

Evaluating the quality change of sunflower oil while frying different food matrixes

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Catering companies serve food for almost every section of social life like factories, schools, hospitals etc. therefore the quality of products produced for catering are important for public health. Although frying oil quality has utmost importance for the production of safe food for catering, in general it is only monitored by visual inspection and it is not reliable enough to decide the correct time for oil replacement that can cause health risks. Consequently, for the benefit of industry and consumer, developing fast, non-chemical used, low labour needed measuring methods, are becoming popular for determining frying oil quality.

In this study, frying oil quality was evaluated by both chemical and physical methods for different types of food frying at local catering companies to determine the effect of the food matrix and processing period on frying oil quality. Sunflower oil samples were collected for five hours (0 min, 60 min, 120 min, 180 min, 240 min and 300 min.) of frying of four different food matrixes like meatball (MB), chicken breast (CB), mixed vegetable (MV) and fish fillet (FF). Physicochemical properties like free fatty acid, fatty acid profile, para-anisidine, peroxide, total polar matter, turbidity, colour, refractive index and static contact angle value of frying oil were evaluated and oil quality dependency to frying time and food matrix dependency were investigated. It was found that frying oil quality was strongly affected by both frying time and fried food matrixes by representing different correlations between measured properties. Although, all oil samples were within control limits at the end of all frying treatments (10-14% TPM, 1.18-2.69 meq. O₂/kg which are below 24-30% TPM and 10 meq. O₂/kg), oil left after mixed vegetable frying served better quality having lowest p-anisidine value (PA), free fatty acid (FFA) and ΔE as 5.29±1.62, 0.15±0.001 oleic acid and 92.27±0.02 respectively compared to other food matrixes in terms of determined quality metrics as oxidation level and colour. Proposed physical and chemical methods had a correlation with each other in some aspects such as strong positive correlation between frying time and ΔE, negative correlation between frying time and L for all frying treatments, but even more attention was required for the precise and quick determination of the oil quality during food frying at catering companies.

Keywords: Frying oil quality. Food matrix dependency. Sunflower oil. Catering

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1. INTRODUCTION

Food frying is a widely used process for both homemade and industrial scale production to develop taste, appearance and texture of food. During the frying process, frying oil is responsible for both heating food as a heating medium and replacing moisture content in food substances. At this time, elevated temperatures around 150-180°C trigger several physical and chemical changes, there-

fore, the quality of frying oil is significantly affected by reactions such as hydrolysis, oxidation, polymer formation, maillard reaction etc. [1-5]. Main degradations involved in frying oil can be grouped into three categories by reason of reactions like aeration, food matrix and temperature. Aeration causes excess amount of oxygen exposure and sterol oxides, volatiles such as hexanol, pentane, pentanol, oxidation compounds such as oxidised triglycerides, epoxides are produced. Food is rich in water, so that during frying process, high water content leads reactions resulting in free fatty acids, monoglycerides. Frying temperatures around 150-190°C catalyse a reaction producing non-polar oligomers and cyclic monomers [6-8]. Produced dioxin-like compounds were found toxic by means of animal experiments. It is found that their Lethal Dose, 50% (LD₅₀) values are high and are greatly carcinogenic. Furthermore, these compounds are liposoluble, volatile and resistant to degradation. Therefore, they also accumulate in animal tissues [6]. Frying processes could be a problem with their volatile compounds. Especially double bounded fats are degraded to aldehydes, ketones, epoxides, hydroxyl compounds, etc. which are toxic and potentially carcinogenic [9]. Oxidation is a big reason for trans fatty acids especially with high temperature for a prolonged treatment. Vaskova and Buckova developed an idea with their study that 5 hours of cooking of sunflower oil at 160°C result in a decomposition products formation and the loss of cis double bonds which are volatile components causing non-smoking lung adenocarcinoma for kitchen workers [10]. Determination of the oil quality is an important parameter for process optimisation, shelf life and quality of fried food and public health. There are some methods developed to evaluate oil quality based on fast physical and chemical analyses such as density, colour, refractive index, dielectric constant, smoking point, free fatty acid level, carbonyl compounds, peroxides, p-anisidine, malondialdehyde, spectroscopic analyses and total polar compound which is formed under high temperature, moisture and air [3, 6, 11]. Oil quality is affected by factors such as the refreshing ratio of oil, frying time and temperature, heating type, composition of frying oil, quality of start-up oil, composition of fried food, fryer type, antioxidants and oxygen availability. It is common to determine frying oil quality by visual examination by owners or cooks; however, to protect public health, the ideal limit conditions for frying oil was recommended as having a maximum of 0.05-0.08% free acidity, 1.0% moisture, 1.0 meq/kg peroxide value, a minimum of 200°C of smoke point with mild flavour and taste [12-14]. Although for certain quality limits for frying oil vary in different countries due to regulations, the total polar materials (TPM) must be ≤% 25 and the smoke point must be >170°C due to 'the control criteria for the solid and liquid oil

used for frying issued by the Ministry of Agriculture (Regulation no: 2007/41) for Turkey, 24% TPM for some European countries like France, Germany, 27% TPM for China and Australia and 30% TPM for Hungary. TPM analysis is the current official method accepted by several countries as indicated above and developed a solvent free method to determine TPM measuring dielectric constant in frying oil. Previously, it was conducted by chromatographic methods [3, 15]. Catering is one of the major application area for frying and there are some academic studies available on the quality of different type of oils used for French fries and chicken frying for mass production [3, 8, 15]. However, some matrixes like meat ball and mixed vegetable have not been studied before.

Although there are regulatory limitations and limits available to control oil quality, generally, frying fat quality is inspected by cooker's visual control of oil instead of using measuring techniques due to their complexity. However, to monitor oil quality to identify the correct time for refreshing or replacing in order to produce healthy food is of crucial importance. On the other hand, there are no comparative studies available on frying different types of product at the catering company in terms of oil quality change during the processing period. It is suggested to analyse some physicochemical properties of frying oil: an indicator like TPM, free fatty acids (FFA), peroxide value (PV), para-anisidine (PA), total oxidation (TOTOX) for chemical properties and colour change, surface tension, viscosity and density like physical properties [16, 17].

Unlike previous researches focusing on one type of food frying, the aim of this study is to evaluate sunflower oil quality dependency to frying time and fried food composition considering mostly consumed foods like meat, chicken, fish and mixed vegetable in accordance with the menu created in the selected catering company.

2. MATERIAL AND METHODS

2.1. MATERIAL

Chemicals like ethanol, chloroform, potassium iodide etc. used for chemical analyses like PV, FFA, PV were analytical graded, methanol and hexane required for fatty acid composition were gas chromatograph (GC) graded and all chemicals were purchased from Sigma-Aldrich (Germany). Chicken breast, minced meat, wheat, rice, egg, potato, cauliflower, pepper and eggplant and sunflower oil were purchased from local markets. Oil samples were collected during food frying period at the catering company and kept in amber bottles at 4°C until performing the tests. All samples were analysed in terms of chemical and physical properties for the evaluation of the variation due to food composition and processing time.

2.2. FRYING AND SAMPLE COLLECTION

Each food was prepared based on the recipe at the catering company.

Oil samples representing one-month frying practice for sampling three replication of frying including meat ball (mixture of minced meat, rice, wheat and egg) (MB), chicken breast (CB), fish fillet (FF) and mixed vegetable (mixture of potato, cauliflower, pepper and eggplant) (MV) frying were collected at every 60 min. 0th time means control oil samples collected just after heating to frying temperature and loading the food inside the start-up oil. Therefore, differences between controls were expected related to the type of the food fried and the possible differences due to the batch of start-up oil. Each frying process was monitored throughout the frying day (5 hours) process at the local catering company that serves 2000 people every day.

As observed, the frying process was applied on an industrial deep fryer at 175±5°C with 2×18L sunflower oil satisfying 2kg/L food/oil ratio. 50 ml of oil sample in triplicate was taken directly from the fryer used to an amber glass and then labelled.

2.3. DETERMINATION OF THE CHEMICAL PROPERTIES

The determination of FFA, PV and PA of oil samples were performed following AOCS standard methods Ca 3d-63, Cd 8b-90 and Cd 18-90, respectively [18]. To determine total oxidation, TOTOX was evaluated using Eq. (1) [19-21].

$$TOTOX\ value = 2PV + PA \quad (1)$$

Fatty acid composition evaluation of the samples was carried out following European Official Methods of Analysis [22]. To prepare methyl esters, 0.1 g oil sample dissolved in GC grade hexane and methanolic potassium hydroxide solution was added for saponification then centrifuged and filtrated to evaluate by injecting supernatant to GC (Agilent 6890, USA). The oxidation index, known as calculated oxidizability (COX), was determined by the Eq. (2) where oleic acid (C18:1), linoleic acid (C18:2) and linolenic acid (C18:3) were considered [21, 23, 24].

$$COX\ value = \frac{(1(18:1\%) + 10.3(18:2\%) + 21.6(18:3\%))}{100} \quad (2)$$

The total polar materials (TPM%) of oil samples were measured by the Testo 265 (Lenzkirch, Germany) sensor (probe).

Previous researchers found that measuring TPM% by probe is the simplest and reliable method and correlates quite well to the column chromatographic method to measure total polar materials [14].

The temperature of the samples was elevated to 50±5°C for their proper measurement and the probe was immersed for 10 sec. [13, 25].

2.4. DETERMINATION OF THE PHYSICAL PROPERTIES

Turbidity of the samples was measured using a turbidimeter (Jenway 6035, UK) at 25±5°C in the range of 550-600 nm wavelength. The measurement procedure was as per the instruction manual. The standard NTU 10-50-100-1000 solutions (Advanced Polymers Systems, Inc., Redwood City, CA) were used as the reference liquids [5]. The refractive index of the samples was measured under daylight by means of a portable refractometer (Mettler Toledo 30 PX, Switzerland) that was calibrated against pure water.

Colour measurement of the samples at 25±5°C were carried out by colour meter (Lovibond RT850i, USA) readings of brightness (L*), a* and b* values and Chroma (C) value. ΔE value was evaluated by calculating ΔL, Δa and Δb against measured values of the control oil sample by using Eq. (3) [13].

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (3)$$

Surface tension of the samples was determined by measuring the contact angle of oil droplets using sessile drop method using goniometer (Kruss DSA 100 E, Germany). Each droplet was obtained by a 0.44 mm polymer needle syringe. Droplets were settled on polytetrafluoroethylene (PTFE) surface at 25±5°C room atmosphere. The droplet generation (4 μL) and evaluation of the contact angle of the droplets after the baseline correction were carried out by Drop Shape Analyser Image software. Three measurements were carried out within 60 sec. if no significant change was observed during each measurement, values were written down for further statistical evaluation [16].

2.5. STATISTICAL METHOD

All physicochemical analysis was applied in triplicate and the means of measurements were used for statistical analysis. All data were subjected to analysis of variance (ANOVA). Post-hoc test for further analysis carried out by Tukey's method for multiple comparison. Statistical software (SPSS 18, USA) was used for ANOVA test and Pearson correlation for determining linear relationship between variables.

3. RESULTS AND DISCUSSION

All measurements taken on oil samples for 300 min. while frying four different foods are summarised in Table I. Chemical composition of the oil was affected as soon as food was loaded at the frying temperature of 175±5°C. Since a statistical difference on the properties of control values were obvious and there was an observable different pathway on the physicochemical change while frying per each sample, splitting method was applied to data and the results obtained were evaluated individually. This significant difference on start-

Table I - Physicochemical properties of sunflower oil samples collected during frying of different food type

Type of food	Frying	TPM%	FFA	PV	PA	TOTOX	L	C	ΔE	Turbidity
Meat Ball	Control	8.70±0.42 ^a	0.05±0.01 ^a	2.69±0.43 ^b	8.29±0.66 ^c	13.68±1.47 ^a	132.20±1.20 ^f	293.61±36.60 ^b	-	8.01±4.52 ^a
	60 min.	9.20±0.29 ^{ab}	0.05±0.00 ^a	1.86±0.19 ^b	11.36±0.82 ^{ab}	15.10±0.79 ^{ab}	126.73±0.97 ^e	222.13±32.95 ^b	80.87±3.85 ^a	112.00±4.00 ^{bc}
	120 min.	9.45±0.64 ^{ab}	0.07±0.00 ^b	0.80±0.22 ^a	12.38±0.91 ^b	13.98±1.12 ^{ab}	110.71±1.46 ^d	111.43±24.97 ^a	184.53±1.77 ^b	104.15±5.85 ^b
	180 min.	10.95±1.34 ^{bc}	0.11±0.00 ^c	0.60±0.03 ^a	14.39±1.07 ^{bc}	15.59±1.04 ^{ab}	86.04±0.11 ^c	80.00±25.00 ^a	211.35±6.38 ^c	131.50±8.50 ^c
	240 min.	12.20±0.28 ^{cd}	0.25±0.00 ^d	0.48±0.34 ^a	13.82±0.97 ^{bc}	14.78±0.35 ^{ab}	40.13±0.10 ^b	74.62±10.20 ^a	230.79±4.72 ^d	259.50±9.50 ^e
	300 min.	14.00±0.35 ^d	0.28±0.00 ^e	0.43±0.16 ^a	16.30±1.18 ^c	17.17±1.04 ^b	24.51±0.06 ^a	54.87±4.24 ^a	247.72±3.16 ^e	232.50±7.50 ^d
Mixed Vegetable	Control	9.20±0.28 ^a	0.13±0.01 ^a	2.36±0.64 ^a	2.25±0.71 ^a	6.96±1.85 ^{ab}	128.32±2.47 ^a	292.68±31.77 ^a	-	2.29±0.29 ^a
	60 min.	10.20±1.70 ^{ab}	0.11±0.00 ^a	1.67±0.34 ^a	2.34±0.72 ^a	5.68±0.83 ^a	127.25±3.42 ^a	273.25±31.24 ^a	21.68±0.94 ^a	2.50±0.48 ^a
	120 min.	11.70±0.42 ^{ab}	0.14±0.00 ^b	4.49±0.48 ^a	2.52±0.78 ^a	11.51±0.28 ^b	128.91±5.85 ^a	246.30±30.57 ^a	53.96±2.74 ^b	3.24±0.16 ^a
	180 min.	10.45±0.64 ^{abc}	0.12±0.01 ^a	8.23±1.72 ^b	3.32±1.02 ^a	19.78±2.92 ^c	125.46±1.09 ^a	241.56±33.30 ^a	51.50±1.17 ^b	4.25±0.45 ^a
	240 min.	12.95±1.34 ^{bc}	0.13±0.01 ^{ab}	8.25±1.09 ^b	5.50±1.96 ^a	21.99±0.37 ^c	122.69±0.80 ^a	224.94±34.74 ^a	66.96±2.65 ^c	5.63±0.63 ^a
	300 min.	14.95±0.64 ^c	0.15±0.00 ^b	9.26±0.66 ^b	5.29±1.62 ^a	23.80±1.34 ^c	123.08±2.21 ^a	204.61±31.90 ^a	92.27±0.02 ^d	12.88±3.88 ^b
Chicken Breast	Control	6.50±0.80 ^a	0.21±0.00 ^a	1.18±0.17 ^a	1.15±0.00 ^a	3.51±0.34 ^a	132.16±1.83 ^c	255.28±34.18 ^b	-	1.82±0.23 ^a
	60 min.	8.00±0.75 ^{ab}	0.18±0.00 ^a	2.98±1.87 ^{ab}	4.28±0.03 ^b	10.24±0.36 ^b	126.14±2.19 ^c	215.38±32.09 ^b	40.96±2.39 ^a	7.72±2.66 ^a
	120 min.	7.50±1.25 ^{ab}	0.41±0.03 ^{bc}	4.46±1.22 ^{ab}	5.95±0.19 ^c	14.87±0.08 ^c	83.53±3.66 ^a	49.61±27.77 ^a	218.09±2.25 ^b	26.55±2.35 ^{ab}
	180 min.	9.00±1.02 ^{ab}	0.34±0.07 ^b	5.83±0.45 ^b	6.23±0.06 ^d	17.89±0.00 ^d	81.57±0.60 ^a	52.88±29.15 ^a	215.92±3.77 ^{bc}	33.04±19.07 ^{ab}
	240 min.	8.50±0.95 ^{ab}	0.35±0.01 ^{bc}	6.22±0.96 ^b	12.44±0.01 ^f	24.88±0.07 ^f	103.34±0.45 ^b	32.42±22.47 ^a	225.43±3.68 ^c	67.55±4.65 ^b
	300 min.	10.50±0.05 ^b	0.46±0.02 ^c	5.08±1.93 ^{ab}	10.85±0.00 ^e	21.01±0.16 ^e	99.15±1.13 ^b	10.00±9.01 ^a	257.02±1.59 ^d	129.20±33.8 ^c
Fish Fillet	Control	7.50±1.08 ^a	0.29±0.01 ^a	3.53±0.80 ^{ba}	1.31±0.05	8.37±0.43 ^a	133.20±2.15 ^a	254.14±32.97 ^e	-	0.03±0.03 ^a
	60 min.	7.13±1.02 ^a	0.30±0.01 ^a	3.39±0.35 ^b	2.60±0.08	9.38±0.44 ^b	109.03±2.80 ^{ab}	96.96±31.67 ^d	164.82±1.67 ^a	14.24±1.44 ^b
	120 min.	8.50±1.50 ^a	0.35±0.01 ^b	2.68±0.25 ^{ba}	4.92±0.08	10.28±0.09 ^c	89.77±4.76 ^b	21.30±18.44 ^c	278.30±2.49 ^b	13.61±2.64 ^b
	180 min.	7.77±1.05 ^a	0.46±0.02 ^c	3.29±0.18 ^b	5.36±0.08	11.94±0.00 ^d	79.15±0.84 ^c	40.68±20.93 ^b	297.13±2.47 ^c	36.15±0.35 ^c
	240 min.	8.83±1.12 ^a	0.54±0.00 ^d	1.72±0.32 ^a	9.01±0.12	12.45±0.08 ^e	72.85±0.62 ^c	52.59±17.09 ^b	305.45±3.17 ^{cd}	55.25±2.65 ^d
	300 min.	10.00±1.50 ^a	0.59±0.01 ^e	1.50±0.29 ^a	10.02±0.11	14.83±0.39 ^f	50.00±1.67 ^d	40.00±12.64 ^a	300.00±0.81 ^d	60.55±0.65 ^d

Results are expressed as mean ± standard deviation (n=3). Means with different letters in row are significantly different according to Tukey's HSD (honestly significant difference) test (P < 0.05)

up oil at 0th time can be expressed by the completely different composition of loaded food. On the other hand, this predictable situation showed the importance on the effect of the composition of food on frying oil quality even at a very early stage of frying [12-14]. Besides, the properties of frying oil of four different food compositions were investigated in terms of frying period. TPM% which is the main indicator of deterioration of frying oil increased with the frying period for all food types and significantly changed ($\alpha < 0.05$) except for FF. Increase in TPM% was also observed for chicken frying as in the previous study [3]. Although TPM% increased from 6.50-8.70 to 10.00-14.00, these values were still acceptable and none of them exceeded the limits indicated with the regulations. A similar trend was observed for French fry processing in a previous work [26].

Pathways of oxidation were quite different within oil samples due to the composition of fried food. In terms of primer oxidation products, all control samples had the value 1.18-2.69 meq. O₂/kg which were within the legal limits being below 10 meq O₂/kg for the sunflower oil. Increase in PV was expected for all products as observed in previous studies [27, 28]. However, this value increased for MV and CB while it decreased for MB and FF with 5 hours of frying. In literature, the PV value increased from 6 meq. O₂/kg to 9.3 meq. O₂/kg after 10 cycle frying and the author explained this increase with the oxidation of linoleic acid content of sunflower oil [26]. Manral et. al found that PV increased and then decreased for fish frying in sunflower oil and the decrease in PV was explained as the formation of secondary oxidation products like PA for prolonged frying [28]. Different pathways observed at oxidation value can be expressed as oxidation dependency to fried food composition. Oxidation could be slower for MV frying due to the availability of natural antioxidants in vegetables [29]. On the other hand, methods like PV measurement is not an enough tool to determine the quality of oil used to fry highly fatty food like meat and chicken [30]. Furthermore, a sharp decrease in PV for MB and FF can be expressed as hydrolysis of primer oxidation products for the creation of secondary oxidation products. It was also found that PA value of sunflower oil for all frying applications increased from 1.31-8.29 to 5.29-16.30 with a prolonged frying period. Consequently, the TOTOX value increased with time for all

frying applications from 6.96-13.68 to 14.83-23.80.

The FFA value of oils except for MV were 0.05-0.29% of oleic acid at the early stage of frying then increased up to 0.28-0.59% oleic acid due to fried food type in parallel with previous studies in which the FFA of oil sample doubles within 4-6 hours of frying [28]. Because CB, MB and FF had high fat content, the FFA increase was also statistically significant ($\alpha < 0.5$) while there was no significant change observed in the FFA value for MV frying.

Fatty acid compositions of oil samples represented in Table II which were consistent with the given general composition of sunflower oil [31] and both results depended on the frying time and on the composition like water and the fatty content of fried food. For the food type, it can be expressed as depending on the fat migration with water from food by means of heating especially for a high fat content food as meat and chicken. As shown in Table II, there was a slight increase in the saturated fatty acid like palmitic acid in MB, FF and CB frying. Due to the oxidation of linoleic acid, which is a characteristic fatty acid of sunflower oil, there was also a decrease in the percentage of this fatty acid during frying process of almost all food matrices parallel to previous studies [24, 26, 32]. Since the water content is an important factor for oxidation and vegetables are rich in water, decrease in linoleic acid was more obvious in MV frying compared to the other oil samples used for frying other food matrices. There was a decrease in the COX value for all frying experiments. This situation can be explained by the oxidation of unsaturated fatty acids like oleic acid and linoleic acid, although linolenic acid content increased slightly by frying.

The refractive index of all oil samples collected during frying were around 1.469, which is the refractive index of sunflower oil [28]. Brightness (L*) and turbidity of oil samples from MV were not significantly affected by the frying time. Measured turbidity for MB, MV, CB and FF were 232.50, 12.88, 129.20 and 60.55 respectively at the end of frying while that value was around 0.03-8.01 for the control samples. Besides turbidity being lowest in all oil samples in MV frying, brightness was the best in MV samples compared to other food matrices. A significant increase in turbidity value can be expressed by the generation of high molecular weight compounds, fatty alcohols and hydrocarbons during frying [33]. On

Table II - Percentage fatty acid composition of oil samples

Type of Fatty Acid	MB ₀	MB ₃₀₀	FF ₀	FF ₃₀₀	CB ₀	CB ₃₀₀	MV ₀	MV ₃₀₀
Palmitic acid (C 16:0)	6.69	7.87	5.55	5.94	5.63	5.83	5.87	5.66
Stearic acid (C 18:0)	3.60	3.98	3.16	3.37	3.17	3.21	3.33	3.30
Oleic acid (C 18:1)	30.53	31.89	42.01	41.25	42.03	41.59	41.56	41.44
Linoleic acid (C 18:2)	56.28	53.66	46.48	46.32	46.74	46.48	47.24	43.56
Linolenic acid (C 18:3)	0.05	0.20	0.01	0.10	0.04	0.10	0.02	0.15
COX	6.11	5.89	5.21	5.20	5.24	5.22	5.29	4.93

Table III - Pearson correlation between parameters of sunflower oil samples used for Meat Ball frying

	Frying time	TPM%	FFA	PV	PA	TOTOX	L	C	ΔE	Turbidity
Frying time	1.000	0.909	0.922	-0.864	0.892	0.573	-0.970	-0.890	0.937	0.921
TPM%	0.909	1.000	0.913	-0.632	0.882	0.770	-0.921	-0.652	0.780	0.852
FFA	0.922	0.913	1.000	-0.658	0.738	0.529	-0.985	-0.696	0.756	0.909
PV	-0.864	-0.632	-0.658	1.000	-0.747	-0.243	0.763	0.982	-0.943	-0.770
PA	0.892	0.882	0.738	-0.747	1.000	0.797	-0.798	-0.770	0.901	0.821
TOTOX	0.573	0.770	0.529	-0.243	0.797	1.000	-0.526	-0.270	0.485	0.530
L	-0.970	-0.921	-0.985	0.763	-0.798	-0.526	1.000	0.796	-0.839	-0.920
C	-0.890	-0.652	-0.696	0.982	-0.770	-0.270	0.796	1.000	-0.950	-0.777
ΔE	0.937	0.780	0.756	-0.943	0.901	0.485	-0.839	-0.950	1.000	0.857
Turbidity	0.921	0.852	0.909	-0.770	0.821	0.530	-0.920	-0.777	0.857	1.000

Table IV - Pearson correlation between parameters of sunflower oil samples used for Mixed Vegetable frying

	Frying time	TPM%	FFA	PV	PA	TOTOX	L	C	ΔE	Turbidity
Frying time	1.000	0.810	0.438	0.897	0.678	0.934	-0.536	-0.664	0.969	0.775
TPM%	0.810	1.000	0.675	0.734	0.822	0.740	-0.168	-0.267	0.852	0.825
FFA	0.438	0.675	1.000	0.460	0.522	0.445	0.109	-0.067	0.559	0.575
PV	0.897	0.734	0.460	1.000	0.779	0.985	-0.359	-0.387	0.848	0.708
PA	0.678	0.822	0.522	0.779	1.000	0.752	-0.092	0.032	0.639	0.731
TOTOX	0.934	0.740	0.445	0.985	0.752	1.000	-0.437	-0.477	0.870	0.731
L	-0.536	-0.168	0.109	-0.359	-0.092	-0.437	1.000	0.809	-0.421	-0.279
C	-0.664	-0.267	-0.067	-0.387	0.032	-0.477	0.809	1.000	-0.636	-0.331
ΔE	0.969	0.852	0.559	0.848	0.639	0.870	-0.421	-0.636	1.000	0.763
Turbidity	0.775	0.825	0.575	0.708	0.731	0.731	-0.279	-0.331	0.763	1.000

Table V - Pearson correlation between parameters of sunflower oil samples used for Chicken Breast frying

	Frying time	TPM%	FFA	PV	PA	TOTOX	L	C	ΔE	Turbidity
Frying time	1.000	0.734	0.778	0.692	0.936	0.934	-0.593	-0.858	0.896	0.867
TPM%	0.734	1.000	0.637	0.685	0.616	0.622	-0.331	-0.401	0.605	0.743
FFA	0.778	0.637	1.000	0.621	0.673	0.696	-0.732	-0.784	0.890	0.768
PV	0.692	0.685	0.621	1.000	0.693	0.786	-0.591	-0.605	0.748	0.596
PA	0.936	0.616	0.673	0.693	1.000	0.965	-0.467	-0.801	0.823	0.783
TOTOX	0.934	0.622	0.696	0.786	0.965	1.000	-0.644	-0.872	0.899	0.707
L	-0.593	-0.331	-0.732	-0.591	-0.467	-0.644	1.000	0.854	-0.867	-0.325
C	-0.858	-0.401	-0.784	-0.605	-0.801	-0.872	0.854	1.000	-0.954	-0.616
ΔE	0.896	0.605	0.890	0.748	0.823	0.899	-0.867	-0.954	1.000	0.698
Turbidity	0.867	0.743	0.768	0.596	0.783	0.707	-0.325	-0.616	0.698	1.000

Table VI - Pearson correlation between parameters of sunflower oil samples used for Fish Fillet frying

	Frying time	TPM%	FFA	PV	PA	TOTOX	L	C	ΔE	Turbidity
Frying time	1.000	0.530	0.974	-0.783	0.983	0.975	-0.979	-0.662	0.850	0.971
TPM%	0.530	1.000	0.579	-0.214	0.577	0.613	-0.450	-0.086	0.391	0.528
FFA	0.974	0.579	1.000	-0.737	0.966	0.965	-0.913	-0.497	0.746	0.982
PV	-0.783	-0.214	-0.737	1.000	-0.834	-0.688	0.771	0.550	-0.582	-0.743
PA	0.983	0.577	0.966	-0.834	1.000	0.946	-0.943	-0.608	0.810	0.961
TOTOX	0.975	0.613	0.965	-0.688	0.946	1.000	-0.948	-0.563	0.779	0.949
L	-0.979	-0.450	-0.913	0.771	-0.943	-0.948	1.000	0.773	-0.899	-0.914
C	-0.662	-0.086	-0.497	0.550	-0.608	-0.563	0.773	1.000	-0.909	-0.551
ΔE	0.850	0.391	0.746	-0.582	0.810	0.779	-0.899	-0.909	1.000	0.771
Turbidity	0.971	0.528	0.982	-0.743	0.961	0.949	-0.914	-0.551	0.771	1.000

the other hand, there was a big loss on the L^* value of the oil samples taken during MB, CB and FF frying similar to previous studies [26], [34]. This can be explained by the high oxidation and browning reactions triggered on protein and food matrixes rich in fat during frying process [1, 5]. With a prolonged frying of MB, CB and FF, ΔE increased and the C value decreased significantly while almost no colour change was observed for MV frying.

As shown in Table III, there was an important positive correlation between frying time and properties like TPM%, FFA, PA, ΔE and Turbidity while L, C and PV had a strong negative correlation for MB and FF frying (Tab. III and Tab. VI). The correlation between frying time and TOTOX in MB is positive but not strong as the frying time and FFA. There was also a strong correlation between frying time and TPM%, PV TOTOX and ΔE for MV frying (Tab. IV), between TPM%, PA, TOTOX, ΔE and turbidity for CB (Tab. V) frying and between FFA, PA, TOTOX ΔE and turbidity for FF frying (Tab. VI). Thanks to the correlation tables, it was clear that food matrixes had an important influence on frying oil quality for different aspects.

One of the physical and fast measurement techniques is static contact angle determination to identify frying oil quality. Temperature dependency to oil sample contact angle and the effect of wettability were studied in literature [16]. As shown in Figure 1, the contact angle of all oil samples decreased from 57.75-65.00° to 51.70-52.42° with prolonged frying. Similar trends were found in literature for the contact angle study on canola oil and the decrease in the contact angle appearance of oxidation products that can increase

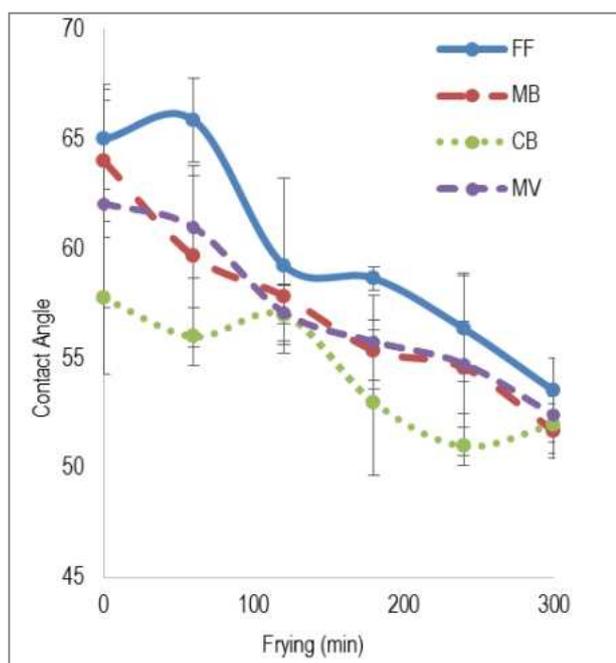


Figure 1 - Change of static contact angle of frying oil for 300 min frying

the wettability of oil [35]. The contact angle measurement is an easy and fast technique and can be proposed to monitor frying oil freshness.

4. CONCLUSION

Some chemical properties (FFA, PA, PV, TPM%) and physical properties (turbidity, colour, refractive index and static contact angle) of sunflower oil for 5 hours of frying of four different food matrixes as MB, MV, FF, CB were evaluated. Although all oil samples were in limits and can be valorised for further uses, it is possible to say that after 5 hours of frying, oil obtained after MV frying served better quality compared to other food matrixes due to having natural antioxidants that helped protect oil oxidation. Additionally, food matrixes with high fat and protein content caused significant colour change and turbidity besides accelerating the production of secondary oxidation products. Developing fast, non-chemical used, low labour needed measuring methods are getting popular for determining frying oil quality especially for industries like catering where only cooker expertise has key role for the determination. Proposed physical and chemical methods served correlation with each other in some respects but even more attention was required for the precise and quick determination of oil quality for public health.

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