Effect of Deep-Fat Frying Performance on Canola Oil, Palm Olein and Sunflower Oil Blends: A- Chemical Parameters

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ABSTRACT

Deep-fat frying process produces desirable and undesirable compounds that can cause impairments to the quality of frying of different oils and the fried foods produced. The quality and stability of frying oils are therefore of concern to food technologists, nutritionists, and consumers. The present study was performed to investigate performance of canola oil (CO) and its blends with either sunflower oil (CO+SF) or palm olein (CO+PO) blended at 1:1(w: w) by using different frying cycles of potato chips up to consecutive 10 frying cycle/ 3 day for each oil /days. Significant chemical changes in the frying oil quality have been occurred during frying process. Different chemical deterioration parameters: Iodine value (IV), Free fatty acid (FFA), Peroxide value (PV), Ansidine value (An.v), Totox value, conjugated dienes , total polar compounds (TPC), fatty acids composition (FAs) and Fourier transform infrared (FTIR) of these frying canola oil and blends were investigated .

The conjugated dienes at 232nm throughout the frying periods were the lowest (3.12) in CO+PO with the highest (43.04) value in CO+SF after 30 frying cycles. At the end of frying period, CO+SF had the lowest ratio of TPC 2.15 than found in CO+SF F30 and CO F30 (23.88 and 18.2), respectively. Generally, all blends did not exceed the 25% cut-off point for rejecting used frying oil. The blend of CO+PO was the superior in regard to frying stability and lowering TPC after deep-fat frying process.

The results of 30 potatoes deep-frying cycles in CO and its blends due to higher saturation, which can be seen from the chemical parameters and (FTIR) data. FTIR provides very useful information about the chemical composition and impaired in oil quality during thermal oxidation, which is equivalent to that used in the ordinary food preparation. Furthermore FTIR method predicting a modification in the oil's nutritional value. The results showed that FAs of blends, that contain PO had oxidative stability for the most of fatty acids with lower values than those occurred in frying of CO or CO+SF oils after 30 frying cycles. Furthermore, these results showed evidence that, the oxidation rate for PO in monounsaturated fatty acids (ΣMUSFAs) is much slower than that of the polyunsaturated fatty acids (ΣPUFAs). The ΣMUSFAs, were oxidized, and lower adverse contributed to the improvement of CO stability. Oil blends and frying process caused modifications in the FAs compositions and ω-3/ω-6 ratio.

These results indicated that frying may be hazardous due to the formation of lipid oxidation products as a result of thermal degradation of lipids during deep- fat frying process. Therefore in the CO+PO oil blend provided a frying oil alternative for the production deep–fried food, delivering low proportions of trans and saturated fatty acids.

Key Words: Oil Blends, canola oil, palm olein, sunflower oil, fatty acid composition, frying, oil deterioration, ω-3/ω-6 ratio, oil stability, totox value, total polar content.

INTRODUCTION

Deep - fat frying is extensively used at home and on a commercial scale to enhance the organoleptic properties of foods (Ngadi *et al.,* 2007). It is a traditional way of Egyptian food preparation in both catering establishments and households as well, which produces desirable attributes for consumers regarding both physical and sensor attributes. Essentially, the process involves immersing a food item in a large quantity of heated oil or fat, which normally replenished and reused several times before being discarded. Cooking methods (boiling, grilling, baking, and frying) have been used to enhance food flavour, taste, inactivates pathogenic microorganisms and increase shelf life (Bognar, 1998).

At high temperatures in the presence of air and food, oxidation, hydrolysis and oil polymerization take place, leading to the formation of desir-

able and undesirable secondary products that affect qualities of both oil and finished product. Acrylamide, which is a hazardous compound on consumer health, is formed at 165ºC (David *et al.,* 2010). The appearance of a number of volatile secondary products changes the physicochemical properties and leads to the deterioration of quality in foods, though by the occasional production of toxic compounds (Ammawath *et al.,* 2006).

One of the most important and widely accepted parameters used to decide whether used oil should be discarded is total polar compounds (TPCs), which refer to degraded products formed in the used oil (Bansal *et al.,* 2010). The ultra-violet (UV)-absorbance at 232 nm has been used for evaluation of oil deterioration whereas absorbance tends to increase initially and then plateaus off during later stages of frying fat deterioration (Shahidi & Zhong, 2005). With extending heating period, amounts of decomposition products, *i.e.* polymers content; polar compounds and absorbance at 232 nm rapidly increased. These compounds confirm polymers and equilibrium between the rate formation of conjugated dienes and the rate at which those compounds form polymers by Diels-Alder reaction may occur during frying as confirmed by Gere (1983). By using UV-absorbance, *trans* ethylenic double bonds (carcinogenic R-CH$_2$ = CH$_2$ –R) are formed at 200 °C for 90 min, but disappeared at 170°C for 90 min for all fried oil samples. The amount of *trans* ethylenic double bonds were higher in fried fish, *Taamia* and potatoes. These conjugated dienoic were confirmed from unsaturated double bonds, which are known as carcinogenic preceptors for humans (EL-Shawaf *et al.,* 2000).

Most widely used techniques for the determination of fatty acid composition are GC and FTIR spectroscopy (Priego-Capote *et al.,* 2007).The FTIR spectroscopy has been used in combination with multivariate analysis for the routine analysis of fats and oils (Sherazi, *et al.,* 2009).Furthermore, FTIR spectroscopy was used to determine deterioration in edible vegetable oils adulterated with used frying oil (Hocevar *et al.,* 2012).Meanwhile, Shen *et al.* (2014) used FTIR spectroscopy to assess the quality (FFA and TPC values) of deep frying canola oil (CO).The FTIR spectroscopy depicted all spectral features originating from vibrations of chemical bonds (or functional groups) in the molecules.

Frying oils containing a high amount of PU-FAs form a higher ratio of oxidized products in deep fat- frying as compared with oils containing high MUFAs or SFAs (Singh, 1995). Auto-oxidation rate of fatty acids is affected by several factors including; presence of prooxidants, antioxidants, homogenizing conditions (Imai *et al.,* 2008), temperature, light exposure and rate of dissolved oxygen (Monroig *et al.,* 2007). Furthermore, reliable scientific evidences support that increasing levels of unsaturated fatty acids such as linoleic (C18:2n6) and oleic (C18:1n9) promote humans health benefits due to reducing low-density lipoprotein (LDL)-cholesterol levels (Wolfarm, 2003). Therefore, it is essential that oil quality be monitered to avoid the use of abused oil due to negative health consequences of consuming foods fried in degraded oil.

Oil blending is one way of the most suitable technology to overcome the problem of poor stability of traditional soybean, sunflower and rapeseed oils. Blending of several oils can change the fatty acid compositions of the resultant blends (Mamat, *et al.,* 2005) and can decrease the oxidation of these blends during deep- fat frying. Blending of oils has been encouraged in the recent past . It is gaining importance on nutritional basis, and has been used for frying purposes (Prakash *et al.,* 2001).

Blending of oils is a simpler way of modifying the fatty acid composition and improving the stability of frying oil. Increasing oil stability has mainly attributed to the modification of the ratio of MUFAs to PUFAs. Conventionally, soybean, rapeseed, sunflower or peanut oils, with high contents of polyenoic fatty acids, are the main edible oils used for domestic cooking purposes (Erickson, 1996). Oils with high unsaturated fatty acid contents such as CO are more susceptible to damage than those containing saturated fatty acids. To stabilize unsaturated oils, they are commonly blended with less unsaturated ones, such as palm olein (Farhoosh, *et al.,* 2009).

Canola oil (CO) is "the healthiest" among all commercially traded oils. It is cholesterol free and it is very effective in reducing the risk of cardiovascular diseases (Ackman, 1990).The CO is especially favourable in terms of health benefits when used as part of a nutritionally balanced diet. The CO has a higher content of MUFAs (60%) which are mostly oleic acid (18:1n9), and also the moderate PUFAs (30–37%) levels of which most are linoleic (18:2n6, 22–25%) and linolenic (18:3n3, 8–12%) acids which are essential dietary fatty acids. Moreo-

ver, CO contains the lowest concentration of SFAs (7%) among all vegetable oils (Lavie *et al.,* 2009). The CO is rapeseed oil with low erucic acid content (<2 %). The drawback of a high content of highly unsaturated fatty acids is the low thermal stability at frying temperatures, which reduces the useful life of the oil for deep-fat frying (Gupta, 2005). The frying stability of a blend of CO and palm olein (PO) has been studied by Farhoosh *et al.* (2009) among other oil blends, and authors reported that the TPC content and *p*-anisidine value were lower when CO was blended with two more oils.

Sunflower oil (SF) is one of the healthiest available vegetable oils, with its higher ranking in PUFAs %, which can be beneficial in lowering cholesterol level, as well as being an excellent source of the essential fatty acids required by the human body (Bourre *et al.,* 1989). Furthermore, Padmavathy *et al.* (2001) reported that FA profile of oil can be improved by blending; hence, the need to hydrogenated unsaturated oils is appreciably reduced, resulting in eliminating the chances of formation of harmful *trans* fatty acids.

Palm olein (PO) is one of the most common frying media and is used extensively, in both household and commercial scale; it is preferred for industrial deep-frying of snack products in South Africa either in pure form or combined with other oils (Foodstuffs, Cosmetics and Disinfectants Act, 1996).

The present work estimated the effect of deep-fat frying on some chemical parameters of canola oil, and its blends with palm olein or sunflower oil. The changes in the chemical properties of these blends were also analyzed by Fourier Transform Infrared (FTIR).

MATERIALS AND METHODS

Materials

Canola oil (CO), sunflower oil (SF) and palm olein (PO) were obtained from Borg El-Arab Company for Oil Extraction, Alexandria, Egypt and Arma Food Industries, 10th of Ramadan, Egypt. Potatoes were purchased from local market in Giza, Egypt.

Methods

Blending of vegetable oils

The vegetable oil blends were formulated by blending CO with either SF or PO at a ratio of 1:1

(w/w). The oils were thoroughly mixed to form uniform blends.

Deep- fat frying procedure

Potato tubers were peeled and sliced into 1.52 mm slices, then deep- fat fried as reported by Rossi *et al.,* (2007). In particular, frying conditions were set as follows: frying temperature, 190 °C; actual frying temperature, 175 °C, every batch about 300 g potato slices, frying time, 8 min per frying cycle, break time between two successive frying sessions, 7 min. Frying lasted continuously for 3 hr/day with no oil replenishment, for a total of 9 hr and for three consecutive for 30 frying sessions for each type of oils (CO, CO+SF and CO+PO). The volume of oil was not replenished during the frying process. Frying experiments were conducted in duplicate on each frying medium. Sample was withdrawn from fryer every day at different frying cycle. The frying oil was transferred into a screw-cap vial and promptly stored in the dark at 5 °C until analyzed.

Experimental measurements

Free fatty acids (FFAs), ansidine value (An.V), peroxide value (PV) and Iodine value (IV) were determined according to the AOCS methods (2013) unless otherwise stated. Totox value was calculated according to the following equation: Totox value = 2PV + An.V.

Total polar compounds (TPC)

The TPC were determined according to IUPAC (1987) with minor modifications made by Dobarganes *et al.* (2000), using a 90:10 hexane/methyl ether mixture to elute the polar fraction. The separation efficiency was confirmed by the purity of each fraction in thin layer chromatography, using a mixture of hexane, ethyl ether and acetic acid (80:20:1 V: V: V) as a development solvent. The determinations of the samples were done in duplicate.

Conjugated dienes at 232 nm ($E_{cm}^{\%}$ 232)

Conjugated dienes absorbance at 232 ($E_{cm}^{\%}$ 232 are) considered as primary products of oxidation. They were determined by measuring dienes absorbance at 232 nm according to Pazos *et al.* (2005).

Fatty acid composition

Fatty acid composition of canola and its blends were trans esterified into their corresponding fatty acid methyl esters (FAMEs) using methanolic NaOH and boron triflouride (BF3) with methanol as described by the AOAC (2012).The FAMEs were quantified by Shematizu Gas Chromatograph Series

2010 equipped with a 2010+Sautosampler (Japan,) and interfaced with a FID. The GC was equipped with a temperature programmable column. The column phase was *Supplco* DB-Wax (carbowax) with the following dimensions: 30 m long, 0.25 mm i.e. with a 0.25μm phase thickness. Helium was used as a carrier gas with flow rate of 40 mL/min. One μL was injected using the inlet in a split mode. The head pressure was set at 2 psi, and the split vent flow was 7 mL/m. The injector temperature was 250°C. The column flow rate at 2 psi was 0.68 mL/m. The column temperature was maintained at 200°C for10°C/s and was held at 260°C for 80 min. The detector was operated in the selected ion monitoring mode. Fatty acids were identified by retention times obtained from the FAME standards (Sigma Company, St. Louis, MO).

Identification of minor compounds by GC/MS

The minor compounds were identified according to the methods of Hinton *et al.* (1990) using GC–MS (Agilent Technologies 6890N computerized system coupled to a MSD, Agilent 5973B mass spectrometer). The minor compounds were separated on 30.0 m×0.25 mmi. d × 0.25 μm film thicknesses, polar Agilent HP-5MS column (5% -phenyl methyl poly siloxane). Helium was used as a carrier gas at a flow rate of 1.0 mL min−1; split injection of 4.0μL of fried oil was performed at an injection temperature 300 °C and 200 °C; the split ratio was 1:100. The oven temperature was programmed from 50 to 280 °C at 5°C/ min; the ionization mode used was electronic impact at electron energy of 70 eV interference temperature 200 °C and acquisition mass range 50-800. Components were identified by computer matching of their mass spectral fragmentation patterns with those of compounds in the NIST and WILEY Library as well as comparison with MS data reported in the literature (Sefidkon *et al.,* 2004, Adams, 2004).

Fourier transform infrared (FTIR)

For this experiment, the equipment used was the Tensor 27 mid-FT-IR spectrometer (Bru¨ker, Wissemberg, France) with a deuterated triglycine sulphate (RT-DLaTGS) detector following the method of Ozen & Mauer (2002). A KBr ATR sampling accessory from Spectra Tech (Shelton, CT) was used for Total Attenuated Reflection measurements. The diaphragm was set to 6 mm and the scanning rate to 10 kHz. In addition, 256 scans were used for both reference and sample be-

tween 4000 and 500 cm-^{1} at 2 cm-^{1} resolution. For measurement, 40 ml oil samples were poured onto the attenuated total reflectance (ATR) KBr crystal. After each operation, the crystal was thoroughly cleaned up with ethanol, washed with water and then dried under nitrogen gas.

Statistical analysis

Data were analyzed using SPSS/PASW statistical software version 17 (SPSS Inc., Chicago, IL, USA). The statistical significance between groups was analyzed using one-way test. The difference was considered significant if was less than or equal to 0.05 , MATLAB ver. 7.0 (Natick, MA, USA) and Microsoft Excel (2007) (Roselle, IL, USA). Also, Duncan post hoc test at 5% probability was used for comparison between mean values .

RESULTS AND DISCUSSION

Chemical assessment of frying oils:

The chemical parameters of canola oil and its blends with palm olein and sunflower oil, before and after deep- fat frying process are shown in Table (1).The FFAs, An.V and PV of fresh canola oil were less than 1 mg KOH /g oil, 4.15 g Kg-^{1}and 4.20 meq O_2 / kg, respectively, indicating that this oil is un-oxidized and of high initial quality (Table 1).The FFAs were significantly higher in CO+SF F30 (0.75%) than the fresh blend of CO+SF (0.31%). Meanwhile, FFAs showed no significant difference in CO F30 and CO+PO F30.

With respect to conjugated fatty acid formation during the deep- fat frying process, the data show that the amount of conjugated dienes were gradually increased by progressing frying cycles (Table 1). The conjugated dienes at 232 nm of fresh canola oil (7.73) was significantly higher (*P*≤0.05) than that of the fresh CO+ SF (4.60) and the fresh CO + PO (3.12). These values were sharply increased to 36.92 CO F30, 43.04 CO+SF30 and 18.59 CO+PO 30, respectively. Similarly, the conjugation of polyunsaturates can be associated with the oxidation process during frying process (Megahed, 2001). In contrast, the fresh CO+PO blend showed lower oxidative stability (3.12 ±0.18) than the values occurred in the fresh CO and/or CO+SF blends. These results are in alignment with those reported by Monika *et al.* (2002) indicating that the oxidative stability of 1:1 (v/v) rapeseed/palm-olein blend was improved up to 60% in comparison with rapeseed oil alone.

The results in Table (1) show that An.V of the fresh CO, CO+SF and CO+PO were 4.15, 6.4 and 4.25, respectively. After 30 frying cycles these values increased to 50.53, 38.45 and 25.13, respectively indicating that blending CO with either SF or PO decreased the values of An.V even after the frying process of 30 cycles comparing with CO alone.

It can be noted also that the values of peroxides increased with increasing the number of frying cycle up to 20, then decreased for CO, CO+SF and CO+PO. The high frying temperature forms peroxides which might be decomposed to secondary products, as reported by Robards *et al.* (1988). Lipid hydroperoxides may be partially polymerized during this reaction, thus leading to the formation of less reactive products. The results of the present study are in agreement with the study of Serjouie *et al.* (2010) who reported that during natural frying of canola oil at the first, hydroperoxide content increased and reached to 10.53 and then decreased.

The results also indicated that the rate of increasing the PV in case of CO+PO blend is much significantly lower than that of both CO and CO+SF blend with increasing the number of frying cycles. This may be due to the lower content of polyene after blending the CO with PO.

Table (1) also shows that there was a significant change ($P \leq 0.05$) in the mean PV and An.V before and after 10 consecutive frying sessions for all types of canola oil blends. Meanwhile, canola oil only has a significant increase in PV and An.V even in the first frying cycle. These increases in PV indicate that the level of the primary lipid oxidation products increased, which resulted in the formation of hydroperoxides (Lalas, 2009). Meanwhile, increased PV imply that the level of secondary lipid oxidation increased and resulted in the formation of aldehydes, generally 2-alkenals and 2, 4-alkadienals (Shahidi & Zhong, 2005). Meanwhile, Zamora *et al.*, (2009) revealed that different lipid oxidation products are able to convert asparagine to acrylamide. The important point is that the levels of only 100 $meqo_2$/kg of PV are neurotoxic (Gotoh & Wada, 2006).

During the deep- fat frying of potato chips, there is a little portions of potato peels in the potato slices. It could be assumed that the thermal treatment significantly enhanced the release of phenolic compounds (bound-form phenolic) from potato peels, which act as an antioxidant to protect oils

from excessive destruction, by prolong frying time. This also agrees with Nayak *et al.* (2011) and Jayawardana, *et al.,* (2012).

Generally, the CO+PO showed more thermal stability than CO and CO+SF after deep- fat frying of potato chips. In the binary blends, the CO+SF and CO could significantly increase ($P \leq 0.05$) the totox values from 19.63 to 99.59 and from 12.55 to 97.63, respectively during the frying process; meanwhile, the CO+PO significantly increased the totox value from 22.35 to 58.78. Using this totox for oils used in deep-fat frying, it is possible to compare the degree of deterioration of these oils resulting from the deep-fat frying process. The fresh CO and its blends with the SF and PO showed totox values of 19.63 and 22.35, respectively. These values were markedly greater than the fresh CO by about 60% in SF blend. During the frying process, the totox value increased with different rates, while the CO showed an increase more than 6 times of the initial totox value, for the CO F30 with the same contributions of the CO+SF in the oil of CO+SF F30. Meanwhile, CO+PO blend showed a little increase in totox value after frying process. This increase was less than 3 times occurred in CO+PO F30 in comparison to the control CO+PO blend. This is because , they contain high amounts of linoleic and linolenic acids. This gives the oxidative stability of CO+PO and hence lower totox value. It is interesting to find that the CO+PO blend with decrease totox value improve the frying stability of this blend. These results are in agreement with those reported by Farhoosh *et al.* (2009) who concluded that frying stability of the canola oil was significantly ($P \leq 0.05$) improved by the blending, and the frying performance of the palm olein in binary blend.

As shown in Table (1), the iodine value of the fresh canola oil, CO+SF and CO+PO were 115.75, 118.33, and 90.43 (g of I_2 / 100 g), respectively. Although the decrease in iodine value is indicative of the oxidation rate it could be a useful quality parameter to control oil quality during frying. Also, the blending showed progressive decreases in unsaturation and changes the double bonds in fatty acids profile of the blend oils.

Total polar compounds (TPCs)

The percentages of total polar compounds of the samples under study are shown in Fig. (1) .The results indicate that the fresh CO and CO+SF blend contained 4.28 and 2.15% TPC, respectively. The

Table 1: Chemical parameters of canola oil and its blends with sunflower oil and palm-olein during deep- fat frying process

Type of frying oils	Chemical parameters					
	(FFAs)	(An.V)	(PV)	Totox value	(IV)	Conjugated Dienes at 232 nm
CO	0.35 ±0.025 [edf]	4.15 ±0.08 [k]	4.20 ±0.02 [i]	12.55 ±0.12 [m]	115.57 ±0.49 [f]	7.73 ±0.13 [k]
COF1	0.54 ±0.032 [cb]	9.01 ±0.02 [i]	20.59 ±0.12 [f]	50.20 ±0.22 [i]	112.33 ±0.56 [e]	10.18 ±0.12 [i]
COF10	0.51 ±0.01 [c]	18.10 ±0.13 [f]	23.57 ±0.08 [e]	65.25 ±0.28 [f]	113.27 ±0.93 [ed]	21.29 ±0.22 [e]
COF20	0.52 ±0.01 [cb]	35.50 ±0.10 [c]	26.34 ±0.18 [d]	88.18 ±0.28 [e]	114.00 ±0.62 [d]	28.37 ±0.33 [d]
COF30	0.56 ±0.04 [b]	50.53 ±0.12 [a]	23.55 ±0.14 [e]	97.63 ±0.27 [c]	114.33 ±1.03 [d]	36.92 ±0.07 [n]
CO+ SF*	0.31 ±0.015 [g]	6.40 ±0.24 [j]	6.47 ±0.08 [k]	19.63 ±0.35 [i]	118.33±0.37 [c]	4.60 ±0.08 [n]
CO +SF1	0.32 ±0.01 [fg]	6.21 ±0.03 [j]	8.50 ±0.14 [j]	23.21 ±0.28 [k]	119.66 ±0.41 [b]	6.56 ±0.01 [i]
CO + SF F10	0.38 ±0.015 [ed]	25.30 ±0.17 [e]	35.00 ±0.87 [b]	95.30 ±1.75 [d]	117.70 ±1.51 [c]	15.43 ±0.35 [g]
CO + SF F20	0.39 ±0.01 [d]	27.17 ±0.03 [d]	38.00±0.53 [a]	103.17 ±1.03 [a]	122.33 ±1.04 [a]	29.46 ±0.22 [c]
CO + SF F30	0.75 ±0.03 [a]	38.45 ±0.59 [b]	30.57 ±0.15 [c]	99.59 ±0.81 [b]	118.87 ±0.29 [cb]	43.04 ±0.04 [a]
CO + PO **	0.35 ±0.01 [fg]	4.25 ±0.21 [k]	9.30 ±0.13 [i]	22.35 ±0.39 [k]	90.43 ±0.35 [g]	3.12 ±0.18 [o]
CO + PO F1	0.53 ±0.021 [b c]	6.29 ±0.13 [j]	8.53 ±0.08 [j]	23.35 ±0.23 [k]	90.42 ±0.16 [g]	5.19 ±0.18 [m]
CO + PO F10	0.54 ±0.021 [bc]	11.74 ±0.20 [h]	13.74 ±0.13 [h]	39.21 ±0.13 [j]	89.71 ±0.06 [gh]	9.08 ±0.07 [j]
CO + PO F20	0.52 ±0.01 [bc]	14.68 ±0.36 [g]	19.60 ±0.06 [g]	53.88 ±0.46 [g]	88.67 ±0.25 [hi]	12.83 ±0.15 [h]
CO + PO F30	0.54 ±0.03 [bc]	25.13 ±0.06 [e]	19.83 [g] ±0.20[f]	58.78 ±0.35 [h]	87.77 ±0.15 [i]	18.59 ±0.06 [f]
LSD P ≤0.05	0.036 [(SN)]	0.36 [(SN)]	0.48 [(SN)]	1.04 [(SN)]	1.13 [(SN)]	0.29 [(NS)]

CO : canola oil, SF : sunflower oil PO : palm olein, CO+SF* : fresh blend canola with sunflower oils, CO+PO** : fresh blend canola with palm olein oils F1-F30 : fried oils in frying first up to 30 frying cycles

Results are expressed as mean ± SD; SN: Means with different letters in the same column imply significant differences at *P≤ 0.05*.

NS: non significantly different *P≤ 0.05*.

FFAs: free fatty acids value (as % oleic acid), PV: peroxide value (meq O_2 / kg oil), IV: iodine value (g of I_2 / 100 g oil).
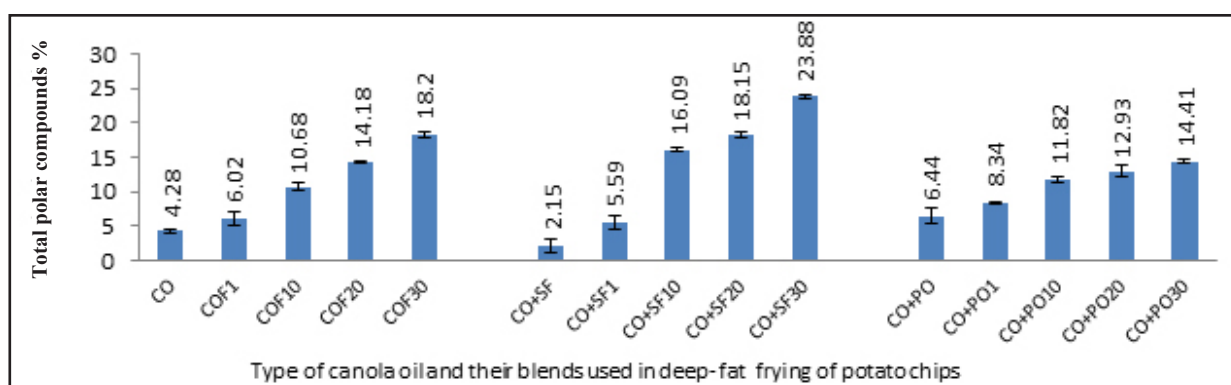
Fig. 1: Total polar compounds (TPC %) in CO and its blends during deep- fat frying process
CO: canola oil, SF: sunflower oil PO: palmolein, CO+SF: fresh blend canola with sunflower oils, CO+PO:
fresh blend canola with palm olein, F1-F30: fried oils in frying first up to 30 frying cycles.

fresh CO+ PO contained 6.44 % TPC; this value of TPC in palm olein is probably due to its content of high levels of diglycerides reflecting the condition of the crude oil. Marquez-Ruiz *et al.* (1995),

Du Plessis & Meredith (1999) indicated that fresh palm olein contained from 7- 7.7%TPC. Changes in TPC of CO and their blends during the deep- fat frying process are shown in Fig. (1).

The highest content of TPC was found in the CO+SF F30 (23.88 %), CO F30 (18.20 %) while the CO+PO F30 oil showed less amounts (14.4%). The TPC content increased in CO+SF blend from 2.15 % to 23.88 after 30 cycles of deep- fat frying , comparing with CO+PO and CO. The results of TPC indicated that significant increases were noted with prolonged frying cycles of potato chips using the different frying oils. It has been shown that the fraction of polar compounds isolated from oxidized oils is the most toxic to experimental animals (Pantzaris, 1998).Therefore, it has been recommended that frying oils containing more than 24–27% of the TPC content should be discarded (Xu, 2003). Also, Serjouie *et al.* (2010) reported that polar content of canola oil during 5 days of frying increased from 6.94 % to 26.78%.

Within different durations during the deep- fat frying process, CO and their blends did not reach the discarding range of the TPC content. As shown in (Fig. 1) assuming that the limit of acceptance for the TPC content is 23.88%, the time required to reach this limit was considered as a measure of frying stability.

Similar results shown by Serjouie *et al.,* (2010) indicated that, among all six frying oils under study, canola oil generally exhibited the least chemical stability during frying process of potato chips and palm olein was the highest in this respect. In the current case study , both CO and CO+PO still had a good frying power even after 30 cycles of frying because TPC level did not exceed the recommend maximum limit (25%), which indicated that the stability of oils against oxidative changes was improved by blending.

It can be concluded from the chemical assessment of CO and its blends during deep- fat frying process of potato chips that , FFAs, An. V, PV, TPC and totox values increased with increasing the number of frying cycles. These can be attributed to aeration, type of frying oil in blend and number of frying cycles. In general, the blend (CO+PO) was more stable during the deep- fat frying process than both the CO alone or the CO+SF. In accordance, FFAs, volatile compounds, and TPC of PO and soya oil were all found to increase (with different magnitudes) upon frying for 5 days (Abdulkarim *et al.,* 2007).

Fatty acid composition

The fatty acid composition of the fresh CO and its blends with either SF or PO and their changes after use in the deep- fat frying process of potato chips are shown in Tables (2, 3, & 4). The data in Table (2) show that fresh CO is dominate in oleic acid (C18:1) as the important mono-unsaturated fatty acid (58.86%), followed by linoleic acid (C18:2ω 6) (19.43%) and linolenic acid (C18:3ω3) (6.19%). After 30 frying cycles, the percentages of the aforementioned fatty acids were 60.18, 19.03 and 5.70 %, respectively. Oleic acid is more resistant toward oxidation, both at ambient storage and at high temperatures (Warner & Knowlton, 1997). On the other hand, high amounts of monounsaturated fatty acids in oils are desirable due to their health benefits (Mensink & Katan, 1990).

Both total saturated (ΣSFAs) and monounsaturated fatty acids (Σ MUSFAs) of CO did not reveal significant ($P\geq0.05$) changes in their ratios during deep- fat frying cycles. On the other hand Σ PUSFAs (as C18:2ω6, C18:3ω6, C18:3ω3 and C18:4ω1) significantly ($P\leq0.05$) decreased during the different deep- fat frying cycles especially from cycle 20 to cycle 30. This decrease accounted 4.6% which is lesser than the fresh CO. Accompanied with the decrease of Σ PUSFAs; the percentage of ΣSFAs relatively increased. Such an increase in ΣSFAs has been occurred probably due to degradation of C18:2ω6 during the deep- fat frying process of potato chips. The frying process on potato chips also generated a slight decrease in the C18:2/C18:1 ratio, from 0.307% to 0.299 % after 30 frying cycles.

The results in Table (2) show that ω3 /ω6 ratio decreased from 0.294 in fresh CO to 0.278 after 30 cycles of deep- fat frying process. This significant decrease can be attributed to the decomposiotion of ω3 by temperature of frying and cycles of frying. Oils with high amounts of monounsaturated (oleic type) fatty acids are associated with decreased risk of coronary heart disease. Consequently, successful attempts were made to produce canola and sunflower plants that produce oils with high mono-unsaturated acids (Corbett, 2003). Since no single refined oil has an ideal fatty acid content, blending vegetable oils is an economic way of modifying fatty acid composition and their physicochemical characteristics (Choudhary *et al.,* 2015).

The data in Tables (3 & 4) show that blends of CO + SF and CO+ PO contained the highest amount of MUFAs being 47.78 % and 53.82%, respectively. Blend CO+SF contained the highest percentage of ΣMSFAs and ΣPUFAs (47.78%and 43.10 %), respectively. While the ΣSFAs in CO+PO blend

Table 2: Relative percentage of fatty acid composition (%) of canola oil (CO) during deep- fat frying process.

Fatty acids	(CO)	(CO F1)	(CO F10)	(CO F20)	(CO F30)	P ≤ 0.05
C16:0	3.94±0.02 [c]	4.09±0.05 [ab]	4.07±0.01 [bc]	4.23±0.09 [a]	4.08±0.01 [abc]	0.038
C16:1ω7	0.22±0.00 [ab]	0.21±0.01 [b]	0.22±0.00 [ab]	0.23±0.01 [a]	0.21±0.01 [b]	0.085
C18:0	1.63±0.01 [b]	1.69±0.03 [ab]	1.67±0.01 [ab]	1.74± 0.05 [a]	1.68±0.01 [ab]	0.109
C18:1ω⁹	58.86±0.02[c]	59.84±0.06 [ab]	59.90±0.04 [a]	59.23± 0.37 [bc]	60.18±0.10 [a]	0.013
C18:1ω7	3.57±0.01 [a]	3.42±0.03 [c]	3.46±0.02 [b]	3.47± 0.01 [bc]	3.47±0.01 [b]	0.000
C18:2ω6	19.43±0.00[a]	19.37±0.04 [a]	19.25±0.01 [b]	19.31± 0.74 [ab]	19.03±0.04 [c]	0.003
C18:3ω6	1.64±0.017[a]	1.42±0.01 [b]	1.434±0.01 [b]	1.47± 0.06 [b]	1.44±0.04 [b]	0.012
C18:3ω3	6.19±0.01 [a]	5.86±0.00 [b]	5.83±0.01 [b]	5.69± 0.02 [c]	5.69±0.05 [c]	0.000
C18:4ω1	1.77±0.00 [a]	1.50±0.01 [b]	1.53±0.00 [b]	1.50± 0.02 [b]	1.51±0.02 [b]	0.000
C20:0	0.54±0.03 [a]	0.55±0.04 [a]	0.57±0.00 [a]	0.55± 0.01 [a]	0.57±0.02 [a]	0.220
C20:1ω9	1.21±0.00 [b]	1.19±0.00 [b]	1.17±0.03 [b]	1.27± 0.02 [a]	1.23±0.04 [ab]	0.050
C22:0	0.29±0.01 [a]	0.28±0.02 [a]	0.29±0.02 [a]	0.26± 0.03 [a]	0.27±0. 00 [a]	0.240
ΣSFAs	6.40±0.01 [b]	6.61±0.01 [ab]	6.60±0.01 [ab]	6.78± 0.17 [a]	6.60±0.04 [ab]	0.120
Σ MUSFAs	63.87±0.02[c]	64.63±0.00 [ab]	64.76 ±0.01 [a b]	64.20± 0.33 [c]	65.10±0.13 [a]	0.014
Σ PUSFAs	29.04±0.01[a]	28.17±0.00 [b]	28.03±0.00 [c]	27.98± 0.02 [c]	27.68±0.08 [d]	0.000
Σ ω-6	21.08±0.01[a]	20.82±0.006[b]	20.67±0.003 [c]	20.78± 0.02 [b]	20.47±0.004[d]	0.000
Σ ω -3	6.19±0.01 [a]	5.86±0.004 [b]	5.83±0.001 [b]	5.69± 0.02 [c]	5.69±0.05 [c]	0.000
ω 3/ ω 6	0.294±0.00 [a]	0.281±0.00 [bc]	0.282±0.000 [b]	0.274± 0.001 [d]	0.278±0.002 [c]	0.000
C18:2/C18:1	0.31±0.00 [a]	0.31±0.01 [b]	0.307±0.00 [d]	0.31± 0.00 [b]	0.299±0.00 [e]	0.000

CO : canola oil, F1- F30 : fried oils in frying first up to 30 frying cycles
Results are expressed as mean±SE; Means with different letters in the same row imply significant differences at *P≤ 0.05.*

significantly decreased to 25.10% (Table 4).The CO+PO blend contained lower ratio of ΣPUFAs than the fresh CO (Table 2).

It can be noted from Tables (3&4) that fatty acid composition of the blends CO+SF and CO+PO significantly changed during the different cycles of deep-fat frying process of potato chips . The blend CO+SF showed a significant increase in C18:1ω9, C18:1ω7 and a significant decrease in C18:2ω6, C18:3ω6 and C18:3ω3.Also, the amount of ΣPUFAs decreased from 43.10 to 40.44 %. A significant decrease in the ratio of C18:2 / C18:1 from 0.82 to 0.72, while the ratio of ω3/ ω6 increased from 0.08 to 0.1 during deep- fat frying process from cycle 0 to cycle 30. On the other hand, the ΣSFAs had no significant change during the process.

Fatty acid composition of the blend CO+PO is shown in Table (4). This blend contained a considerable amount of palmitic acid (C16:0) about 21%. This blend showed significantly lower levels of ΣMUFAs. In addition, this blend contained also a lower amount of ΣPUFAs than that found in both CO alone or CO+SF Significant differences were noted in ΣMUFAs and ΣPUFAs during the deep- fat frying process starting from cycle 0 up to cycle 30

It can be concluded from the aforementioned results that CO+PO blend is an excellent blend in *trans* of the frying stability comparing with CO alone or CO+SF. This results are in accordance with data of Majid *et al.* (2014).

Minor compounds

Minor compounds in CO and its blends with SF and PO identified by GC/MS are shown in Table (5). These minor compounds include caravacrol, butylated hydroxytolueune and vitamin D3 in the fresh CO. The m-xylene 2,3-dehydro-4-oxo-β-ionol and cresol 4,6-di-tert-butyl were identified in CO after the first frying cycle. Benzene butanol, α, β-dimethyl 4, 6, di-tert-butyl-m-cresol was identified in CO after 10 frying cycle. Although, no identified minor compounds were noted in CO after 20 and 30 frying cycles, respectively. These compounds were completely degraded according to prolonged frying period and frying temperature (Table 5). The results in Table (5) show that butylated hydroxytoluene 2-t-butyl-4-(dimethyl benzyl) phenol and butylated hydroxyl toluene 2, 6-di-tert-butylhydroquinone were identifed in the fresh CO+SF and the CO+SF after 1 frying cycle, respectively.

Table 3: Relative percentage of fatty acid composition (%) of (C0+SF) during deep- fat frying process.

Fatty acids	(CO+SF)	(CO+SF F1)	(CO+SF F10)	(CO+SF F20)	(CO+SF F30)	P ≤ 0.05
C16:0	5.21±0.06 [a]	5.07 ± 0.14 [a]	5.25 ± 0.00 [a]	5.27 ± 0.08 [a]	5.34 ±0.16 [a]	0.504
C16:1ω7	0.15±0.00 [a]	0.07 ± 0.08 [a]	0.17 ± 0.01 [a]	0.15 ± 0.01 [a]	0.17 ±0.00 [a]	0.506
C18:0	2.49± 0.03 [a]	2.49 ± 0.01 [a]	2.48 ±0.00	2.44 ±0.01 [a]	2.47 ±0.09 [a]	0.878
C18:1ω9	44.95± 0.50 [d]	45.09 ±0.04 [d]	45.38 ±0.09 [c]	45.87±0.02 [b]	47.38 ±0.02 [a]	0.000
C18:1ω7	2.07± 0.01 [c]	2.07 ±0.01 [c]	2.06 ±0.00 [c]	2.12 ±0.01 [b]	2.22±0.01 [a]	0.000
C18:2ω6	38.54 ± 0.04 [a]	38.71±0.02 [a]	38.16 ±0.09 [b]	37.72 ±0.10 [c]	35.64 ±0.16 [d]	0.000
C18:3ω6	0.75 ± 0.00 [a]	0.71±0.01 [a]	0.73 ±0.001 [a]	0.60±0.01 [b]	0.61±0.00 [b]	0.004
C18:3ω3	3.00 ± 0.00 [c]	2.97±0.01 [c]	2.89±0.03 [d]	3.22±0.02 [b]	3.53±0.01 [a]	0.000
C18:4ω1	0.80 ± 0.01 [ab]	0.79 ±0.00 [ab]	0.87±0.09 [a]	0.66±0.00 [b]	0.67 ±0.00 [b]	0.064
C20:0	0.42 ± 0.01 [b]	0.43±0.00 [b]	0.42 ±0.00 [b]	0.43 ±0.00 [ab]	0.44±0.01 [a]	0.090
C20:1ω9	0.68 ± 0.01 [b]	0.67±0.02 [ab]	0.64 ±0.00 [ab]	0.68 ±0.00 [a]	0.70 ±0.01 [a]	0.070
C22:0	0.42 ± 0.01 [a]	0.41 ±0.04 [a]	0.43 ±0.00 [a]	0.43±0.02 [a]	0.45±0.01 [a]	0.745
ΣSFAs	8.55± 0.07 [a]	8.40± 0.11 [a]	8.59± 0.00 [a]	8.56± 0.03 [a]	8.69± 0.26 [a]	0.667
Σ MUSFAs	47.78± 0.02 [d]	47.91± 0.04 [d]	48.24± 0.07 [c]	48.82± 0.05 [b]	50.47± 0.02 [a]	0.000
Σ PUSFAs	43.10± 0.04 [a]	43.19± 0.00 [a]	42.62± 0.06 [b]	42.20± 0.01 [c]	40.44± 0.18 [d]	0.000
Σ ω-6	39.29± 0.03 [a]	39.42± 0.02 [a]	38.86± 0.13 [b]	38.32± 0.10 [c]	36.2± 0.16 [d]	0.000
Σ ω -3	3.00± 0.05 [c]	2.97± 0.01 [c]	2.89± 0.03 [d]	3.22± 0.02 [b]	3.53± 0.01 [a]	0.000
ω 3/ ω 6	0.08± 0.00 [c]	0.075± 0.00 [c]	0.070± 0.00 [c]	0.084± 0.00 [b]	0.100± 0.00 [a]	0.000
C18:2/C18:1	0.82± 0.00 [a]	0.83± 0.00 [a]	0.80± 0.00 [b]	0.79± 0.00 [c]	0.72± 0.00 [d]	0.000

CO+SF : fresh blend canola with sunflower oils, F1-F30 : fried oils in frying first up to 30 frying cycles
Results are expressed as mean ± SD; Means with different letters in the same row imply significant differences at P≤ 0.05.

Table 4: Relative percentage of fatty acid composition (%) of (C0+PO) during deep- fat frying process

Fatty acids	(CO+PO)	(CO+PO F1)	(CO+PO F10)	(CO+PO F20)	(CO+PO F30)	P ≤ 0.05
C14:0	0.45±0.00 [c]	0.46±0.01 [ab]	0.46±0.00 [ab]	0.45±0.00 [bc]	0.46±0.00 [a]	0.023
C16:0	20.98±0.06 [a]	21.07±0.06 [a]	20.91±0.03 [a]	20.59±0.05 [a]	21.04±0.05 [b]	0.006
C16:1 ω7	0.18±0.00 [a]	0.09±0.09 [a]	0.13±0.00 [a]	0.18±0.00 [a]	0.10±0.097 [a]	0.725
C18:0	3.01±0.04 [a]	2.90±0.00 [b]	2.90±0.01 [b]	2.89±0.00 [b]	2.93±0.00 [b]	0.018
C18:1ω9	50.89±0.11 [a]	50.99±0.04 [a]	50.74±0.59 [a]	51.24±0.03 [a]	51.23±0.04 [a]	0.652
C18:1ω7	2.10±0.02 [a]	2.12±0.01 [a]	2.13±0.015 [a]	2.13±0.00 [a]	2.13±0.01 [a]	0.452
C18:2ω6	15.72±0.04 [c]	16.01±0.01 [b]	16.11±0.11 [ab]	16.30±0.04 [a]	16.04±0.02 [b]	0.008
C18:3ω6	0.78±0.01 [a]	0.78±0.00 [a]	0.70±0.01 [b]	0.78±0.01 [a]	0.78±0.02 [a]	0.021
C18:3ω3	3.16±0.02 [c b]	3.27±0.01 [a]	3.13±0.02 [c]	3.30±0.02 [a]	3.23±0.03 [ab]	0.001
C18:4ω1	0.83±0.00 [a]	0.84±0.01 [a]	0.86±0.01 [a]	0.85±0.01 [a]	0.87±0.01 [a]	0.379
C20:0	0.49±0.10 [a]	0.44±0.00 [a]	0.19±0.06 [b]	0.45±0.00 [a]	0.45±0.01 [a]	0.004
C20:1ω9	0.65±0.00 [a]	0.93±0.29 [a]	0.83±0.17 [a]	0.62±0.01 [a]	0.64±0.01 [a]	0.575
C22:0	0.17±0.01	ND	ND	ND	ND	-
ΣSFAs	25.10 ±0.01 [a]	24.87 ±0.056 [b]	24.45 ±0.083 [c]	24.38 ±0.044 [c]	24.87 ±0.007 [b]	0.0013
Σ MUSFAs	53.82 ±0.093 [a]	54.13 ±0.167 [a]	53.82 ±0.783 [a]	54.18 ±0.033 [a]	54.10 ±0.04 [a]	0.906
Σ PUSFAs	20.49 ±0.068 [c]	20.90 ±0.01 [ab]	20.79 ±0.165 [bc]	21.34 ±0.081 [a]	20.91 ±0.089 [ab]	0.023
Σ ω-6	16.51 ±0.047 [bc]	16.79 ±0.013 [b]	16.80 ±0.130 [b]	17.08 ±0.047 [a]	16.82 ±0.04 [b]	0.017
Σ ω -3	3.16 ±0.016 [a]	3.27 ±0.009 [a]	3.13 ±0.020 [c]	3.29 ±0.024 [a]	3.23 ±0.031 [ab]	0.0097
ω 3/ ω 6	0.21 ±0.004 [b]	0.195 ±0.007 [a]	0.186 ±0.000 [c]	0.193 ±0.001 [ab]	0.192 ±0.001 [ab]	0.0041
C18:2/C18:1	0.296 ±0.001 [a]	0.301 ±0.006 [a]	0.305 ±0.006 [a]	0.305 ±0.001 [a]	0.300 ±0.000 [a]	0.269

CO+PO: fresh blend canola with palm olein, F1-F30: fried oils in frying first up to 30 frying cycles
Results are expressed as mean±SD; Means with different letters in the same row imply significant differences at P≤0.05

Table 5: Identified minor compounds of CO and its blend during deep-fat frying process

Type of frying oils	Identified compounds
(CO)	Caravacrol , Butylated hydroxytoluene 24, 25-dihydroxy vitamin D3
(CO F 1)	M-xylene 2, 3-dehydro-4-oxo-β-ionol m-cresol, 4, 6-di-tert-butyl
(CO F 10)	Benzene butanol , α, β-dimethyl 4, 6, di-tert-butyl-m-cresol
(CO F 20)	-
(CO F 30)	-
(CO+SF)*	Butylated hydroxy toluene 2-t-butyl-4-(dimethylbenzyl) phenol
(CO+ SF F1)	Butylated hydroxytoluene 2, 6-di-tert-butylhydroquinone
(CO+ SF F10)	-
(CO+ SF F20)	-
(CO+ SF F30)	-
(CO+ PO)**	Butylated hydroxy toluene Thymol-TMS Cavonyl
(CO+ PO F1)	2,6-di-tert-butylbenzoquinone 2-t-butyl-4-(dimethylbenzyl) phenol 3, 5-di-t-butylcatechol
(CO+PO F10)	Curdione 4, 6-di-tert-butyl-m-cresol Dihydro-3-oxo-β-ionol
(CO+PO F20)	-
(CO+PO F30)	3, 5-di-t-butylcatechol 2, 6-di-tert-butylhydroquinone

CO : canola oil, SF : sunflower oil PO : palm olein, CO+SF* : fresh blend canola with sunflower oils, CO+PO** : fresh blend canola with palm olein F1-F30: fried oils in frying first up to 30 frying cycles.

These previous minor compounds disappeared after 10, 20, and 30 frying cycle. A considerable amount of antioxidant could be identified in the fresh CO+PO blend and CO+PO after 1 cycle of frying , these include butylated hydroxyl toluene, thymol-TMS cavonyl and 2,6-di-tert-butylbenzoquinone 2-t-butyl-4-(dimethyl benzyl) phenol 3,5-di-t-butylcatechol , respectively. Both Curdione 4, 6-di-tert-butyl-m-cresol and dihydro-3-oxo-β-ionol were identified in CO+PO after 10 frying cycles. After 30 frying cycles, CO+PO blend contain 3, 5-di-t-butylcatechol 2, 6-di-tert-butylhydroquinone. These identified minor compounds come mainly from the antioxidants added to oils as preservatives. These minor compounds may be reflex the behaviour of oil against oxidation during deep-fat frying process.

FTIR spectra of canola oil and its blends

It is clear from Fig. (2) that there are dominant spectral features between 4000 and 500 cm⁻¹ that correspond to different functions occurring naturally in oils during processing. Fresh CO +SF and CO+SF after 30 cycles of frying process showed some over-lapping. Peaks in the 3000-2800 cm⁻¹ region result from C-H stretching vibrations, whereas the large peak around 1740 cm⁻¹ is due to C=O vibration (Fig. 2).

Different forms of C-H and C=O vibrations cause the appearance of peaks in the 1500-650 cm⁻¹. By the monitor these changes in the blend CO+SF undergoing thermal stress, by identifying common oil oxidation end products, and relating them to representative decreases in the unsaturation of fatty acids. The CO+SF exhibit reduction in IR transmittance at 3050-2800 cm⁻¹ region .These findings indicated an appreciable lowering of the concentration of –CH₃ and – CH₂ functional groups in this blend.

These bands corresponding to oxidative changes in CO+SF blend after frying process. Furthermore, the changes in the carbonyl absorption of the triglyceride ester linkage at around 1700 cm were reported as a main FTIR event denoting lipid oxidation. From Fig. (2), it can be identified that, the region between 2500-4000 was stretched between fresh CO+SF and CO+SF F30; hydroperoxide moieties exhibit characteristic absorption bands between 2500 and 4000 cm⁻¹ due to their –OO–H stretching vibrations (Fig. 2). Van de Voort *et al.* (1994) reported that absorbance at 3800–3100 cm⁻¹ in the ATR/FTIR spectra is due to the OH stretching region.

The observed lowering in the concentration of C–O, CH₂ as well as CH₃. functional groups could be related to the production of dimers and polymers of triglycerides in the more advanced stages of lipid oxidation (Tiencheu *et al.,* 2013), as well as decrease in absorbance IR band is consider to reduction in unsaturated fatty acids (Guillen & Cabo, 2000).

The FTIR spectra for CO+PO blend before and after deep- fat frying process for 30 cycle, show well-resolved peaks in (Fig. 3). The peaks are representative of the chemical groups of the components present in the CO+PO and after frying up to
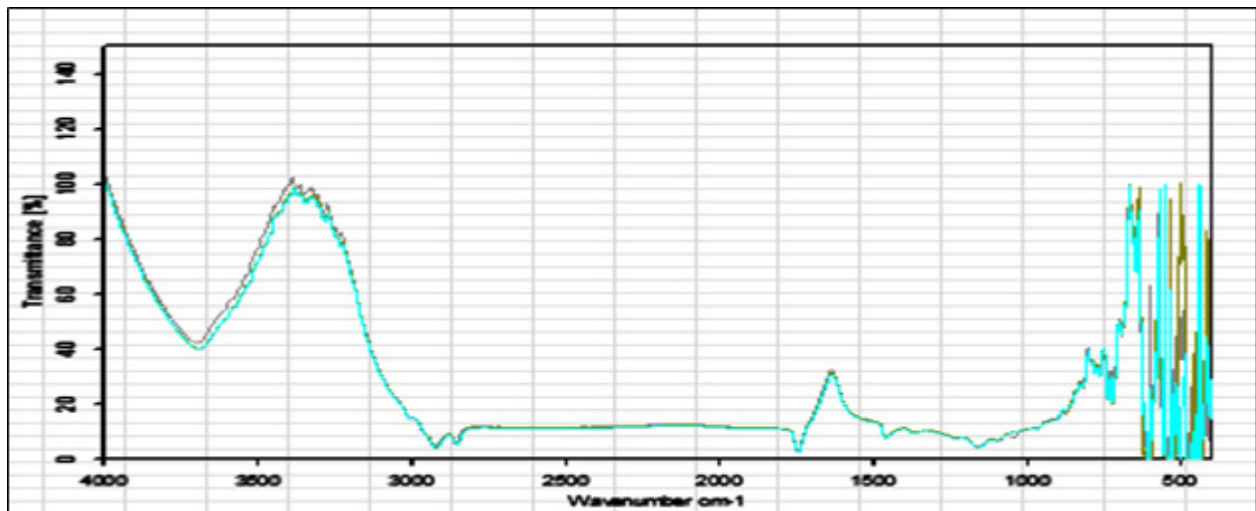
Fig.2: FTIR for fresh CO and its blend with SF after 30 cycle of frying
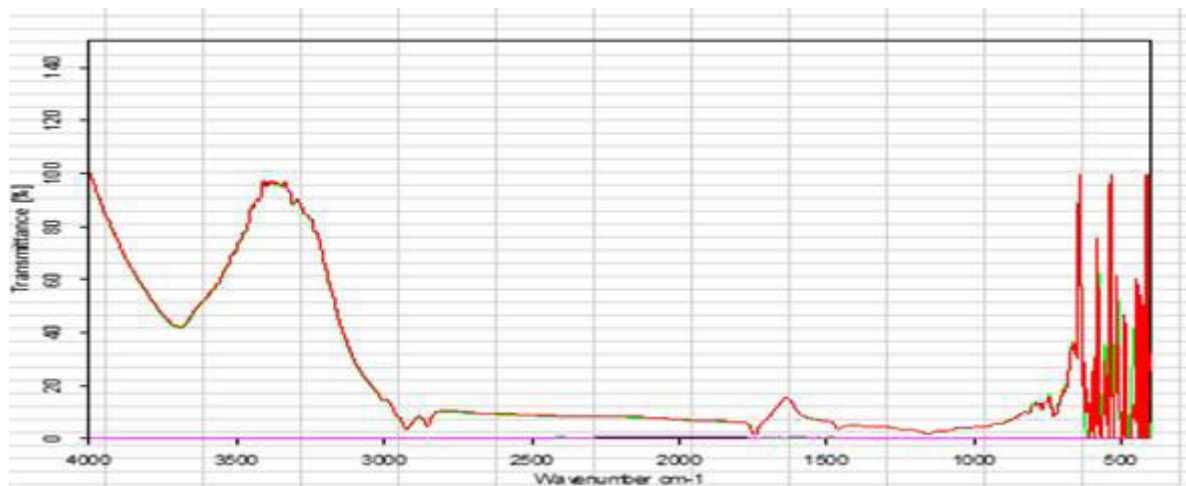

Fig.3: FTIR for fresh CO and its blend with PO after 30 cycle of frying

30 cycles. It illustrate the dominant spectral features associated with oils and fats. The entire range of spectra looks very similar for the fresh (before frying) and (after frying). Three distinct peaks at 3433, 2788 and 1736 cm^{-1} could be observed (Fig. 3). The peak at 1736 cm^{-1} is a result of the absorption of the ester carbonyl group (C = O) of the triglycerides. Unsaturated fatty acids present in CO+PO gave a small peak at around 2788 cm^{-1} which is characteristic of the cis double bond stretching absorption (Van de Voort et *al.,* 1995). The sharp peak in region at about 700 to 500 cm^{-1} is associated with the rocking vibration of the methylene group as it was indicated by Guillen & Cabo (2000).

The narrow broad distances between the FTIR spectra of Fresh CO+PO and the same blend after 30 cycles of frying process shows the extent of lower oxidation and stability of this blend (Fig. 3). The aldehydes bands at 1736 cm^{-1} region are mainly due to the high absorptivity of their carbonyl groups. The region of aldehyde does not stretch after 30 cycle of frying process. According to the results obtained in the present study, the CO+PO blend exhibited heating stability upon prolonged time of the deep- fat frying process. This also was reported by Siddique *et al.* (2015). Thus, it can be seen that much information about the stability of CO+PO after frying can be obtained from the entire range of FTIR spectra**.**

CONCLUSION

The results of this particular study suggested that repeated frying cycles for oil blends diminished the health-protective effects. Canola oil is especially favourable in terms of health benefits when used as part of a nutritionally balanced diet depend on its fatty acid composition. Among all CO blend, CO+SF (1:1 w:w) and CO+PO (1:1 w:w) were found to be the least susceptible to deg-

radation based on chemical parameters. CO+PO showed better performance to thermal oxidation during deep- fat frying process than CO+SF.

This is a consequence of high saturation, which can be seen from the chemical parameters and Fourier transform infrared data. Fourier transform infrared provides very useful information about the chemical composition and impaired the oil quality during thermal oxidation, equivalent to that used in the ordinary preparation of food. Furthermore, Fourier transforms infrared method predicting a modification in the oil's nutritional value. Regarding the fatty acid composition, CO + PO subjected to all frying cycles come out to be the best blend compared to all palm olein blends appeared to be the least deteriorated blend and thereby the most stable blend during frying .

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تأثير أداء عملية القلي العميق لزيت الكانولا ومخاليطه مع زيت أوليين النخيل وزيت دوار الشمس: أ- الخصائص الكيميائية

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تعتبر عملية القلي العميق من أهم طرق الطهي التي ينتج معها مكونات مرغوبة وغير مرغوبة والتي بدورها تؤثر علي جودة الأغذية المقلية وعلي جودة الزيوت المستخدمة للقلي. وتوجد كثير من الطرق للحفاظ علي تلك الجودة من خلال طرق تصنيعية وتغذوية للحفاظ علي صحة المستهلكين. تطرقت هذه الدراسة إلى استخدام زيت الكانولا المهم تغذويا بخلطه مع زيوت مختلفة مثل زيت دوار الشمس و زيت أوليين النخيل (وزن : وزن) واستخدامها في القلي لمدة ٣ أيام بواقع ١٠ قليات يوميا لرقائق البطاطس. وقد حدث تغيرات معنوية في كل الخصائص الكيميائية مثل الأحماض الدهنية الحرة وتركيب الأحماض الدهنية والبيروكسيد والأنسيدين والمواد القطبية ورقم التوتكس وكذلك الأيونات المرتبطة (Diene) والتي قيست على طول موجة ٢٣٢ نانوميتر فكانت في البداية لزيت الكانولا مع زيت أوليين النخيل ٣,٢ وارتفعت حتي ٤٣,٠٤ بعد الدورة الثلاثين للقلي في الزيت المستخدم لقلي رقائق البطاطس. أما عملية القلي التي اجريت علي مخلوط الكانولا مع زيت دوار الشمس فاحتوت في البداية علي ٢,١٥٪ مواد القطبية وارتفعت بعد الدورة الثلاثين للقلي إلى ٢٣,٨٨٪ في حين أن زيت الكانولا فقط حتي دورة القلي الثلاثين احتوي علي ١٨,٢٪ مواد قطبية ويعتبر الزيت غير صالح للاستخدام بعد نسبة ٢٥٪ مواد قطبية والتي ينبغي من بعدها التخلص من الزيت. وأستخلص من الدراسة ان زيت الكانولا مع زيت أوليين النخيل هو من أفضل الطرق المسئولة عن خفض نسبة تكوين المواد القطبية وثبات الزيوت المستخدمة.

ومن الطرق الحديثة التي تستخدم لقياس كفاءة الزيوت وجودتها الحرارية والتي يتوقع معها التراكيب الكيميائية للزيوت هو استخدام المطياف الضوئي المسمي ب FTIR حيث حدد منه زيادة نسبة الأحماض الدهنية المشبعة بعد الدورة الثلاثين للقلي والتي تشير إلى خفض الجودة التغذوية للزيوت المستخدمة بعد عملية القلي. ووجد بتحليل الأحماض الدهنية أن زيت أوليين النخيل هو الأكثر ثباتا بالقلي حتي الدورة الثلاثين وذلك لإرتفاع محتواه من الأحماض الدهنية أحادية عدم التشبع والتي تكون أكثر ثباتا بالمعاملة الحرارية عن الأحماض الدهنية عديدة عدم التشبع. وبالتالي يعتبر الخلط من أفضل الطرق لتعديل تركيب الأحماض الدهنية وخاصة الاوميجا –٣ / الاوميجا –٦ وقد تقاربت هذة النسبة إلى ماهو موجود في الكانولا المستخدم أو المخلوط من الكانولا مع زيت دوار الشمس بما لا يشكل تأثيرا علي الجودة التغذوية من الكانولا مع زيت أوليين النخيل. وخلصت الدراسة إلى أن المواد الضارة المتكونة في زيوت القلي يمكن تلافيها باستخدام خلط الكانولا مع زيت دوار الشمس والتي من شأنها تقليل مشاكل الأحماض الدهنية المشبعة وعدم تكوين صور ضارة من الأحماض الدهنية الأخري.