ESTIMATION OF QUALITY ATTRIBUTES AND FRYING TIMES OF COTTONSEED AND SUNFLOWER OIL BLEND DURING DEEP-FAT FRYING OF POTATO CHIPS

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ABSTRACT

The chemical, physical and some sensory changes induced upon deep-fat frying of potato chips in a blend of cottonseed and sunflower oil were investigated. The chemical changes were correlated with the frying times aiming at establishing prediction models for estimating frying times. The oil blend became dark in colour after each successive frying. The correlation coefficient between the frying time and A_{400} was very high (r=0.9967). Similar trend was also observed in the relationship between the frying times and A_{450}. Oil viscosity increased significantly with increasing frying times indicating evidence of thermal decomposition of frying oil blend. The correlation coefficient between the frying times and the refractive index was high (r=0.9898). Slight and continuous losses in unsaturated fatty acids of the oil blend during deep-fat frying of potato chips have taken place.

The peroxide value (meq O_2/kg oil) increased initially from 3.86 to 11.81 after 10 fryings, then dropped to 5.23 after 20 fryings followed by another rapid increase to 19.76 (meq. O_2/kg oil) after 30 fryings. The UV absorption at 232nm increased initially from 0.4 to 1.5 after only 5 fryings and unchanged from the 5th frying to the 20th frying then dropped after 30 fryings. A considerable increase in the TBA value has occurred up to the 20th frying and then the TBA value showed no change for the next 10 fryings. The correlation coefficient between the frying time and TBA value was 0.93.

The rate of polar compounds formation for the first 5 fryings was 3.62 mg/100mg oil/hr. whereas from the 5th frying to the 30th frying such rate was reduced to only 1.12 mg/100mg oil/hr. Sensory evaluation of the oil blend indicated that odour and colour scores were inversely related to the frying time. The most important and accurate mathematical models which express the relationship between the independent and dependant variables were established. The frying time could be successfully and accurately predicted by wise and intelligent chose of dependant variables incorporated in the best fit equations.

Keywords : quality attributes, deep-fat frying, cottonseed oil, sunflower oil, potato chips

INTRODUCTION

Changes that may occur in nutritional value of oils heated to high temperatures in deep-fat frying process are in concern with deep-fat fried foods assuring a place of importance in the diets of many individuals (Bennion, 1967). A premise has been accepted that frying-oil chemistry is incredibly complex and has provided many opportunities for organic and analytical chemists. A measure of the heat abuse taking place in oil and an understanding of the products formed during deep-fat frying are of great interest and importance from the consumer point of view and to the food industry as well (White, 1991). The visible changes taking place in a fat or oil during frying include dark colour, an increase in viscosity, decrease in smoke point and an increase in foaming (Perkins, 1967, Rock & Roth, 1967, Tangel *et al.*, 1977, Gere, 1983). Intermittent heating and cooling of cottonseed oil showed that when oil heated for only 62 hr for several intervals,

it contains as much polar materials as oil heated continuously for 166hr. This is apparently caused by an increase in fatty acyl peroxides as the oil cools and their decomposition upon heating, causing further damage to the fat. This is repeated with each heating and cooling cycles. The presence of water introduced as steam upon frying is greatly accelerated the deterioration of oil (Perkins & Van Akkeren, 1965).

The chemical reactions of oxidation, polymerization, and hydrolysis occur rapidly during deep-fat frying. The extent of these reactions depends on frying conditions, princ-ipally the temperature, duration, and aeration involved. The kind of food being fried also affects the resulting composition of the frying fat. In frying oils, fatty acids are released and their concentration in the cooking fat increases with repeated use (Clark & Serbia, 1991).

Measurement of heat abuse of oils should be based on the changes described.

Many methods of analysis measure the formation of volatile or nonvolatile components or some portions or indicators of change in the fraction. The measurement of volatile decomposition products is very time-consuming and tedious. On the other hand, the nonvolatile decomposition products (NVDPs) remain in the frying fat to promote further degradation and are absorbed by the fried food and thus subsequently eaten by the consumer (Stevenson *et al.*, 1984).

Determination of total polar compounds (PCs) has proven to be accurate, simple, reproducible and one of approved standard methods of IUPAC (1987). A level of 25–27% PCs has been suggested as the limit beyond which a restaurant should discard its frying oil (Paradis & Nawar, 1981a, b).

When polyunsaturated fatty acids (PUFAs) are oxidized, a shift in one of the double bonds occurs, producing conjugated dienes that can be measured by ultraviolet absorption at 232nm. The absorbance increases initially, and then become stable during frying. This has been related to the establishment of equilibrium between the rates of formation of polymers formed by a Diels-Alder reaction involving conjugated dienes (Peled *et al.*, 1975). A large decrease in PUFAs of oils used for frying were reported by Fleischman *et al.* (1963) in comparing with fatty acid composition of the same brand of oil before use.

The methods available for measuring heat abuse in frying oils ranged from simple to complex and vary in their accuracy (White, 1991). Therefore, the present study aims at continuing efforts of researchers to provide more information and shade the light on frying stability and frying performance of cotton seed and sunflower oil blend (1:1w/w) which is used extensively in Egypt. This current research emphasized on the chemical changes occur in this oil blend when used in deep-fat frying of some popular fried products namely potato chips to simulate their processing in Egypt's restaurants. Establishing prediction models for estimating the frying times and/or number of frying from the known dependant variables is also considered.

MATERIALS AND METHODS

Materials :

A vegetable oil blend of cottonseed and sunflower oil (1:1w/w) was obtained from a local processing oil company. The potatoes purchased from the local market having the following composition, moisture 77.48±0.87%, protein 2.18±0.23%, fat 0.41±0.09%, ash 1.13± 0.06% and total carbohydrates 18.80± 1.12%. Potatoes was peeled and sliced into elliptical chips (6cm diameter, 1.20mm thickness) and sub-merged in water until needed. Four thermo-statically controlled Phillips deep-fat fryers with aluminum interior and frying basket were used for the deep-fat frying of potato chips. Exactly 3L oil blend were heated from 26°C to 180°C within 8.5min. and a batch of potato chips weighing 500g was fried for 8.5-9.0min. until the potato chips colour reach to the desired light brown golden colour. The oil blend was subjected to 30 consecutive fryings within 4 days. The batches were fried half-hour intervals for 2.5hr (5 fryings) on the first and 2nd days and then 5hr/day (10 fryings) for two consecutive days. The oil temperature was found to be ranged between 116 to 180°C during frying operations. The oil was not replenished with fresh oil during frying operation, but after each 10 fryings, one fryer was poured to the other fryers to reach the original volume. On the 3rd and 4th day, the oil was allowed to cool after each 5 fryings to 30°C within 3.5hr and then the oil was heated again to 180°C to start a new frying cycle. Table (1) shows the time-temperature relationship during each 5 consecutive fryings. After frying operations, the weight of potato chips was reduced to 24.77±1.35% (average of 50 replicates) from the original weight. Frying experiment at the final stage was conducted in two replicates as the contents of two fryers were emptied to the others.

Analytical methods:

Oil samples were withdrawn after 0, 5, 10, 15, 20 and 30 fryings in duplicate for analysis.

The colour of the oil (20% in chloroform) was measured at 400 and 450nm using a Unicam HEλ-IOSα UV-visible Specrophotometer (model v 2.03) (Hassan, 1980).

Oil viscosity was determined in centipoises at 25°C prior the initial frying and after 5, 10, 15, 20 and 30 fryings as described by Jaslyn, (1950).

The refractive index of each sample was taken concurrent with both colour and viscosity determination using Abbé refractometer with a circulating water bath at 25°C±0.1°C according to AOAC (1995).

Fatty acid composition: The oil blend (cottonseed and sunflower oil) of unused and

used frying oil was analyzed in duplicate for fatty acid composition by the gas chromatographic procedure. After preparation of methyl esters, analysis was performed in a Perkin-Elmer Gas Liquid Chromatograph series 8300 with flame ionization detector equipped with a 2m column (packed with 15% Ov-275, chromosorb W, A/W, 80/100). The chromatographic conditions were as follows: Injection port temperature, 240°C, and column temperature was 100°C for 2min. and increased to 190°C with rate of 7°C/min, then isothermally for 20min at 190°C, the detector temperature was 240°C (Ashour, 1991). Identification of the fatty acids on the chromatogram was made by comparing the retention times of the frying oil methyl esters with those of known mixtures of methyl esters run on the same column under the same conditions. The fatty acid composition was expressed as area perce-ntage of the total area from all methyl esters.

Free fatty acids (FFA's), peroxide value (PV) and polar compounds % (PC's) were determined in triplicate according to AOAC (1995).

Natural conjugated and unconjugated constituents were determined using UV absorption at 232 and 268nm in purified solvent using (using a Unicam HEλ-IOSα UV-visible Specrophotometer model v 2.03) as described by Danopolus & Ninni (1972). Thiobarbituric acid value (TBA) was determined as mg malonaldehyde/kg oil as described by Keeney (1971).

Sensory analysis: The odour intensity of the frying oil was evaluated by trained, experienced 15 member panel after 0, 2.5, 5, 7.5, 10, and 15hr of heating, frying and cooling cycles. Panelists rated the oil odour for overall intensity on a 10-point intensity scale with 10 = excellent oil odour and 0 = strong unacceptable odour. Colour of the frying oil was also evaluated using the same previously mentioned scale with 10 = excellent colour and 0 = dark unacceptable colour (Kramer & Twigg, 1970).

Statistical analysis and mathematical models: The standard error was computed (Larmond, 1970). A correlation test was applied to study the relationship between different components and the frying times and/or

Table 1: Changes in frying temperatures of cottonseed and sunflower oil blend (1:1) during the first five frying of potato chips

Time (min)	Temperature (°C)									
	Frying No (1)		Frying No (2)		Frying No (3)		Frying No (4)		Frying No (5)	
	Pan (1)	Pan (2)	Pan (1)	Pan (2)	Pan (1)	Pan (2)	Pan (1)	Pan (2)	Pan (1)	Pan (2)
0	26	26	147	150	130	134	96	97	140	140
1	45	39	158	164	148	149	104	104	148	149
2	51	51	172	177	156	157	120	122	165	166
3	82	80	180*	180*	176	179	144	142	180*	180*
4	94	94	126	119	180*	180*	162	162	126	124
5	115	115	122	117	122	116	180*	180*	120	125
6	130	127	122	120	129	120	125	125	122	124
7	155	157	131	124	132	126	124	117	126	128
8	180*	180*	134	135	138	133	126	120	138	137
9	130	121	145	144	147	144	132	127	144	148
10	122	114	156	152	155	154	138	136	160	164
11	124	118	168	166	170	170	145	149	174	180**
12	129	124	180**	179**	180**	180**	160	160	180**	182
13	138	133	187	185	190	192	172	178	190	194
14	140	140	190	191	185	187	180**	180**	187	189
15	154	152	184	183	180	178	188	190	184	184
16	166	166	182	185	176	174	185	186	180	181
17	180**	176**	175	179	170	170	180	180	170	170
18	185	186	170	174	166	166	170	169	163	165
20	188	190	160	163	164	164	161	160	166	166
21	180	184	152	154	154	158	155	158	160	161
23	170	174	150	151	145	148	148	148	158	156
25	166	169	142	144	140	142	145	143	150	152
27	158	162	136	141	136	138	140	140	145	145
29	154	153	133	136	130	133	134	132	138	136
30	147	150	130	133	129	130	130	130	133	130

* Temperature at the beginning of frying.

** Temperature at the end of frying.

the number of fryings. Simple and multiple regression analysis were carried out using Excel Program "Windows 2000".

RESULTS AND DISCUSSION

Data in Table (2) reveal that, the oil blend (cottonseed and sunflower oil) became dark after each successive frying. The colour of the oil blend, deteriorated continuously with the elongation of frying times. The correlation coefficient between the frying times (X) and A_{400} (Y) was very high (r= 0.9967). The corresponding value of R^2 (0.9933) indicates that about 99% of changes in A_{400} were attributed to the extension of frying time. The linear regression equation for prediction the frying time of the oil blend was:

$$Y (A_{400}) = 0.244 + 0.0292 X (time/hr)$$

Where: Y is the A_{400} and X is predicted frying time from the same Table.

When the similar time-temperature relationship was observed between the frying times and A_{450}, slight lower correlation coefficient was undertaken as seen in Table (2). However, a positive proportional relationship was found between the frying times (X) and A_{450} (Y) where the r and R^2 values were 0.896 and 0.803, respectively and the obtained equation was:

$$A_{450} = 0.124 + 0.00694X (time/hr)$$

Table (2) also shows the viscosity of the oil blend over the course of 30 fryings. The mean viscosity for the unused oil blend (6 replicates) was 50.64±0.52 centipoise X g /cm³ at 25°C. Oil viscosity increased significantly with extension the frying times as well as frying numbers. Carlin et al. (1954) and Defouw et al. (1981) reported that increment of viscosity was evidence of the

thermal decomposition of frying fat. High correlation coefficient was observed between the frying time and viscosity (r = 0.9269). A level of 70 centipoise of oil blend from cottonseed and sunflower oil could be suggested as the limit (15-20 fryings) beyond which this oil should be discarded as will be discussed.

Refractive index (RI) of the oil blend during repeating of the discontinuous deep-fat fryings of potato chips is gradually increased as shown in Table (1). This increment may be attributed to polymer formation and thermal degradation of the oil (Carlin et al.. 1954, Tyagi & Vasishtha. 1996) during the deep-fat frying process. The correlation coefficient between the frying time and RI was very high (r = 0.9898).

The effects of frying numbers in fatty acid compositon of cottonseed and sunflower oil blend used in deep fat frying of potato chips are shown in Table (3). Although the calcul-ations were carried out by the integrator of the gas chromatogram on the basis of the fractional peak areas, there was an apparent slight increase in saturated fatty acids and a relative decrease in polyenoic acids content of oil blend as frying numbers increased. The percentages of unsaturated fatty acids in the oil blend particularly those for monoenes and dienes were high (76.89%). Lauric $(C_{12:0})$, myristic $(C_{14:0})$, palmetoleic $(C_{16:1})$, linolenic $(C_{18:3})$ and arachidonic $(C_{20:0})$ acids were presented in the oil blend in trace amounts. The slight loss in unsaturated fatty acids $(C_{18:1}$ and $C_{18:2})$ during deep-fat frying of potato chips in the oil blend may be attributed to oxidative polymerization, scission, cyclization and other side reactions that would have taken place

Table 2: Effect of number and time of deep frying on absorptivity (400 and 450nm), viscosity and RI of cottonseed and sunflower oil blend used in processing of potato chips.

No of frying	Frying Time hr (X)	A 400 (Y)±SE	A 450 (Y)±SE	Viscosity (CP) (Y)±SE	Refractive index (RI)
0	0.0	0.225±0.000	0.100±0.010	50.64±0.52	1.4692
5	2.5	0.323±0.032	0.145±0.007	56.60±1.43	1.4695
10	5.0	0.405±0.050	0.170±0.010	64.52±0.84	1.4696
15	7.5	0.467±0.040	0.190±0.014	68.20±0.95	1.4700
20	10.0	0.543±0.040	0.210±0.014	70.54±0.61	1.4701
30	15.0	0.670±0.000	0.205±0.000	72.19±0.43	1.4705
		Y=0.244+0.0292X	Y=0.124+0.00694X	Y=54.1+1 46X	Y=1.47+8.6x10⁻³X
Calculated T (time/hr)		24.49	4.04	4.94	13.87
F		599.64	16.34	24.38	192.41
r		0.9967	0.8963	0.9269	0.9898
R^2		0.9933	0.8034	0.8591	0.9796

Table 3: Fatty acid composition (%) of cottonseed and sunflower oil blend as affected by deep-fat frying of potato chips.

Identified Fatty acids	Control	Frying numbers		
		10	20	30
$C_{12:0}$	0.70	0.44	0.45	0.51
$C_{14:0}$	0.51	0.48	0.01	0.03
$C_{16:0}$	18.89	19.02	19.80	20.00
$C_{16:1}$	0.50	0.55	0.51	0.56
$C_{18:0}$	3.36	3.30	3.35	3.47
$C_{18:1}$	24.27	23.08	23.20	24.02
$C_{18:2}$	52.04	52.90	52.18	51.00
$C_{18:3}$	0.08	0.20	0.31	0.24
$C_{20:0}$	0.28	0.03	0.19	0.17
Total saturated	23.11	23.27	23.80	24.18
Total unsaturated	76.89	76.73	76.20	75.82
Unsaturated/saturated	3.327	3.297	3.20	3.136
Linoleic + linolenic	52.12	53.10	52.49	51.24
Linoleic/palmetic	2.75	2.78	2.635	2.55

Dependant variables	R	R^2	F	Regression equation
Total saturated FA (Y_1)	0.9822	0.9647	54.60	$Y_1 = 23.0 + 0.0374\ X_1$ (7.39)*
Total unsaturated FA (Y_2)	0.9822	0.9647	54.60	$Y_2 = 77.0 - 0.0374\ X_2$ (-739)*
Unsaturated/saturated (Y_3)	0.9820	0.9643	56.89	$Y_3 = 3.34 - 0.00670\ X_3$ (-7.35)*
Linoleic + Linolenic (Y_4)	0.5392	0.2907	0.8198	$Y_4 = 52.7 - 0.0325\ X_4$ (-0.91)*
Linoleic/palmetic (Y_5)	0.9054	0.8198	9.15	$Y_5 = 2.79 - 0.00745\ X_5$ (-3.02)*

* Values under the equations indicate the calculated " t_s ".

during the course of deep-fat frying (Tyagi & Vasishtha, 1996).

The effect of number and time of deep-fat frying on some chemical properties of cotton seed and sunflower oil blend used in deep-fat frying of potato chips is shown in Table (4). Acid value of fresh oil was 0.155 mg KOH/g oil and reached to 0.434 after 15hr of repeating the discontinuous frying. The steady rise in acid value can be attributed partly to both the hydrolysis of tri-glyceride (TG) of oil and to the carboxylic groups present in the formed polar polymeric products during frying (Perkins, 1967, Peled *et al.*, 1975).

The peroxide value of fresh oil blend increased from 3.86 to 11.81 (meq./kg oil) after ten fryings then dropped to 5.23 after 20 fryings followed by another rapid increase to 19.76 (meq./kg oil) after 30 fryings. Increment of peroxide means that the rate of peroxides formation was more than their degradation, and vice versa when decreased. The correlation coefficient between the frying time and peroxide value was relatively low (r = 0.6449) es-

pecially when compared with that of other determined chemical parameters.

Table (4) illustrates the UV absorption of the oil blend during deep-fat frying of potato chips. The UV absorption at 232nm changed initially from 0.4 to 1.5 after only 5 fryings and unchanged from the 5th frying to the 20th frying then dropped after 30 fryings. As seen from Table (4), the correlation coefficient between the frying times and A_{232} was too weak (r = 0.0494). On the other hand, the UV absorption at 268nm was 0.28 for fresh oil blend then reached 1.40 after 20 fryings and dropped suddenly to 0.3 after 30 fryings. This may be attributed to the volatilization of aldehydic and ketonic compounds which have been formed during the early stages of deep-fat frying of potato chips in the oil blend.

Changes in TBA value as oxidation proceeds during deep-fat frying of potato chips are shown in Table (5). During repeating the discontinuous frying of potato chips in the oil blend, a considerable increase in the TBA values has occurred up to the 20th frying and then

Table 4: Acid value, peroxide value and UV absorption of cottonseed and sunflower oil blend as affected by deep-fat frying of potato chips

No of frying	Frying time hr (X)	Acid value (Y) (mg KOH/g oil)	Peroxide value (Y) (mequ/Kg oil)	UV absorption at 232 (Y)	at 268 (Y)
0	0	0.155 ± 0.006	3.86 ± 0.24	0.40 ± 0.08	0.28 ± 0.01
5	2.5	0.228 ± 0.011	9.58 ± 0.05	1.50 ± 0.15	0.68 ± 0.02
10	5.0	0.277 ±0.002	11.81 ± 0.37	1.50 ± 0.00	0.87 ± 0.00
15	7.5	0.271 ±0.002	6.21 ± 0.10	1.50 ± 0.00	0.89 ± 0.00
20	10.0	0.280 ± 0.005	5.23 ± 0.01	1.50 ± 0.00	1.40 ± 0.03
30	15.0	0.434 ± 0.060	19.76 ± 0.18	0.70 ± 0.01	0.30 ± 0.01
		$Y=0.168+0.0160X$	$Y=4.75+0.699X$	$Y=1.15+0.0046X$	$Y=0.656+0.0121X$
Calculated T (time/hr)		5.64	1.69	0.10	0.31
F		31.86	2.85	0.01	0.10
r		0.9426	0.6449	0.0494	0.1549
R^2		0.8884	0.4158	0.0024	0.0240

the TBA value maintained stable for the next 10 fryings (up to 30 fryings). The correlation coefficient between the frying time and TBA value was high ($r = 0.9260$). The prediction equation in Table (5) revealed that the frying time needed about 35hr for the formation of 1 mg malonaldehyde in the oil blend when the same heating, conditions of oil are employed. Data in Table (5) show a dramatic increase of total PC's content from 10.0% in the unused oil to 19.05% when the oil was used for five fryings only. According to Blumenthal (1991), fat or oil must be discarded when its polar fraction is more than 25%.

Results in Table (5) reveal that the levels of PC's% between the 15th to 20th frying ranged between 24.80% to 26.00% which are almost similar or slightly beyond the recommended levels (27%) of oil discarding. From the prediction equation presented in the same Table, it could be anticipated that the formation of 1% PC's needs about 45min of frying. The correlation coefficient between the frying times and

PC's% was relatively high ($r=0.9527$) indicating that PC's determination is one of the most promising and accurate methods of evaluating the quality of frying oils.

Odour and colour scores in Table (5) were inversely related to the frying times. Correlation coefficients between odour and colour scores and frying times were -0.9029 and -0.6381, respectively. There were high standard deviations for sensory estimating of both oil odour and colour. However, the mean panel scores for oil colour were significantly higher than those for odour evaluations throughout the course of frying. It is found from the prediction equations give in Table (5), that the frying times could be accurately estimated by using odour scores (X_1) as a dependant variable, whereas colour scores did show less accuracy. The frying time (X) of the used oil blend could be predicted more accurately when both dependant variables $(Y_1$ and $Y_2)$ are introduced in a multiple regression equation. From this equation, the calculated frying

Table 5: Thiobarbituric acid, polar compounds, odour and colour scores of cottonseed and sunflower oil blend as affected by deep-fat frying of potato chips

No of frying	Frying time hr (X)	TBA (Y) (mg alonaldehyde/Kg oil)	Polar compounde (Y) (%)	Odour score (Y)	Colour score (Y)
0	0	0.533 ± 0.004	10.00 ± 0.41	8.17 ± 1.47	8.67 ± 1.51
5	2.5	0.549 ± 0.001	19.05 ± 0.90	6.83 ± 1.17	7.33 ± 1.86
10	5.0	0.574 ± 0.020	23.00 ± 1.34	6.83 ± 1.47	7.33 ± 1.51
15	7.5	0.730 ± 0.070	24.80 ± 0.21	7.00 ± 1.10	7.67 ± 1.75
20	10.0	0.820 ± 0.009	26.00 ± 0.60	6.17 ± 1.17	6.00 ± 0.89
30	15.0	0.820 ± 0.002	33.00 ± 1.44	5.67 ± 1.21	7.17 ± 1.17
		$Y=0.517+0.0232X$	$Y=13.592+1.36X$	$Y=7.72 - 0.142X$	$Y=8.02 - 0.0989X$
Calculated T (time/hr)		4.91	6.27	-4.2	-1.66
F		24.07	39.29	17.65	2.75
r		0.9260	0.9527	-0.9029	-0.6381
R^2		0.8575	0.9076	0.8152	0.4072

time is estimated to be 15.07 hr (30 fryings) when the oil blend should be rejected organolepticaly.

Multiple regression equations were established to evaluate the amount of heat which the oil blend has been exposed during repeating the discontinuous frying of potato chips. Table (6) presents the most important mathematical models which express the relation-ship between the independent variable (X) and dependant variables (Y_1, Y_2, ..., Y_8). The multiple regression equation number "1" in Table (6) shows the relationship between the frying time (independent variable.) and three dependant variables ($Y_1 = A_{400}$, $Y_2 = A_{450}$ and $Y_3 = $ TBA value).The correlation coefficient between the frying time and these three variables was 0.9999. In Table (6) the predicted frying times are compared with the corresponding real values. From these comparisons, it is appeared that the predicted values are almost similar to the real ones. On the other hand, the dependant variables introduced in equation 2 (Table 6) are A_{400} (Y_1), acid value (Y_5) and peroxide value (Y_7). The correlation coefficient between these variables and the frying time (X) was 0.9998. The partial correlations between the frying times and the aforementioned variables were far below the correla-

tion coefficient between the independent and the dependant variables included in the equations presented in Table (6).

In conclusion, the frying time or in other words the amount of heat received in 1:1 w/w cottonseed and sunflower oil blend during repeating the discontinuous frying of potato chips could be successfully and accurately predicted by wise and intelligent chose of dependant variables incorporated in the suitable equations.

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Table 6: The best mathematical models employed for accurate evaluation of frying times of potato chips in cottonseed and sunflower oil blend (1:1) during repeating the discontinuous frying operations

No	Best mathematical models	(r)	(R²)	(F)	True (X) (hr)	Calculated (X) (hr)
1	X = - 7.79 + 37.7 Y1 - 27.6 Y2 + 3.90 Y3 (49.07) (-11.29) (5.31)	0.9999	0.9999	6911.23	10.00	10.00
2	X = - 8.97 + 26.9 Y1+17.7 Y5 - 0.105 Y7 (1.05) (0.27) (-0.23)	0.9998	0.9995	106.16	10.00	10.02
3	X = -7.75 +43.5 Y1 -0.230 Y4 +0.0547 Y7 (11.89) (-2.84) (1.64)	0.9994	0.9989	519.65	7.50	7.46
4	X = -16.1 +20.8 Y3 +31.4 Y5 + 0.022 Y7 (4.06) (2.25) (0.15)	0.9994	0.9987	636.16	10.00	10.03
5	X = -18.1 +13.0 Y2 +28.7 Y3 + 0.347 Y7 (1.47) (11.00) (11.34)	0.9991	0.9982	374.11	10.00	9.98
6	X = -17.4 +28.6 Y3 +0.0891 Y4 + 0.306 Y7 (9.27) (1.24) (5.54)	0.9990	0.9979	318.56	5.00	5.03
7	X = - 14. 4 + 17.4 Y3 + 0.415 Y4 (2.26) (3.09)	0.9828	0.9659	42.46	5.00	5.08
8	X = - 7.91 + 42. 2 Y1 - 0.175 Y4 (9.44) (- 1.90)	0.9985	0.9970	496.73	2.50	2.50

X   = Time of frying (hr).
$Y_1 = A_{400}$ $Y_2 = A_{450}$ $Y_3 = $ TBA $Y_4 = $ PC (%)
$Y_5 = $ Acid value $Y_7 = $ Pv. $Y_8 = $ Refractive index $Y_9 = $ Viscosity

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تقدير خصائص الجودة وعدد مرات القلى لخليط من زيت بذرة القطن وزيت عباد الشمس أثناء عمليات القلى العميق لرقائق البطاطس

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تم تقدير التغيرات الكيميائية والطبيعية والحسية لعينات من الزيت المستخدم في قلي رقائق البطاطس بطريقة القلي العميق. وكان الهدف من البحث ربط هذه التغيرات الكيميائية بعدد مرات القلي المثلى واستنتاج معادلات رياضية للتنبؤ بوقت التحمير. وقد ثبت أن لون الزيت يصبح أغمق بعد كل تكرار لعملية القلي. واظهر تقدير معامل الارتباط ارتباطا قوياً (٠.٩٩٦٧) بين عدد مرات القلي ولون الزيت عند طول موجي ٤٠٠ نانوميتر. ووجد نفس الاتجاه في العلاقة بين عدد مرات القلي وقياس اللون عند طول موجي ٤٥٠ نانوميتر. كما أشارت النتائج إلى زيادة لزوجة الزيت بزيادة عدد مرات القلي وكان معامل ارتباط إيجابي قوي (٠.٩٨٩٨) بين عدد مرات القلي ومعامل الانكسار. وكان هناك فقد بسيط مستمر في الأحماض الدهنية غير المشبعة في خليط الزيت أثناء عمليات القلي العميق لرقائق البطاطس.

وارتفعت قيمة البيروكسيد (مللي مكافئ أكسجين/ كجم زيت) من ٣.٨٦ إلى ١١.٨١ بعد ١٠ مرات من تكرار القلي ثم حدث انخفاض إلى ٥.٢٣ بعد تكرار عملية القلي ٢٠ مرة تبعها زيادة سريعة إلى ١٩.٧٦ مللي مكافئ أكسجين/كجم زيت بعد ٣٠ مرة. هذا وقد ارتفع الامتصاص في منطقة الأشعة فوق البنفسجية على طول موجي ٢٣٢ نانوميتر من ٠.٤ إلى ١.٥ بعد خمس مرات من القلي العميق ثم كان هناك ثباتاً حتى تكرار القلي العميق من ٥ مرات إلى ٢٠ مرة ثم انخفض بعد ٣٠ مرة قلي. وصاحب ذلك زيادة كبيرة في قيمة حمض الثيوباربتيوريك. وقد حدثت هذه الزيادة بعد تكرار القلي ٢٠ مرة ثم ثبات لمستوى الحمض فى مرات القلي العشر التالية.

وكانت نتيجة معامل الارتباط هي ٠.٩٣ بين عدد مرات القلي وقيمة حمض الثيوباربتيوريك. وكان معدل تكون المركبات القطبية في المرات الخمس الأولى من القلي هو ٣.٦٢ مللجم/١٠٠ مللجم زيت/الساعة. وانخفض إلى ١.١٢ مللجم /١٠٠ مللجم زيت/ الساعة من ٥ إلى ٣٠ مرة قلي. وأفاد التقييم الحسي لعينة الزيت المخلوط والمستخدم على فترات لقلي رقائق البطاطس أن هناك تناسباً عكسياً بالنسبة بين نتائج الرائحة واللون وتكرار استخدام الزيت في القلي. وتم استخدام المعادلات الرياضية لتوضيح العلاقة بين المتغير المستقل والمتغيرات التابعة للزيت.

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