summarized in Table 2.

Table 2. *Oxidation parameters*

Parameter	RO-cook (ox-1)	RO-cook (ox-2)
Temperature, °C	170	170
Time, h	8	16
Air, dm^3/h	20	20
Volume of oil, cm^3	20	20

3.2. Total acid number

The total acid number (TAN) is a measure of the amount of weak organic and strong inorganic acids in the oil. It was determined following the ASTM D974 [13] standard.

3.3. Saponification number

The saponification number expresses the amount of potassium hydroxide (mg KOH/g) required to completely saponify 1 g of a given substance. This was determined according to the ISO 3657 [14] standard.

3.4. Iodine-bromine number

The iodine-bromine number provides information on the degree of saturation and unsaturation of the oils, which was examined according to the MSZ EN 14111:2004 [15] standard.

3.5. Kinematic viscosity

Kinematic viscosity (KV) was determined at 40 °C following the ASTM D445-06 [16] standard.

4. Results

The experimental results are summarized in tables.

Fig. 1 illustrates that the total acid number of the oxidized samples increased compared to the edible rapeseed oil, indicating that the frying process led to an increase in free fatty acid content.

Fig. 2 presents the saponification number of the oxidized samples, which showed an increase. Notably, the saponification number of the sample oxidized for 16 hours equaled that of crude rapeseed oil.

As a result of oxidation, the iodine-bromine number of cooking rapeseed oil decreased, with a similar value observed for crude rapeseed oil (Fig. 3).

Table 3. *Kinematic viscosity of the samples*

Samplke	KV at 40 °C (mm^2/s)
RO-crude	41.0
RO-cook	43
RO-cook (ox-1)	57.3
RO-cook (ox-2)	123.3

The kinematic viscosity increased due to oxidation (Table 3), which can be attributed to polymerization reactions and contamination.

Our results indicate that significant differences can be observed between the properties of the examined raw materials and those of industrial crude rapeseed oil, with both lower and higher values. As a result, the property range of potential raw materials has been successfully expanded, representing an important step in evaluating alternative vegetable oils and used oils for surfactant synthesis.

5. Conclusions

Our findings confirm that the aging of rapeseed oil induces significant physical and chemical changes that may influence its subsequent applications. Oxidation led to an increase in both the total acid number and the saponification number, while the decrease in the iodine-bromine number indicates the degradation of unsaturated fatty acids. The rise in kinematic viscosity reflects modifications in the molecular structure, which can

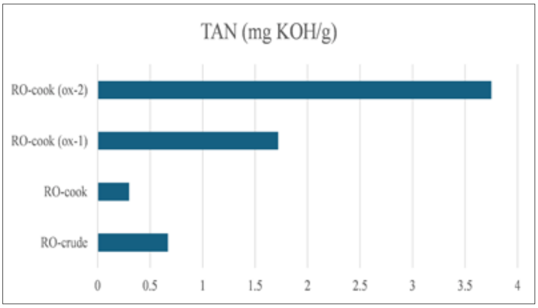

Fig. 1. *Total acid number of the samples.*

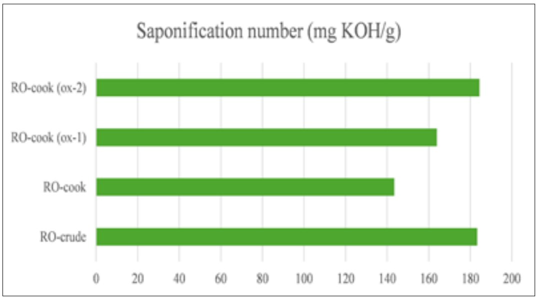

Fig. 2. *Saponification number of the samples.*

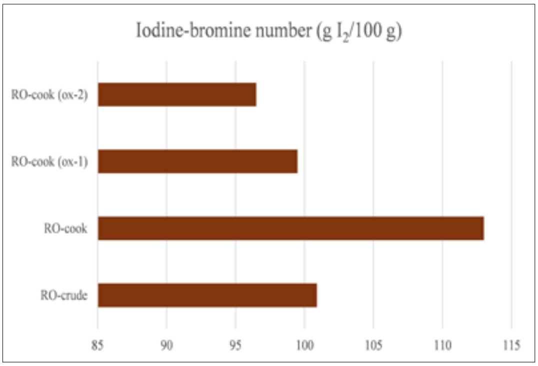

Fig. 3. *Iodine-bromine number of the samples*

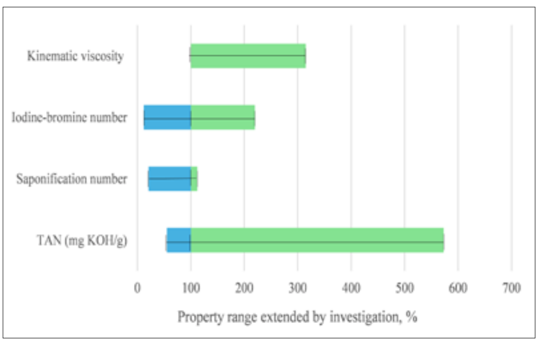

Fig. 4. *Summary of the results*

affect industrial applicability.

It was established that, based on the similar properties of industrial crude rapeseed oil and the oxidized samples, used cooking oils may also be suitable for surfactant synthesis. This broadens the range of applicable raw materials and contributes to promoting sustainable raw material utilization while reducing the environmental burden associated with waste cooking oil disposal. Our results support the optimization of used cooking oil recycling and the expansion of raw material sources; however, further studies are needed to determine the optimal processing conditions.

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