



Nutritional Changes in Commercial Oil Blend During Repetitive Deep Fat Frying of French Fries with Sensory Characteristic of Fried Food

Samina Sohu^{1*}, Aftab Ahmed Kandhro¹, Farah Naz Talpur²
Ahmed Ali Sohu³ and Naiz Ali Malgani²

¹Dr. M.A. Kazi Institute of Chemistry, University of Sindh, 76080- Jamshoro, Sindh, Pakistan.

²National Centre of Excellence in Analytical Chemistry, University of Sindh, 76080- Jamshoro, Pakistan.

³Quaid-e-Awam University of Engineering, Science & Technology, 77150- Larkana, Sindh Pakistan.

*Corresponding Author Email: saminasohu1988@gmail.com

Received 23 January 2020, Revised 10 November 2020, Accepted 15 November 2020

Abstract

In present study, the effect of repetitive deep frying cycles (6 batches) of French fries was evaluated for nutritional changes of commercial oil blend (Canola, Sunflower, Cottonseed and Soybean) along with sensory characteristics of fried food. Each deep fat frying cycle was lasted for 13 min and resultant oil was analyzed for nutritional quality by assessing, free fatty acids (FFA), acid value (AV), para Anisidine value (p-AV), viscosity and fatty acid composition (FAC), while sensory characteristics of French fries were determined by evaluating appearance, color, crispness, taste and overall acceptability. Results showed that with increasing repetitive cycle's leads to increase in FFA, AV, p-AV, and viscosity which is an indicator of frying oil deterioration. Up to 3 continuous cycles oil quality was within the permissible limits of INSO, however beyond that oil quality was not suitable. Result of FAC showed progressive increase in SFA (19.23 to 28.84%) from 1st to 6th frying cycle, while PUFA was significantly decreased during frying (39.31 to 31.75%). Sensory properties of French fries indicated particularly significant change ($p > 0.05$) in color during last frying cycle as compared to other cycles (score 9.5 vs. 7.3).

Keywords: French fries, Frying, Physicochemical parameters, Free fatty acid, Acid value, Para-Anisidine, Viscosity, Fatty acid composition

Introduction

The popularity of processed potato products, particularly frozen French fries is increasing worldwide. The deep-frying process is one of the most popular and complex food preparation methods, and is commonly preferred by the fast-food industry [1-2]. The process is described as more complex, because during heating at 150–190°C in the presence of atmospheric oxygen and moisture, frying oils themselves undergo a great number of physical and chemical changes. These changes occur as a consequence of the autoxidation,

thermooxidation, pyrolysis, and polymerization reactions, and a wide range of undesired degradation compounds have been detected in frying oils [3-4]. The species, formation, and quantity of degradation products differ according to the several parameters of the frying process conditions. Frying process parameters of significance are expressed as; frying oil nature, process/oil temperature, frying time, design of the fryer, and moisture content of the foodstuffs. Among these parameters; more specifically, nature/type of

the frying oil acts as a heat-transfer medium and contributes to the quality of fried nutrients [5]. The quality of fried products is affected by that of the properties of oil and some regulations have been reported in many countries to guarantee high-quality fried foodstuffs. Limits for the degradation compounds have been established some official regulations that are limiting the degradation of fats/oils for human consumption. Therefore, the preference and properties of oils used in process are very important for the quality of frying medium and fried foodstuffs, also shelf life of the food products [6-8]. These traditional oils with high levels of polyunsaturated fatty acids (PUFA) are not quite proper for frying due to their fatty acid composition, para-Ansidine (P-AV) characteristics, and also their higher degree of oxidation tendency [9-10]. To improve the oxidative stability/quality of the oils or to enhance their frying stability; there are ways to modify them through fractionation, inter-esterification, hydrogenation, blending, or combination of these processes [11-12]. Among these methods, the blending of different types of fats and oils has appeared as an economical way for improving their physicochemical characteristics, also enhancement in oxidative stability [13-14]. It has been used to modify vegetable oils to get better their physicochemical functionalities, enhance their frying/oxidative stability, and improve their prefer ability for fried foodstuffs. The nutritional properties of blends are mainly based on fatty acid profile that are saturated fatty acids (SFA) to unsaturated fatty acids (USFA) ratio, antioxidant capacity, etc. [15-16]. The type of oil that is used for frying is usually a compromise between stability and health aspects. SFA are very stable against deterioration at frying temperature, but are known to cause coronary heart diseases. USFA are beneficial for health, but especially PUFA are not very stable [17-18]. By hydrogenation the level of saturation can be

increased, and this results in more stable oils. However, during hydrogenation also *trans* fatty acids are formed, and clinical studies have shown that these compounds are even more harmful than saturated fatty acids in causing coronary heart disease [19-21].

Therefore, vegetable oils with a lower degree of PUFA or blend of oils with different characteristics are used for frying. Therefore, nutritional quality and shelf life of the fried products depend upon the quality of the oil used for frying. Vast parts of the population in many countries, including Pakistan, still consume fried foods in the diet because of their customary eating habits and life style, so there is strong need of monitoring and regulation on frying food, and check the quality of oil and related products. In Pakistan and in some other developing countries where there are no standards with regard to repetitive frying of fast food consumed locally. Therefore, present study aim to investigate influence of repetitive oil frying of French fries on sensory properties. In present study, the effect of repetitive deep frying cycles (6 batches) of French fries was evaluated for nutritional changes of commercial oil blend.

Materials and Method

All chemicals and reagents were of analytical grade obtained from E. Merck (Darmstadt, Germany). FAMES standards (GLC 607/481B) were purchased from Nu-Check Prep, Inc (Elysian, MN) used without any further treatment. The commercial oil blend (Canola, Sunflower, Cottonseed and Soybean) for the frying of French fries was purchased from a local supermarket (Jamshoro, Sindh, Pakistan).

French Fries Frying Process

Fresh potatoes were purchased from the local market of Jamshoro, Pakistan. The potatoes were peeled, washed and sliced into 0.5 cm thick and 2.5 cm long using a

mechanical slicer 10 min before use. The French fries frying was carried out in a 4L oil capacity (West Point E-2016) deep fryer at 170 °C with thermostatic temperature control. When the oil reached at mentioned temperature, 300 g of French fries fried in each cycle. The frying time of French fries was set at 13 min (till golden brown color). After each frying cycle the oil was allowed to cool at room temperature and then started next frying cycle. The frying frequency was 6 batches per day, at the end of every frying batch approximately 300 mL frying oil was withdrawn for quality parameter analysis.

Sensory Analysis of French Fries

Semi trained 10 panels members selected for sensory analysis of French fries. The sample evaluated for appearance, color, crispness, taste and overall acceptability. Each attribute was evaluated using a 9-point hedonic scale (9-extremely, 8-like very much, 7-like moderately, 6-like slightly, 5- neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely). The scores received by each samples were then averaged and compared with the average score received by other samples in the series as reported in the literature [22].

Physicochemical Properties of Oil

The following physicochemical parameters were focused for the analysis during repetitive frying oil such as free fatty acid (FFA), acid value (AV), p-Ansidine value (P-AV), viscosity, and fatty acid composition including cis and *trans* fatty acid ratio.

Free Fatty Acid

FFA content as percentage of oleic acid was determined by the titration of a

solution of oil dissolved in hot neutral ethanol with sodium hydroxide in the presence of phenolphthalein indicator using AOCS Official Method Ca 5a-40 [23].

Acid Value

The AV of the oil samples were determined by titration method. Two gram of the oil was weighed into a 250 mL conical flask. 50 mL of neutralized ethyl alcohol was added to the oil sample. The mixture was then heated in a water bath. The solution was titrated against 0.1 M KOH using phenolphthalein as indicator. The AV was calculated using the following formula [23].

$$\text{Acid value} = \frac{A \times M \times 56.1}{W}$$

Where,

A = Amount (mL) of 0.1M KOH consumed by sample

M = Molarity of KOH

W = weight (g) of oil sample

Para-Anisidine Value

The p-AV measures the extent of secondary oxidation in heated oil samples. The p-AV was determined and calculated using the method AOCS Cd 18-90 [23] as shown in equation.

$$p\text{-AV} = 25 * 1.2 * (A_r - A_b - A_u) / \text{Oil mass (g)}$$

A_r = absorbance of the test oil samples after reacting with Anisidine reagent.

A_b = blank absorbance; and A_u = absorbance of the test oil samples that were not reacted with Anisidine reagent).

Viscosity

The viscosity of the oil samples was recorded using an Ostwald-U-tube viscometer [23]. The viscometer was

suspended in the constant temperature bath ($32 \pm 2^\circ\text{C}$) so that the capillary was vertical. The instrument was filled to the mark at the top of the lower reservoir with the oil by means of pipette inserted into the side arm, so that the tube wall above the mark is not wetted. The instrument was then left to stand for few minutes before reading in order to equilibrate the sample temperature with that of the instrument ($32 \pm 2^\circ\text{C}$). By means of the pressure on the respective arm of the tube, the oil moved into the other arm, the meniscus was 1 cm above the mark at the top of the upper reservoir. The liquid was then allowed to flow freely through the tube and the time required for the meniscus to pass from the mark above the upper reservoir to that at the bottom of the upper reservoir was recorded. The viscosity was calculated using the equation.

$$V = (T - T_0) / T_0$$

Where:

V = Viscosity.

T = Flow-time of the oil.

T₀ = Flow-time of distilled water

Fatty Acid Composition (FAC) of frying Oil

For the determination of fatty acid profile of fresh and recycle oil was determined as per standard methods [24]. According to the standard procedure, 2-3 drops of the oil samples were taken in the 100 mL conical flask containing 4 mL of 0.5 N solution of sodium hydroxide and 5 mL of methanol solution of BF₃. After reflux for 15 min, the extracted methyl esters with hexane were injected in to GC-MS. The GC-MS analysis of fatty acid methyl esters (FAME) was carried out using an Agilent Technologies gas chromatograph (GC-6890 N, Little Fall,

NY, USA) equipped with an Agilent auto sampler 7683-B injector (Agilent Technologies, Little Fall, NY, USA) and MS-5975 inert XL Mass selective detector (Restek Corp., Benner Circle, Bellefonte, USA). Analytical separation was achieved using a HP-5 MS capillary column (30 m×0.25 mm i.d×0.25 micron film thickness) for the separation of FAME. The initial oven temperature 140°C was maintained for 2 min, raised to 230°C at the rate of 4°C/min, and kept at 230°C for 5 min. The split ratio was 1:50, and helium was used as a carrier gas with the flow rate of 0.8 mL/min. The injector and detector temperatures were 240°C and 260°C, respectively. The mass spectrometer was operated in the electron impact mode at 70 eV; with an ion source temperature of 230°C, a quadrupole temperature of 150°C, and a translating line temperature of 270°C. The mass scan ranged from 50–550 m/z with an Em voltage, 1035 V.

Calculations and Statistical Analyses

Methyl esters identification was carried out by NIST and Willy Libraries installed with GC-MS software. While One-way analysis of variance (ANOVA) was carried out using SPSS 10.0 (IBM Corporation, Armonk, NY) to compare nutritional/sensory data obtained for different frying cycles. The differences were considered significant when $P < 0.05$ at a confident level of 95%.

Results and Discussion

Sensorial Property of Repetitive Frying of French Fries

The sensory score for the French fries fried at 170 °C for 13 min per batch in commercial cooking oil were evaluated based on sensory attributes. Quality parameters of interest for French fries include

physical properties such as appearance, color, crispness, test and overall acceptability. As depicted in Table 1, the sensory data showed significant differences in term ($p \leq 0.05$) of color, taste, crispness and overall acceptability for French fries fried for six cycles/intervals.

Table 1. Sensory score of the French fries fried in different batch of frying oil cycles.

Sensory attributes	Frying cycle					
	1	2	3	4	5	6
Appearance	9 \pm 0.3 ^a	9 \pm 0.5 ^a	8.1 \pm 0.4 ^b	7.5 \pm 0.4 ^c	8.5 \pm 0.4 ^b	8.4 \pm 0.4 ^b
Colour	9 \pm 0.4 ^a	9 \pm 0.2 ^a	8.9 \pm 0.2 ^a	7.8 \pm 0.4 ^b	7.6 \pm 0.3 ^b	7.3 \pm 0.3 ^b
Crispness	9 \pm 0.4 ^a	9 \pm 0.4 ^a	8.7 \pm 0.4 ^a	7.8 \pm 0.2 ^b	7.9 \pm 0.3 ^b	7.3 \pm 0.4 ^b
Taste	9 \pm 0.3 ^a	8.6 \pm 0.4 ^a	7.9 \pm 0.4 ^b	7.7 \pm 0.2 ^b	7.2 \pm 0.4 ^b	7.1 \pm 0.4 ^b
Over all acceptability	9 \pm 0.1 ^a	9 \pm 0.1 ^a	7.9 \pm 0.1 ^b	7.1 \pm 0.4 ^c	7.1 \pm 0.4 ^c	7.3 \pm 0.3 ^c

The different alphabet in a row shows significant differences ($p \leq 0.05$).

Physicochemical Characteristics of Frying Cycles in Oil

Free fatty acid and acid value

FFA value increases with increase in the number of frying cycles and heating, the change in FFA after frying is more in comparison to heating. The increase in FFA is because of the cleavage and the oxidation of double bonds to form carbonyl compounds and low molecular fatty acids during frying [25]. FFA was also determined during repetitive frying cycle of French fries (Fig. 1). There was an increase in FFA in course of increasing 1st to 6th frying cycles of French fries, ranging 0.29 to 4.96% compared to fresh Oil (0.01%). Similarly, Sebastian *et al.* [26], reported that FFA levels in fresh oil samples varied from 0.05 to 0.08% and, for in-use samples from the fryer, ranged widely from 0.25 to 3.99% during repetitive frying. For the industrial production of potato chips, the FFA level of 0.5% has been reported as the threshold for discarding the used frying oil,

whereas a maximum value of 1% FFA is usually allowed by the processors of pre-fried French fries [27].

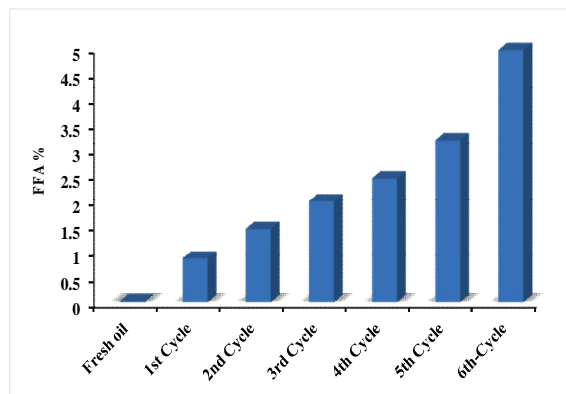


Figure 1 Impact of deep frying cycles (1-6) on FFA of frying oil in comparison to fresh oil

Current study results showed an increase in AV with the increasing repetitive frying cycles for French fries from 1st to 6th batch i.e. 1.15 to 7.87 mg KOH/g with fresh oil having lower acid value (0.29 mgKOH/g) as shown in Fig. 2. Gupta *et al.*, [28] suggested that AV during frying increased and this parameter is used to assess hydrolytic degradation in oils. Maszewska *et al.*, [29] used rapeseed oil, palm oil and mixed oil for frying of French fries and reported that AV increased from 0.32 to 1.78 mg KOH/g at 47.4 h, 0.22 to 0.99 at 70 h, and 0.33 to 1.13 at 95.5 h, respectively for rapeseed oil, palm oil and mixed oil.

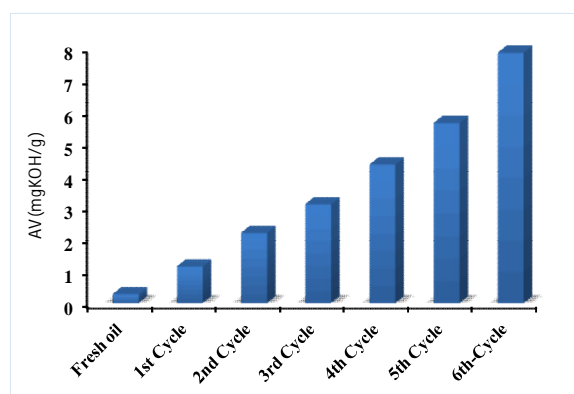


Figure 2 Impact of deep frying cycles (1-6) on AV of frying oil in comparison to fresh oil

Para- anisidine value and viscosity

The p-AV is used to monitor the degree of oil oxidation during frying. This parameter determines the content of aldehydes when hydro peroxides, which are developed in the early stage of oxidation, decompose instantly when exposed to high frying temperatures [30]. As shown in Fig. 3, a rapid increase in p-AV was observed as a function of time for all frying cycles during 1st to 6th. The p-AV increased from 12.62 to 58.25 during 1st to 6th cycle as compared to fresh oil (7.87).

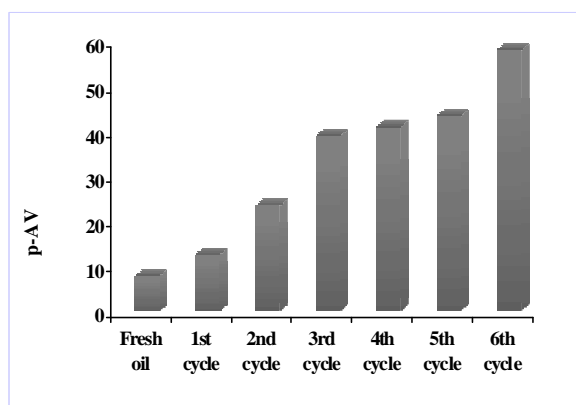


Figure.3. Impact of deep frying cycles (1-6) on p-AV of frying oil in comparison to fresh oil

Viscosity is one of the indicators used to evaluate the physical changes in edible oil. It depends upon density, molecular weight, melting point, degree of unsaturation and temperature [31]. Viscosity increases during hydrogenation as the increase in the chain length of tri-glyceride fatty acid and decreases during unsaturation of fatty acids. Changes in the viscosity were also noticed for deep frying cycles of French fries from 1st to 6th frying process 51.0 to 100.0 cP as shown in Fig. 4. The comparable results has been discussed by Shakak *et al.*, [32], for increased in viscosity during deep frying of potato chips of cottonseed and sunflower oil, the viscosity value increased from (CSO) 67.07cP (SFO)71.00cP [32].

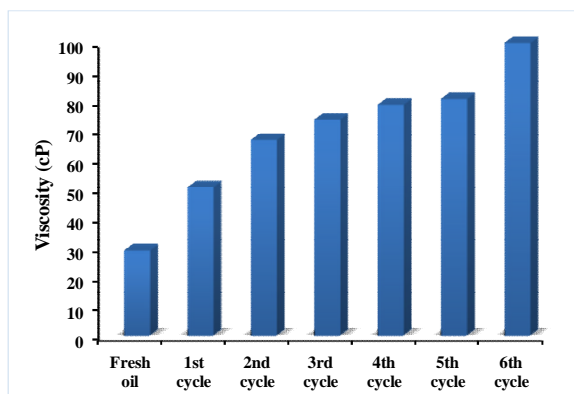


Figure.4. Impact of deep frying cycles (1-6) on viscosity of frying oil in comparison to fresh oil

Fatty acid composition

The FAC of oils changes during frying due to the polymerization, cyclization, hydrolytic, oxidative, and other chemical reactions promoted by deep frying [33]. The results of the FAC for repetitive frying cycle of French fries are shown in Table 2. The fatty acids were divided into SFA, UFA, MUFA, PUFA, and *trans* fatty acids (TFA) as shown in Table 3. Results indicated an increase in SFA from first to sixth cycle ranging 13.56 to 21.58% of total FA, which comprises lauric (C12:0), myristic (C14:0), palmitic (C16:0), stearic (C18:0) and arachidic (C20:0) acids. The results indicated that C16:0 has greater contribution i.e. 14.5 to 19.2% of total SFA during repetitive in frying batches of French fries. Results indicated an decrease in USFA from 1st to 6th cycle ranging 80.77 to 71.16% of total FA, which comprises elaidic (C18:1), linoleic (C18:2), α -linolenic (C18:3), acids. The results indicated that C18:2 has lower contribution i.e. 38.26 to 31.24% of total USFA during repetitive in frying batches of French fries.

There was considerable change ($p \leq 0.05$) in MUFA during first to sixth frying cycles Table 3. MUFA content was

increased during frying cycles with oleic acid (C18:1 cis-9) as the major fatty acid, while PUFA were decreased progressively from first to sixth cycles (39.31 to 31.75%). The levels of TFAs in the frying oil of French fries were significantly increased with compared to their initial frying oil samples. The previous study also showed that repeated use of frying oils causes

increase in the TFA concentration [34]. In present study the level of TFA were increased progressively from first to sixth cycles (1.06 to 6.54%) due to the fast exchange of oil with the fried food as well as the high temperature and prolonged frying process as described earlier [34].

Table 2. The fatty acid composition (%) of frying oil during different cycles for preparation of French fries.

Fatty acids	Fresh oil	Frying cycle					
		1	2	3	4	5	6
C12:0	0.23±0.6 ^a	0.26±0.1 ^a	0.35±0.17 ^b	0.43±0.02 ^b	0.51±0.02 ^c	0.62±0.03 ^d	0.77±0.03 ^e
C14:0	0.12±0.2 ^a	0.14±0.07 ^a	0.18 ±0.09 ^b	0.37 ±0.01 ^c	0.52±0.02 ^c	0.63±0.03 ^c	0.88±0.04 ^d
C16:0	13.03±0.3 ^a	14.50±0.72 ^a	15.2±0.78 ^b	17.5 ±0.87 ^c	17.9±0.89 ^c	18.87±0.91 ^c	19.2±0.96 ^d
C18:0	3.90±0.1 ^a	4.30±0.21 ^a	5.02±0.25 ^b	5.80±0.29 ^b	6.0±0.3 ^c	6.37 ±0.3 ^c	7.37±0.67 ^d
C18:1c	41.75±2.0 ^a	40.66±2.08 ^a	39.95±1.98 ^b	37.36±2.1 ^c	35.94±2.09 ^c	34.56±2.01 ^d	33.41±2.07 ^e
C18:1t	0.30±0.01 ^a	0.80±0.04 ^a	1.30±0.06 ^b	2.50 ±0.12 ^c	4.50±0.22 ^d	5.10±0.25 ^e	6.0 ±0.2 ^f
C18:2c	39.40±1.9 ^a	38.0±1.91 ^a	36.71±1.84 ^b	34.8±1.74 ^c	33.35±1.74 ^e	32.5±1.63 ^f	30.7±1.57 ^f
C18:2t	0.12±0.01 ^a	0.26 ±2.08 ^a	0.32±0.01 ^b	0.34 ±0.1 ^b	0.43±0.02 ^c	0.53±0.02 ^d	0.54 ±0.02 ^d
C18:3	1.15 ±0.5 ^a	1.05 ±0.06 ^a	0.90 ±0.1 ^b	0.80 ±0.13 ^b	0.71 ±0.14 ^c	0.18 ±0.14 ^a	0.25 ±0.15 ^d
C20:0	0.01 ±0.5 ^a	0.03 ±0.1 ^a	0.07± 0.03 ^b	0.10±0.05 ^a	0.14 ±0.07 ^c	0.18 ±0.09 ^c	0.25±0.05 ^d

The different alphabet in a row shows significant differences ($p \leq 0.05$).

Table 3. Major changes in major fatty acid composition (%) of vegetable oil blend during prolonged heating and frying.

Fatty acids	Fresh-oil	Frying cycle					
		1	2	3	4	5	6
ΣSFA	17.29	19.23	20.82	24.22	25.07	26.69	28.84
Σ MUFA	42.05	41.46	41.25	39.86	40.44	39.66	39.41
ΣPUFA	40.67	39.31	37.93	34.49	33.65	33.68	31.75
ΣUFA	82.71	80.77	79.18	75.8	74.93	73.31	71.16
ΣTFA	0.42	1.06	1.62	2.84	4.93	5.63	6.54

The ratio of cis /trans and PUFA/SFA during frying cycles

Table 4 shows the cis and trans fatty acids with the corresponding ratios during different frying cycles of French fries in comparison to fresh oil. A decline in the sum of cis fatty acids was observed, while the increase in trans fatty acids was detected as frying cycles proceeded. The highest ratio of 0.10 was found in sixth frying cycle while the lowest first frying cycle 0.01 and 0.00 were detected in the fresh oil and during the 1st frying cycle, respectively. These results are consistent with previous studies by Liu *et al.*, [35]. The authors have reported that during repeated cycles of frying oil just before its discarding provided the significant level of cis and trans ratio (0.4–0.9%) as compared to fresh oil (0.04%).

Furthermore, due to increasing levels of SFA throughout frying cycles, the decline in PUFA levels was also observed. Among to this reason PUFA/SFA was decreased progressively during frying cycles. In fresh oil the PUFA/SFA was 2.35%, while during the 6th cycle a fourfold reduction was observed with a mean value of 1.10%. The PUFA/SFA ratio is termed as the polyene index, which measures the degree of PUFA and the tendency of the oil to undergo oxidation [36]. Comparable polyene index values ranged from 1.72 to 3.78 has been reported for potato chips frying (180°C) with oil blends comprising canola oil, palm olein, olive oil and corn oil samples [37]. Ma *et al.*, has also reported decrease in polyene index when vegetable oils subjected to prolonged frying processes with or without a replacement of fresh oils [37].

Table 4. Cis/trans fatty acids and PUFA/SFA ratio of fresh and repetitive used oil during French fries deep frying.

Fatty acids (%)	Fresh oil	Frying cycle					
		1	2	3	4	5	6
<i>Trans</i>	0.42	1.06	1.62	2.84	4.93	5.63	6.54
<i>Cis</i>	81.14	78.66	76.66	72.16	69.29	67.06	64.11
<i>trans/cis</i>	0.00	0.01	0.02	0.03	0.07	0.08	0.10
PUFA	40.67	39.31	37.93	34.49	33.65	33.68	31.75
SFA	17.29	19.23	20.82	24.22	25.07	26.69	28.84
PUFA/SFA	2.35	2.04	1.82	1.42	1.34	1.26	1.10

Conclusion

Present study revealed that repetitive frying of French fries imparts a negative impact upon sensory characteristics of fries with better overall acceptability up to three cycles, further increase causes decrease in sensory scores. Moreover, frying oil blend nutritional quality also showed that the repetitive frying leads to increase in FFA, AV, P-AV, and viscosity. FFA were acceptable within recommended range (0.5 -0.8%) for initial three repetitive cycles, however, after preceding cycles of frying exhibited negative effects. In addition saturated FA's were increased while PUFA were progressively decreased as frying cycles increased, indicating that repetitive frying deteriorate the oil and fried food quality, hence oils should not be reuse more than three cycles for French fries frying.

Disclosure statement

The authors have no conflict of interest to declare.

Acknowledgements

This work was supported by the National Center of Excellence in Analytical Chemistry (NCEAC), University of Sindh,

Jamshoro. Pakistan for support and provided the necessary facilities throughout study.

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