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Research Article

Effect of Repetitive Frying on some Physicochemical Characteristics of four Edible Vegetable Oils

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Abstract

Vegetable oils are fats that are extracted from some fruits, seeds and nuts. They have been used for human food as frying and cooking oils. Deep-frying is a method in which food is submerged in hot oil and has become more and more popular in recent years. However, repeated frying of the same batch of oil may lead to oil spoilage, which in turn might cause some negative effects on human health. In this work, some physicochemical properties (density, viscosity and acid value) of four edible vegetable oils were evaluated at room temperature (25±0.1^{o}C) before and after repeated frying five times using potatoes. Generally, statistical analysis showed a significant positive correlation ($p<0.05$) between the number of frying times and the studied parameters, especially, for density and viscosity measurements. In addition, Pearson correlation coefficient analysis showed strong positive correlations between every two oils for density measurements while the coefficient values varied between -1 and 1 for viscosity and acid value measurements. It is worth mentioning that the frying process followed in this work is a common practice of Libyan households.

Keywords: Vegetable oils; Deep frying; Physicochemical properties; Statistical analysis.

Introduction

Vegetable oils are triglycerides mostly extracted from the seeds or fruits of plants. They provide us with vitamins and energy and they are used for manufacturing soaps, cosmetics and perfumes [1,2]. In the last few years, edible vegetable oils have been extensively used for food preparations; cooking and frying. Deep-fat frying method under atmospheric pressure at high temperatures is a common method of preparing food in many countries. It is a fast and popular process generally performed at temperatures between 150 and 190°C [3] in which food is immersed in hot oil for certain time. Frying at high temperatures leads to some physical and chemical changes [4,5], such as the formation of polymeric and oxidative compounds as a result of oil decomposition. These changes depend on several factors including frying conditions, quality of the frying oil and type of food materials [6]. In addition, it is a common practice in many countries that the same fried oil is used several times for reducing costs [7], which has an effect on the quality of oil.

Among physical and chemical properties measured for monitoring oil deterioration after deep frying, include density, viscosity and acid value. Density is related to the heaviness of a substance and it is given as mass per unit volume. It increases with deep-fat frying [8], therefore, it can be considered as an indicator for oil spoilage. In addition, knowing the density of oil allows to calculate its viscosity. Oil viscosity refers to the resistance of an oil to flow. Since viscosity increases as the length fatty acids and polymer formation increase [9], it can be used as an indication of oil degradation [10]. Acid value or acidity of oil is the amount of potassium hydroxide in milligrams needed to neutralize the fatty acids in 1 gram of the oil. It is also directly proportional to deep-fat frying [8], and can be used as a good index for oil degradation.

This work is aimed at exploring the effect of repeating frying on some physicochemical properties i.e., density, viscosity and acid value, of four vegetable oils usually consumed in Libya.

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Materials and methods

Materials

Olive oil was obtained from a local mill. Sunflower, corn and soybean oils as well as potatoes were purchased from a local supermarket in Sabratha, Libya. Distilled water was used to prepare all solutions and all chemicals used were of analytical grade.

Frying process

In the beginning, 3 l of the oil was heated up to 190°C, and then about 1Kg of potato slices were fried for 8 min. The oil was then allowed to cool and approximately, 150 ml of the oil was collected after every cycle, filtered and kept in a glass bottle in the fridge until analysis. This process was repeated for 5 days (one frying each day) for each oil.

Methods

The density of the oils was measured using a pecnometer with a capacity of 25 ml and it was expressed in g/ml. The viscosity of the oils was monitored using Ostwald viscometer and it was calculated using the following formula:

$$\eta = \eta_w \rho t / \rho_w t_w$$

where: η is the viscosity of oil, η_w is the viscosity of water, ρ is the density of oil, ρ_w is the density of water, t is the flow time of oil and t_w is the flow time of water.

Acid value was determined as follows: A known weight of the oil was dissolved in a mixture of 50 ml ethanol-ether (1:1 v/v). The mixture was then titrated against potassium hydroxide solution (0.1 N) in the presence of phenolphthalein as an indicator (with shaking) until the formation of the color pink. Pink coloration persisting for about 15 sec was the indication of the end point. The acid value is then calculated according to the following formula:

Acid value = ml KOH x N KOH x 56.1 /W_s

where: W_s is the weight (g) of the analyzed sample. All experiments were done at room temperature (25±0.1°C).

Data Analysis

Analysis was conducted in triplicate (n = 3). All data were expressed as the mean value ± standard deviation (SD), which was calculated using MS excel. P values and Pearson correlation coefficients were determined using statistical package for social sciences (SPSS, version 14.0; Chicago, IL).

Results and discussion

Table 1 shows the values of the density of the four oils during five days. Among the fresh oils used, soybean oil was found to have the highest density (0.9184 g/ml) whereas olive oil had the lowest one (0.9094 g/ml). This is expected to be due to the variation in composition [11]. Studying the change in density after every cycle of frying for the four types of oil showed that most of P values were less than 0.05 ($p<0.05$) indicating significant change. This change could be due to the polymer formation in the oils [12].

The obtained viscosity values of the pure oils were 49.41, 39.55, 32.18 and 30.58 cP for olive oil, sunflower oil, corn oil and soybean oil respectively (Table 2). After five days of frying, the viscosity values were 46.45, 42.97, 43.89 and 38.52 cP for olive oil, sunflower oil, corn oil and soybean oil respectively. The variation in viscosity values could be due to the fatty acid composition of oils [13]. After frying, there is a general increase in viscosity and this increase in viscosity is clearer for corn and soybean oils. The increase in viscosity of oils by frying was reported earlier by Choe and Min [14] for cottonseed oil, Tyagi and Vasishtha [15] for soybean oil and Mudawi et al. [16] for corn and sunflower oils. In addition, the change in viscosity after every cycle of frying was found to be generally significant ($p<0.05$) for all studied oils.

Table 3 presents the results of acid value of the four oils and shows almost the same trend for all types of oil. The acid values of the fresh oils were in the range of (0.41-10.52) and their increment was in the order: olive oil > sunflower oil > corn oil > soybean. Results showed that there is a general increase in acid values after deep frying and that it is more remarkable in olive oil. In addition, it was found that the change in acid values was significant ($p<0.05$) after the first and second cycle of frying for the olive oil, after the first and third cycle for the sunflower oil, and after the first cycle for soybean oil. According to Song et al [17], the increase in acid values of oils is an indication of triglyceride hydrolysis due to oil decomposition.

A Pearson correlation coefficient analysis was performed to determine the strength and

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direction of the linear relationship between the variables after deep-frying process. The value of Pearson coefficient varies between +1 and -1 representing a positive or negative correlation. If the value is equal to zero, it indicates no relationship between the variables. In this work, an attempt was made to see if there is a linear correlation between every two oils before frying and after every cycle of frying (for the three physicochemical properties) using Pearson correlation coefficient analysis (Tables 4-6). Table 4 shows a strong positive correlation for density measurements between every two oils after every cycle of frying. However, the Pearson coefficient values varied between -1 and 1 for viscosity and acidity measurements. A close look at tables 4 and 6 reveals that some Pearson coefficient values are equal to 1 or -1 indicating a perfect positive or negative linear relationship.

Table 1. Density (g/ml) of the four oils before and after frying (value ± SD)

Day	Olive oil	P-value	Sunflower	P-value	Corn oil	P-value	Soybean	P-value
0	0.9094 ± 0.0002		0.9152 ± 0.0003		0.9132 ± 0.0003		0.9184 ± 0.0002	
1st	0.9095 ± 0.0003	0.0189	0.9152 ± 0.0003	0.3333	0.9132 ± 0.0003	0.3333	0.9184 ± 0.0004	0.3709
2nd	0.9095 ± 0.0003	0.0189	0.00030.9153 ±	0.0286	0.9132 ± 0.0002	0.3709	0.9184 ± 0.0005	0.5
3rd	0.9096 ± 0.0003	0.0175	± 0.00040.9154	0.0076	0.9135 ± 0.0004	0.0744	0.9186 ± 0.0000	0.1499
4th	± 0.000450.909	0.0371	0.00040.9153 ±	0.1348	0.9136 ± 0.0002	0.0638	0.9189 ± 0.0001	0.0131
5th	0.9091 ± 0.0001	0.0917	0.00010.9162 ±	0.0065	0.9135 ± 0.0003	0.0175	0.9192 ± 0.0004	0.0066

Table 2. Viscosity (cP) of the four oils before and after frying (value ± SD)

Day	Olive oil	P-value	Sunflower	P-value	Corn oil	P-value	Soybean	P-value
0	49.41 ± 0.10		39.55 ± 0.05		32.18 ± 0.13		30.58 ± 0.10	
1st	49.57 ± 0.40	0.0940	40.73 ± 0.05	0.0002	35.79 ± 0.04	0.0003	33.77 ± 0.07	0.0004
2nd	46.11 ± 0.09	-	39.83 ± 0.30	0.1261	37.53 ± 0.20	0.0002	33.83 ± 0.04	0.0002
3rd	52.70 ± 0.02	0.0001	41.32 ± 0.05	0.0004	38.58 ± 0.20	0.0004	34.35 ± 0.15	0.0004
4th	50.65 ± 0.04	0.0011	40.81 ± 0.11	0.0011	41.36 ± 0.11	-	37.67 ± 0.13	-
5th	46.45 ± 0.06	0.0003	42.97 ± 0.76	0.0078	43.89 ± 0.18	-	38.52 ± 0.14	-

Table 3. Acid value of the four oils before and after frying (value ± SD)

Day	Olive oil	P-value	Sunflower	P-value	Corn oil	P-value	Soybean	P-value
0	10.52 ± 0.12		06± 0.0.65		11± 0.0.45		06± 0.0.41	
1st	± 0.0610.66	0.0183	0.52 ± 0.06	0.0340	0.60 ± 0.06	0.0917	06± 0.0.30	0.0004
2nd	10.75 ± 0.12	0.0183	0.49 ± 0.06	-	0.52 ± 0.06	0.2113	00± 0.0.34	0.0918
3rd	10.83 ± 0.11	0.0937	± 0.000.45	0.0150	0.06 ± 0.49	0.2113	06± 0.0.26	0.0918
4th	10.87 ± 0.03	0.1696	0.06 ± 0.64	0.3902	0.03 ± 0.58	0.0553	06± 0.0.37	0.2113
5th	10.92 ± 0.05	0.0806	0.06 ± 0.64	0.3902	12± 0.0.54	0.2344	06± 0.0.37	0.2113

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Table 4. Pearson coefficient values for the correlation between every two oils (density measurements)

Day	Olive+sun	Olive+corn	Olive+soy	Sun+corn	Sun+soy	Corn+soy
0	0.9449	1	0.8029	0.9449	0.9538	0.8029
1st	0.9820	0.9897	0.9959	0.9449	0.9608	0.9986
2nd	0.9922	0.9963	0.9984	0.9993	0.9977	0.9996
3rd	0.9843	0.9449	0.9449	0.8724	0.9878	0.7857
4th	0.9991	0.8485	0.9332	0.8260	0.9177	0.9820
5th	1	0.9820	0.9608	0.9820	0.9608	0.9959

Table 5. Pearson coefficient values for the correlation between every two oils (viscosity measurements)

Day	Olive+sun	Olive+corn	Olive+soy	Sun+corn	Sun+soy	Corn+soy
0	-0.0339	0.1040	0.6744	-0.9975	-0.7608	0.8045
1st	-0.8301	-0.866	-0.1273	0.9977	0.6586	0.6061
2nd	-0.6253	-0.986	-0.9786	0.4866	0.4512	0.9992
3rd	0.9522	-0.371	0.7206	-0.0698	0.8979	0.3764
4th	0.4193	0.0038	-0.9735	-0.9062	-0.2006	-0.2324
5th	0.3592	-0.9275	-0.9333	-0.6820	-	0.7313

Table 6. Pearson coefficient values for the correlation between every two oils (acidity measurements)

Day	Olive+sun	olive+corn	olive+soy	sun+corn	sun+soy	corn+soy
0	-0.2035	-0.6658	-0.9496	0.8660	0.5	0.8660
1st	-0.8660	0.8660	0.8660	-1	-0.5	0.5
2nd	-0.2735	0.6962	-	0.5	-	-
3rd	-	0	0.8660	-	-	-0.5
4th	-0.5	0.5	0.5	-1	0.5	-0.5
5th	0.5	-0.3004	-0.5	0.6758	0.5	0.9762

Conclusion

Based on the results obtained from the experiments conducted in this study, it can be concluded that a general significant positive relationship exists between the evaluated characteristics and number of frying times for all studied oils. This observation is an indication that repeated frying several times, even for short time, could be harmful to human health. The authors suggest the conduction of further

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intensive studies extended to other parameters and other types of oil marketed in Libya.

Conflict of interest

The authors declare that there is no conflict of interests relevant to this article.

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