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Effect of Steam Blanketing Method on the Stability of Oil during Deep Fat Frying on a Modified Fryer

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ABSTRACT

Recent consumer trends towards healthier and low fat products have a significant impact on the deep fat frying industry. The objective of this study was to design a modified deep fat fryer (MDF) to have a smaller surface area relative to height, with made a steam blanketing over the fryer. Different levels of water injection flow rates were studied (0.0, 0.1, 0.2 and 0.3 ml/20 min per 1 liter), compared with conventional deep fryers (CDF). Frying was conducted at 170°C into sunflower oil using CDF ($H\sqrt{A}$ = 0.24) and MDF ($H\sqrt{A}$ = 0.8) in batch 8 min. batch every eight an hour hrs for up to 40 hrs. The modification was intended to reduce oil deterioration. Water injection had a dual effect. In comparison with CDF, water injection increased the acid value from 0.34 to 0.97 (mg KOH/g of oil), after 40 hrs at 170± 10°C, and a contrarily protective role was found in all the other quality indices. Significant reductions in TBA value (from 8.9 to 4.81malonaldehyd/Kg of oil), *P*- anisidine value (from 35.6 to 12.9alkenal/Kg of oil), TPC content (from 34.5 to 18.64), conjugated diene (CDs) (from 8 to 5.59) and conjugated triene (CTs) (from 1.9 to 1.33) were measured in sunflower oil. These quality indices of oil deterioration decreased dramatically in the first level of water injection flow rate. Consequently, the first level of water injection had the highest ($P \geq 0.05$) inhibitory effect from the other levels of water injection. Fatty acid composition of fried oil properties during CDF and MDF designs were determined. There were a significant difference ($P \geq 0.05$) between the fried oil properties during using of CDF and MDF designs. Total unsaturated fatty acid at MDF design gave the highest values. Also, organoleptic evaluation of fried potato chips by CDF and MDF were evaluated by panelists. Fried potato chips during the first level of water injection flow rate had the highest ($P \geq 0.05$) flavor (4), crisp (4.5), greasiness (4.6), and overall acceptability (4.8), compared with fried potato chips during the other levels of water injection flow rates. Findings suggest that determination of the oil quality indices are good makers of sensory evaluation during deep fat frying. Also, results suggest that during deep fat frying by MDF design may reduce the thermal deterioration of sunflower oil. Water injection can be applied as a simple method to improve oil quality during deep fat frying.

Key word: Modified fryer, Acid value, P-anisidine, Thiobarbituric acid, Polar compounds, Ultra violet absorbance, Sensory evaluation, Water injection flow rate.

Introduction

Frying is a fast and convenient technique widely used either in home or in restaurants. The popularity of frying is related to the unique sensory properties of fried food. The quality of oils and fats during the frying process has a major influence on quality of final product. (Andrikopoulos, *et al*., 2003 ; Suxuan and William, 2012).

Unfortunately, the aforementioned beneficial effects of frying are accompanied by undesirable alteration of the frying medium. Thermal treatment of the frying oils results in oxidative and hydrolytic reactions; chemical and physical changes take place leading to the formation of undesirable secondary products (Seppanen and Csallany, 2002; Sammak, 2013).

During intermeeting deep fat frying, hydrolysis, oxidation and polymerization reaction cause a spectrum of physical and chemical changes, leading to the formation of decomposition products posing a direct impact damaging both the oil quality and the frying food nutritional value (Dana *et al*., 2003)

Several studies indicated that products generated through oil oxidation can mutagenic and cartinogenic (Abd El-Tawab and El-Naggar, 2012). Due to public health concens, there is a strong demand to reduce the oil deterioration during deep fat frying.

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Thermally abused fats and oils are usually discarded because accumulation of oxidation products from fats and oils will not only reduce the sensory quality of fried foods but may also diminish their nutrition value (Martin and Ames, 2001, Sammak, 2013 and Shaker, 2014)

Generally, 30 % of used oils with batch process was discarded per week in a commercial frying operation. It is very important to minimize the waste oils generated during deep fat frying the point of the cost for disposal of the waste oil and effective utilization of oils. (Rimac -Brncic *et al*., 2004)

Fujisaki, *et al*., (2002), designed a deep fat fryer with low oxygen atmosphere (2% O_2) using N_2 and then fried frozen chicken with vegetable oil. They reported that the increase in acid value, carbonyl values and the production of polymerized materials, and the decrease in tocopherols were related during frying. However, an N_2 bomb is necessary for this system. Susinggih *et al*. (2000) designed a deep fat fryer under different vacuum levels the fried pineapple with vegetable oil. They found that the best frying temperature and vacuum pressure which were needed to produce pineapple crispy chips using simple vacuum fryer were 90°C and 700 mm Hg. The vacuum deep fat fryer was developed to reduce the thermal oxidation of fat and oils (Garayo and Moreira, 2002; Negishi *et al*., 2003; Fan, *et al*., 2005; Dueik, *et al*., 2010; Basuny *et al*., 2012; Ahmad *et al*., 2013 ; Diamante *et al*., 2015).

Water injection had a dual effect. Water spray over corn and canola oils at various flow rate increase the AV, and a contrarily protective rule was found in all the other quality indices-head space air flow, or direct nitrogen injection were significant factors affecting oil quality (Dana *et al*., 2003). Based on this findings, it was hypothesized that high rates of water evaporation create an inert "steamblanket" which could provide a physical barrier between the (oxygen) and the oil, similar to the protection achieved under vacuum technique (Fujisaki, *et al*., 2002)

The oil surfaces are designed to be large to enhance the production capacity in conventional fryers. However, the large oil surface increases the likelihood of thermal oxidation. When we measured the surface area (A) and height (H) of the oil bath of the conventional fryers, the $H/\sqrt{A}$ ratio was below 0.6 (Negishi *et al*., 2003 ; Diamante *et al*., 2015).

Hence, we need to improve oil stability and prevent deterioration with a new design that minimize the effect of oxygen, are required. We designed a modified deep fat fryer MDF to have a smaller surface area relative to height, which the $H/\sqrt{A}$ of the oil bath was 0.8, then made steam blanketing over the oil under three different levels of water injection flow rates, compared with conventional fryers (CDF). We evaluated a deep-fried potato chips by using the MDF and CDF, and then determined chemical characteristics and sensory evaluation during deep fat frying.

Materials and Methods

1- Materials:

Sunflower oil:

The refined sunflower oil was obtained from Sohag oil and Soap Company, Sohag, Egypt.

Potato tubers:

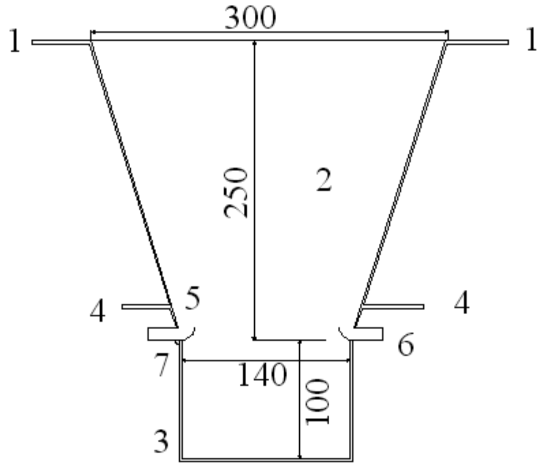
Potato (*Solamum tuberosum*) tubers, were purchased from the local market of Assuit. They were cleaned, sorted, manually peeled using a sharp knife and then sliced to a thickness of 1.2-1.3 mm with a mechanical slicer, the slices were washed with tap water, immersed in 2% salt solution for 5 min. and then washed again with tap water and left for 10 min. to drain of excess water before they fried as reported by Abd-ElGhany, (2010).

Reagents:

All chemical and reagents used in the analytical methods (analytical grade) were produced by Sigma chemical Co. (St. Louis, Mo, U.S.A) and obtained from El-Gamhouria Trading Chemicals and Drugs Co., Egypt.

Modified fryer (MDF):

It was consisted of bath and steam blanket as shown in Fig. (1). The bath was fabricated from stainless steel. It was 140 mm diameter, 100 mm height and 2 mm thickness. A steam blanket was also fabricated from stainless steel and hinged with bath. It was like a cone and trapezoid cross section. The down base was 140 mm, upper base was 300 mm and 250 mm height. The steam blanket had dual walls to through water tap from up to down as condensation operation of water vapor inhalation contained volatile compounds, which was collected by trap out MDF. The H/√A of the oil bath was 0.8. The steam blanket partially removed in two cases a- Put oil, water injection and potato chips. b- Take out the potato chips after frying. Water was injected by a nozzle to reduce the size of water droplets.



Scale in mm

1- Water tap in 2- Steam blanket 3-Bath 4- Water tap out 5- Trap
6- Water vapor inhalation contained volatile compounds out 7- Hinge

Fig. 1: Modified deep fat fryer (MDF)

Conventional fryer (CDF):

The bath was fabricated from stainless steel. It was 280 mm diameter, 60 mm height and 2 mm thickness. The H/√A of the oil bath was 0.241

2- Methods:

Frying process:

1.5kgs (for each treatment) of sunflower oil were used in the MDF, under different level of water injection flow rates (0, 0.1, 0.2 and 0.3 ml/20 min. per 1 liter) and three Kgs in CDF, at 170 ±10°C for 8 min. with a constant product weight/oil volume ratio of 1:6, for up to 40hrs (Garayo and Moreira, 2002). Potato chips were used for frying in batches every eight hours (8 min./batch), after each frying the oil level was checked and replenished. At 4 an hours intervals during frying, about 20 milliliters of heated oil was withdrawed and kept in brown bottles in freezer at -18°C until used.

All fried samples were allowed to cool at room temperature and sensory evaluated. All experiments were run in triplicate and the present results are the average of the obtained results.

Analytical methods:

Acid value (as mg KOH/g of oil) was determined by the method of IUPAC, (1987). *P*-anisidine value (alkenal/kg of oil) was determined by using the method of AOCS, (1992). Thiobarbituric acid (TBA) value (malonaldehyde/Kg of oil) was determined by using the method of Keeney, (1971). The polar compounds content (TPC %) was determined using chromatographic glass column method as described by Takeoka *et al*., (1997). The ultra violet absorbance at 233 nm conjugated diene (CDs) and 268 nm conjugated triene (CTs) of oil samples were measured using (UV-visible spectrophotometer) as described by Danopolus and Ninni, (1972).

Organoleptic evaluation:

A tested panel of 10 students from the food Science and Technology Department, faculty of agriculture, Al-Azhar University, Branch Assiut were asked to evaluate the effect of either conventional or modified deep fat frying on the fried potato for flavor, crisp, greasiness and overall acceptability using a scale from 1-5 points for each character (5) very good, (4) good, (3) fair, (2) poor and (1) very poor. This method was conducted according to the method of (El-Naggar, 2007).

Data analysis:

Experimental data were analyzed by analysis of variance (ANOVA). The results were subjected to standard deviation and significance was tested by students (t) test. Differences between samples at the 5% ($P \geq 0.05$) level were considered significant (Statistical Graphics Crop., 1998).

Results and Discussion

During frying, a variety of reactions cause a spectrum of physical and chemical changes occur due to hydrolysis, oxidation and thermal decomposition. Fats and oils are oxidized to from hydroperoxides, the primary oxidation products and secondary oxidation products. These peroxides as extremely unstable and decompose via fission, to form as variety of chemical products such as alcohols, aldehydes, ketones, dimmers, trimmers, polymer and cyclic compounds (Basuny *et al*., 2012)

Hence, we need to improve oil stability and prevent deterioration with the design that minimize the effect of oxygen, are required. We designed the MDF (steam blanketing) in which the H√A of the oil bath was 0.8 to minimize the generation of waste oil by reducing thermal oxidation deterioration of oils. The structure of MDF (higher H√A) contributed to the smaller oil surface. Therefore, new design that reduce oxidation and thermal decomposition.

Figure (2) shows the evaluation of acid value of fried oil properties during CDF and MDF. The differences in CDF and MDF at various water injection flow rates (0, 0.1, 0.2 and 0.3 ml/20 min. per 1 liter) were studied. Water injection had a dual effect on oil quality. In comparison with CDF, acid value of 0.25 % for sunflower oil but increasing the water injection flow rate from 0.1 to 0.3 ml/20 min. per 1 liter after 40 hrs at 170°c accelerated, as expected, the hydrolytic reactions giving rise to the formation of free fatty acids and increased acid values (0.97 % for first water injection flow rate), (1.04 % for second level), (1.08 % for the third level) and (0.3% for without water injection treatment) against 0.34% for CDF. Consequently, spraying of the frying oil with water remarkably increased the acid values throughout the whole experiment period. The relatively higher values for acid value than control samples could be attributed to rate of hydrolysis reactions. A water spray injection rate of 0.3 ml /20 min. per 1 liter over sunflower oil led to an acid value of 1.08 % after 40 hrs at 170°C, while in oil kept under the same conditions and without water spray, the values was 0.3 %. The increase in acid values due to large water injection. The results obtained were nearly similar with those obtained by Basuny *et al*., (2012).

The role of water spray and oil quality during frying were evaluated. The water released during frying enhances heat transfer, may cause oil deterioration, and on the other hand also can prevent oxidation reaction (Saguy and Dana, (2003) and Dana *et al*., (2003).

It is worthy to mention that a linear with a significantly correlation between frying time and acid value. The correlation coefficient of the third level of water injection flow rate was the lowest (r^2 = 0.684) followed by the first and second levels of water injection flow rate (0.758) while in oil kept under the same conditions and no water spray injection (r^2= 0.958) against (r^2= 0.995) for CDF design.

An opposite trend was observed in most parameters of deterioration. It could be observed that, the changes in *P*-anisidine values in sunflower oil during prolonged frying with CDF and MDF as shown in Fig. (3). In comparison with the control, *P*-anisidine value of 5.3, increasing the water injection flow rate from 0.1 to 0.3 ml/20 min. per 1 liter decreased *P*-anisidine values. The *P*-anisidine values were markedly lower due to water injection in sunflower oil. The P-anisidine values decreased from 23.45 to 12.9 when the water injection flow rate was 0.1 ml/20 min. per 1 liter. The *P*-anisidine values for CDF oil was much higher 35.6 for sunflower oil. Nevertheless, had significantly ($P \geq 0.05$) changes were observed in *P*-anisidine value cited above between all levels of water injection flow rate throughout the 40 hrs at 170°C of deep fat frying. Whereas, *P*-anisidine value decreased dramatically in the first level of water injection flow rate (12.9) when the water flow rate was decreased. Hence, the first level of water injection flow rate had the highest ($P \geq 0.05$) inhibitory effect on *P*-anisidine value in sunflower oil.

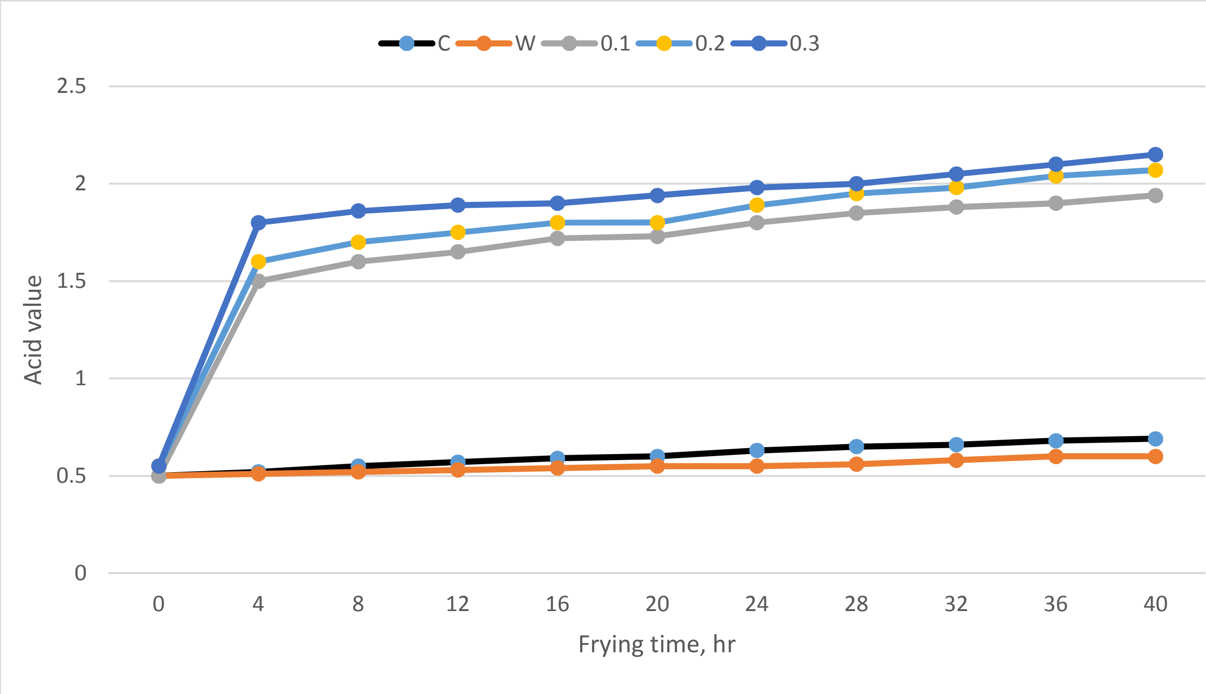


Fig. 2: Effect of injecting water to sunflower oil during prolonged frying of potato chips at 170º c for 40 hrs on acid value

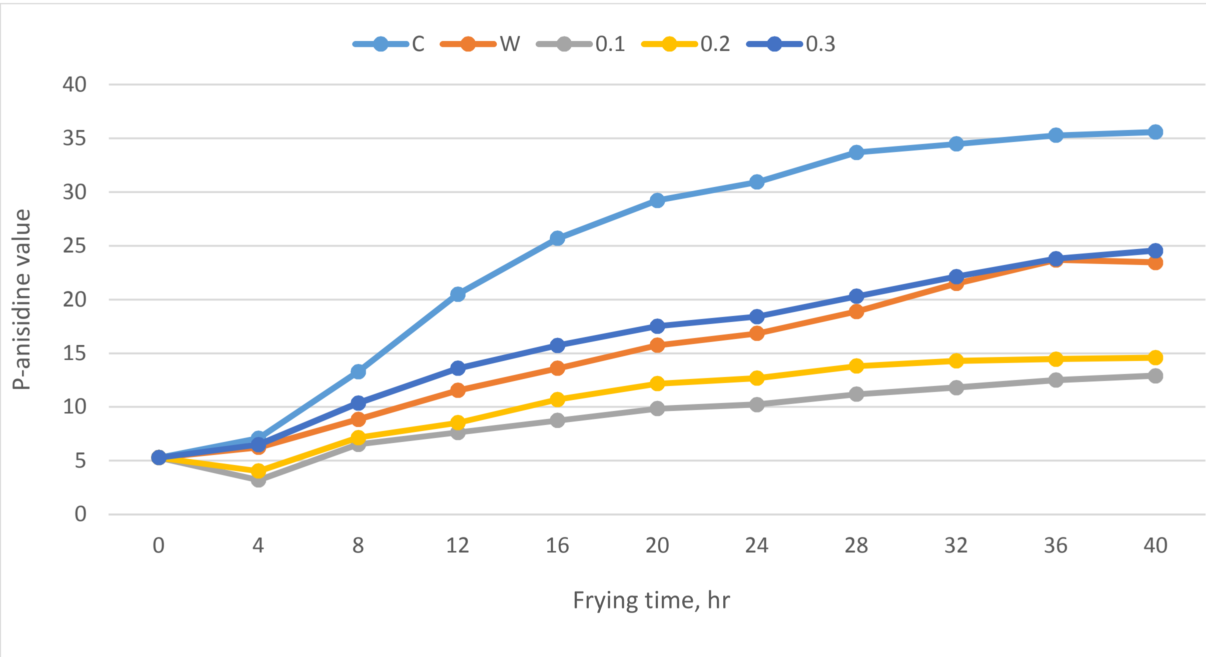


Fig. 3: Effect of injecting water to sunflower oil during prolonged frying of potato chips at 170° c for 40 hrs on P-anisidine value

These reduction effect may be due to generating a steam (blanket) over the oil and preventing contact between air and oil. It can also play a role as a physical agent for ((steaming out)) the volatile oxidative products from the oil and enhancing their evaporation (Rimac-Brncic, *et al*., 2004 and Shaker, 2014). This protective effect was observed previously during the frying of corn and canola oil saturated with water, P-anisidine value decreased from 77 and 97 to 39 and 67 mmol/kg respectively, when the water flow rate increased from 0.1 to 1 ml/min. after frying for 20 hrs (Dana *et al*., 2003).This protective role of water could be due to the large steam bubbles released from the oil. These results are coincident with those reported by (Saguy and Dana, 2003 and Dana *et al*., 2003).

It is interesting to notice that a linear increasing with a significantly correlation between frying time and P-anisidine value. The positive correlation coefficient between frying time and P-anisidine value was very high (r^2= 0.994). Therefore, the linear regression equation for prediction the P-anisidine value of sunflower oil was:

Y (*P*-anisidine value) = 5.225 + 0.492X (frying time)

Meanwhile, it could be observed a weak correlation coefficient between *P*-anisidine value and acid value (r= 0.682).

The measure of *P*-anisidine value is useful to correlate total polar compounds (TPC), which is a laborious and expensive method. To examine the relationship between *P*-anisidine value (Rapid and simpler measurements of oxidation, we plotted the data obtained during frying experiments at 170°C for 40 hrs, *P*-anisidine value has a linear relationship with TPC. The respective correlation coefficient were (r^2= 0.979). The linear regression equation for prediction the TPC of oil was:

Y (TPC) = -2.635 + 1.3858X (*P*-anisidine value)

Thereafter, the results suggest that determination of *P*-anisidine value is good marker of TPC in deep fat frying.

With regards to the influence of TPC as abasis for the assessment of the end point of frying we chose 25 – 27 % TPC which is the regulatory limit in many European contries (Dueik *et al*., 2010 and Ahmad *et al* ., 2013).

It is obvious from Fig. (4) that, the water injection appreciably TPC concentration in MDF design in comparison with the CDF design, a water spry rate of 0.1 ml / 20 min per 1 liter over sunflower oil let to a TPC of 18.64 % after 40 hrs at 170° C, while in oil kept under the same condition and no water spray, the TPC was 22.74 %. TPC value decreased ($p \geq 0.05$) dramatically in the first level of water injection flow rate (18.64 %) as the rate of water injection decreased. Meanwhile, TPC content formed in sunflower oil significantly increased with prolonging frying time. The obtained data in Fig. (4) also showed that , caused in general , a highly inhibition of TPC content at a variable rates depend upon frying time and water injection flow rate . This findings are in agreement with those Negishi *et al*., (2003) who reported that the thermal oxidation that produced TPC during deep fat frying at fryer the ratio between height (H) and surface area (A) was 0. 93, could be retarded due to small surface of oil in contact with air.

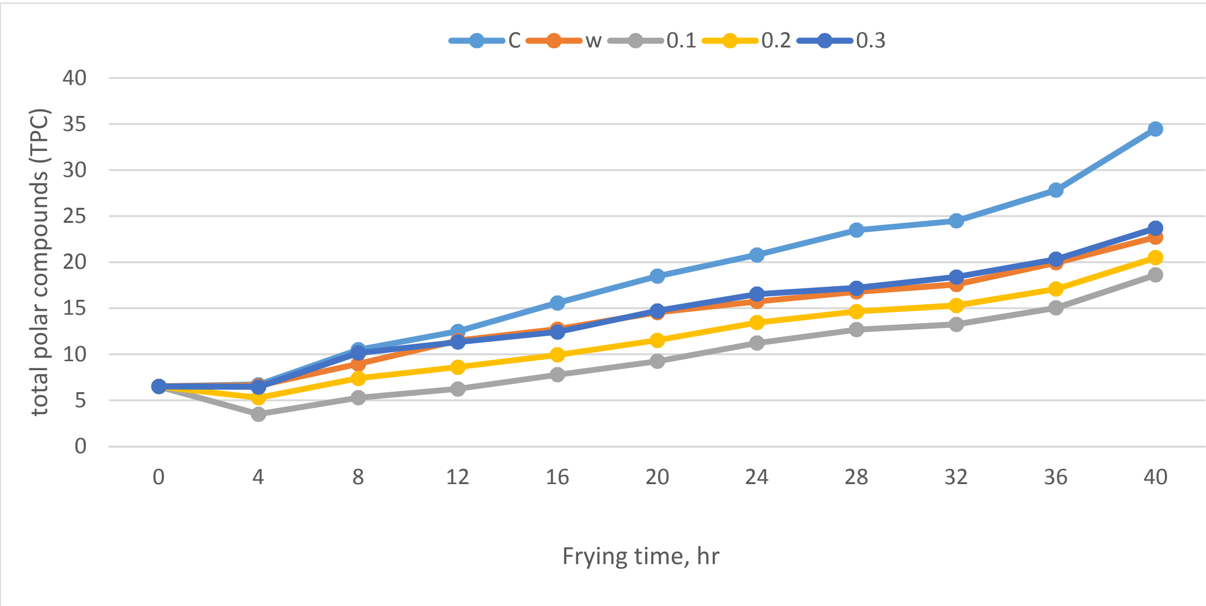


Fig. 4: Effect of injecting water to sunflower oil during prolonged frying of potato chips at 170° c for 40 hrs on total polar compounds (TPC)

These results demonstrated that MDF was able to retard oxidation during deep fat frying .Hence, the inclusion of TPC value as a criterion for oil quality should be considered for monitoring changes in frying oils.

It is worthy to mention that TPC content increased linearly with prolonged time during deep fat frying of oil at 170°C. The correlation coefficient between the frying time and TPC was (r = 0.955), and the linear regression equation for prediction TPC value was :

Y (TPC) = 3.27 + 0.3342 X (frying time).

The above mentioned results are in harmony with those obtained by (Suxuan and Willium, 2012).

With respect to thiobarbituric acid (TBA) value, which is considered a good chemical quality measure to identify the oxidation state of oil to measure the secondary oxidation .TBA test is a condensation reaction between the TBA and malonaldehyde (EL- Naggar, 2007).

As shown in Fig. (5) Water injection appreciably reduced TBA value in MDF method in comparison with CDF method. TBA value decreased from 8.9 to 4.81 when water flow rate was 0.1 ml / 20 mi per 1 liter . A water spray rate of 0.1 ml / 20 min over sunflower oil led to a TBA value of 4 . 81 after 40 hrs at 170°C , while in oil kept under the same conditions and no water sprayinjection , the TBA value was 7 . TBA value was considerably higher in CDF design, probably due to the higher surface area as compared with MDF design.

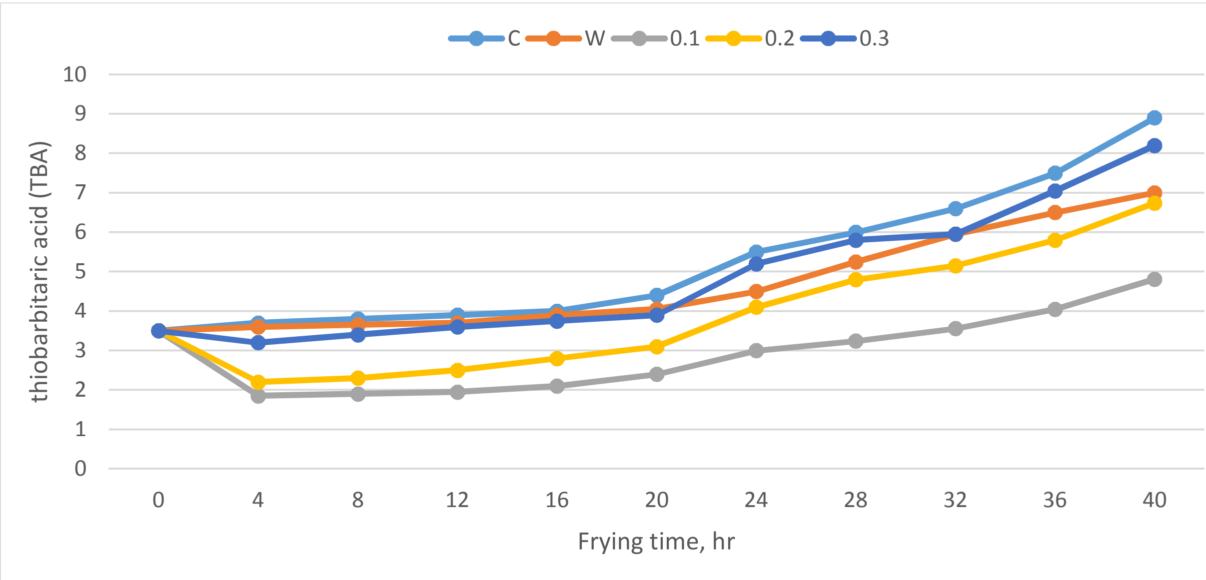


Fig. 5: Effect of injecting water to sunflower oil during prolonged frying of potato chips at 170° c for 40 hrs on thiobarbitaric acid (TBA)

Generally, first level of water injection flow rate had significantly ($p \geq 0.05$) lower TBA value (4.81) compared with the second level of water injection flow rate (6. 74) and / or third level of water injection flow rate . These findings are in harmony with those obtained by (Dana *et al* ., 2003).

Interestingly, TBA value increased linearly with a significantly correlation between frying time and TBA value. The positive correlation coefficient between TBA values and frying time were high (r = 0.939). Thereafter, the linear regression equation for prediction the TBA values of oil was:

Y (TBA) = 2.4864 + 0.1191 X (frying time).

On the other side, the correlation coefficient between TBA value and TPC content was (r = 0.937). Consequently, the linear regression equation for prediction the TPC content of oil was:

Y (PC) = 0.3740 + 2.935 X (TBA value)

Thus, consequently the results suggest that determination of TBA test is also good marker of TPC content in deep fat frying.The aforementioned findings of TBA test are in line with those obtained by Shaker, (2014). Concerning the changes in ultra-violet absorption. The absorbance values reflect the presence of conjugated double bonds in the structure of oil molecule. These bonds are probably result of the formation of peroxides and other by products of oil oxidation. When unsaturated fatty acids are oxidized, to form hydroperoxides, the double bonds in the oils become conjugated, conjugated diene (CDs) may result from decomposition and absorption bond at about 232nm which measures the degree of the primary oxidation products, while absorption bond at about 268 nm measures the secondary oxidation products formed from the initial compounds detected at 232 nm. Both of conjugated diene (CDs) and conjugated trien (CTs) have been used as a good successful index for detecting the formation degree of conjugated fatty acids diens (CDs) and conjugated fatty acids trienes (CTs), respectively and they have been used to assess the changes during deep fat frying (Tompkins and Perkins, 1999, El-Naggar, 2007 and Ahmad *et al*., 2013). As shown in Fig. (6).

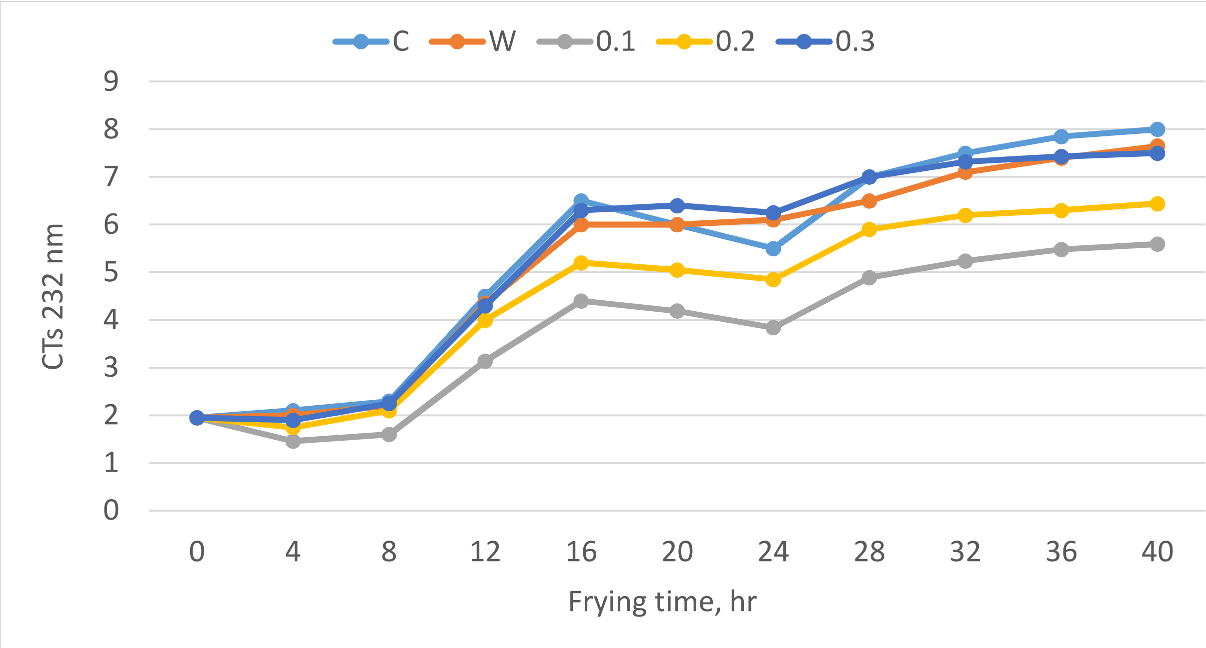


Fig. 6: Effect of injecting water to sunflower oil during prolonged frying of potato chips at 170° c for 40 hrs on K 232 nm

Data given in Fig. (6), indicated that the water injection flow rate reduced CDs concentrations. A flow rate of 0.1 ml/20 min. reduced the CDs from 8 to 5.59. Increasing the water flow rate to 0.3 ml/20 min. was not effective in reducing the CDs in sunflower oil after 40 hrs at 170°C of frying compared with the 0.1 ml/20 min. water injection flow rate. These results are in agreement with a similar decrease in CDs due water dispersion in corn and canola oil after frying for 20 hrs at 180°C (Dana *et al*., 2003). The same trend was observed in CTs. As shown in figures (6) and (7) indicated that the CDF design samples contained a higher absorbance values at 232 nm (8) and at 268 nm (1.9) of oil than MDF design treatments. Meanwhile, absorbance values at 232 and 268 nm decreased ($P \geq 0.05$) dramatically in the first level of water injection flow rate (5.59) and (1.33) in oils respectively as the rate of water injection decreased.

Hence, the first level of water injection flow rate had the highest ($P \geq 0.05$) inhibitory effect on absorbance values at 232 and 268 nm in oil compared to another water injection flow rates and CDF design samples. The reduction effect of the first level of water injection flow rate on absorbance values at 232 and 268 nm in oils may be owing to generating a steam ((blanket)) over the oil and preventing contact between oxygen and oil, caused small surface area of the modified stainless steel vessel. Similar results are very close to those reported by (Dana *et al*., 2003).

It is interesting to notice that the positive correlation coefficient between both CDs, CTs and TPC contents and both of CDs ($r = 0.937$) and CTs ($r = 0.908$). The linear regression equation for prediction the TPC contents of oils were:

Y (TPC) = 0.961 + 2.4X (CDs) and

Y (TPC) = -12.5654 + 20.069X (CTs)

Thereafter, the data suggest that determination either CDs or CTs is also good marker of TPC content in deep fat frying.

Table (1) shows the evaluation of fatty acid composition of fried oil properties during CDF and MDF designs. There were significant difference ($P \geq 0.05$) between the fried oil properties during CDF and MDF design samples. Total unsaturated fatty acids at MDF gave the highest values. Meanwhile, total unsaturated fatty acid values increased in the first and second levels of water injection (71.14) against (67.81) for MDF design without water injection and (65.7) for CDF design after 40 hrs at 170°C. Linoleic and palmitic acids are usually used as indicators of the extent of oil deterioration, because linoleic acid is more susceptible to oxidation, whereas, palmitic acid is more stable toward oxidation. Consequently, the ratio of C18:2/C16:0 was used to indicate the degree of oxidation deterioration of frying oil. The ratio of C18:2/C16:0 was reduced during CDF and /or MDF while, first level of water injection flow rate contained the highest value of these ratio (1.82) followed by the second level of water injectionflow rate (1.73) and then the third level of water injectionflow rate (1.55) compared with (1.33) for MDFdesign without water injection flow rate and/or (1.07) for CDF after 40 hrs at 170°C.

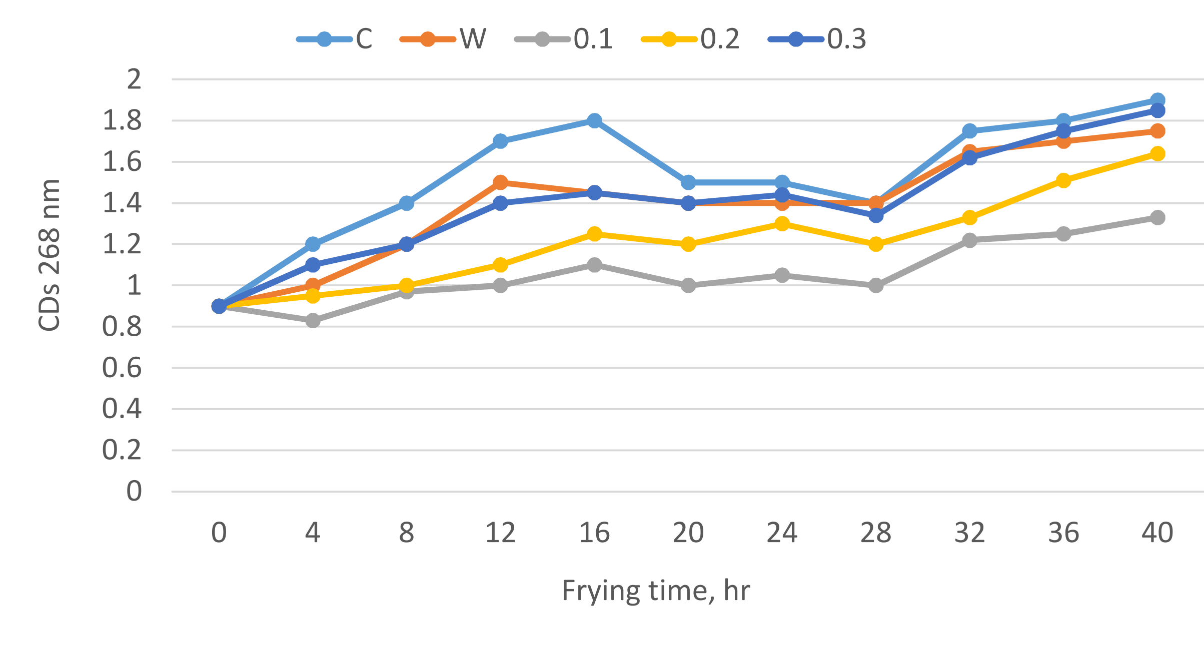


Fig. 7: Effect of injecting water to sunflower oil during prolonged frying of potato chips at 170° c for 40 hrs on K 268 nm

Table 1: Effect of injecting water to sunflower seed oil after deep fat frying of Potato chips at 170°C for 40 hrs on fatty acid compounds

Treatment	Control		Without water injection	Water injection		
Fatty acid	Zero hr	A. 40 hr		0.1	0.2	0.3
C12:0	0.36	0.65	0.6	0.54	0.55	0.57
C14:0	0.5	0.15	0.2	0.33	0.3	0.25
C16:0	17.04	30	28	24.7	24.69	26.01
C16:1	0.3	0.35	0.34	0.3	0.33	0.34
C18:0	3.8	3.5	3.38	3.29	3.32	3.2
C18:1	23.1	33	30.03	25.72	27.88	29
C18:2	55.5	32.2	37.3	45.12	42.8	40.5
C18:3	0.1	0.15	0.14	0.12	0.13	0.135
Total Sat. fatty acid	20.98	4.3	32.18	28.86	28.86	30.03
Total Unsat.fatty acid	79	65.7	67.81	71.14	71.14	69.97
C18:2/C16:0	3.25	1.07	1.33	1.82	1.73	1.55

Organoleptic evaluation of fried potato chips by using the modified fryer:

As shown in table (2) the sensory evaluation revealed that fried potato chips was more acceptable with the best flavor, crisp and greasiness compared to CDF design samples. Whereas, overall acceptability scores for those samples were ranged from 3 and 4.8 against 3.8 of CDF method. Fried potato chips during the first level of water injection had the highest ($p \geq 0.05$) flavor (4.6), crisp (4.5) greasiness (4.6) and the overall acceptability (4.8) compared to fried potato chips during another levels of water injection flow rates. From the overall acceptability rating, it was concluded that a MDF could be injected water up to 0.2 ml/20 min. per 1 liter without affecting their sensory quality. It is interesting to notice that sensory evaluation correlated significantly with the deterioration occur in quality attributes in oil during deep fat frying. Additionally, sensory evaluation data are providing us with the information about the thermal stability for quality properties of fried potato chips and oil frying media.

Table 2: Organoleptic evaluation during prolonged frying of potato chips at 170 ° C for 40 hrs.

Properties (Score)	Rate of injecting water during prolonged frying of potato chips									
	Control					Without water injection				
	8	16	24	32	40	8	16	24	32	40
Flavour	4.3	4.4	4.2	3.4	3.0	4.5	4.5	4.3	3.8	3.5
Crisp	4.0	4.1	3.8	3.3	3.0	4.2	4.4	4.0	3.7	3.5
Greasiness	3.6	3.6	3.4	3.2	3.1	4.2	4.0	3.8	3.5	3.3
Overall acceptability	3.8	3.8	3.5	3.0	3.0	4.5	4.4	4.0	3.6	3.4

Properties (Score)	at 170 ° C for 40 hrs for MDF (ml/batch)															L.S.D
	0.1					0.2					0.3					
	8	16	24	32	40	8	16	24	32	40	8	16	24	32	40	
Flavour	4.5	4.6	4.5	4.0	3.6	4.3	4.4	4.1	3.6	3.2	4.1	4.0	3.8	3.4	3.0	1.01
Crisp	4.2	4.5	4.3	4.0	4.0	4.1	4.4	4.1	4.0	3.8	3.9	4.0	3.8	3.6	3.4	1.05
Greasiness	4.6	4.4	4.0	3.8	3.6	4.4	4.3	4.0	3.6	3.4	4.1	4.0	3.8	3.4	3.2	0.5
Overall acceptability	4.8	4.6	4.2	4.0	4.0	4.6	4.2	3.8	3.6	3.4	4.2	3.8	3.4	3.2	3.0	0.7

The negative correlation coefficient between overall acceptability and *P*- anisidine values was high (r= 0.935). For the third level of water injection flow rate followed by the first level of water injection flow rate (r= -0.832) and then the second level of water injection flow rate (r= -0.795), compared with CDF design. The linear regression equation for prediction the anisidine values of oil was:

Y (*p* – anisidine) = 59. 913 – 11.383 X (overall acceptability)

r = (-0.935)

Same trend was noticed with the most another sensory attributes throughout the whole experiment period . These findings could be supported by Basuny, *et al*., (2012) and Ahmad *et al*., (2013).

Generally, it is worthy to mention that a linear decrease with a significantly correlation between sensory evaluation and oil deterioration parameters except acid value, the correlation coefficient was very weak.Hence, the results suggest that determination of oil deterioration parameters are good marker of sensory evaluation during deep fat frying. These data are in the same line with those reported by(El-Nagar, 2007).

Nevertheless, water spray injection may provide protection to the frying oil by steaming out volatile oxidized substances and free radical, and reducing residual dissolved oxygen. It seems to play a crucial role as physical agent for steaming out the volatile oxidative products were found in vapor inhalation and enhancing their evaporation and condensation by steam blanketing design.

In conclusion,water injection can both a accelerate hydrolysis and furnish protection against oxidation. Thereafter, these data suggest that the evaporating water do indeed create a steam blanket above the oil surface. The additional properties role of the evaporating water is due to the steam out and distillation effect that reduces the concentration of dissolved oxygen, and drives out oxidized volatile compounds, and possibly also free radicals generated during the frying processMDF design can be applied as a simple method to maintain oil quality during deep fat frying.

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