



Evaluation of Fatty Acid Indices and Fatty Acid Content Including Trans Fat of Different Fried Food Types Using Gas-Liquid Chromatography Technique

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Abstract | Nowadays, fried foods gaining a worldwide popularity although deep-frying of foods leads to many adverse changes in the food constituents and fatty acid profile. These changes make fried foods more harmful to human health upon consumption especially when frying oils are used for several cycles. In this study, fatty acid profile status of the most popular fried foods sold in street restaurants and shops was assessed using gas liquid chromatography (GLC). The examined fried food types included variable items as chicken wings, nuggets, broasted chicken, fish, shrimp, octopus, French fries, mashed potato, falafel, eggplant and onion rings. Results revealed a high saturation as well as high trans fatty acids content among the examined samples which reached to 49.55% and 5.3%, respectively. Regarding fatty acid indices, nearly all samples failed to meet the international recommended guidelines of polyunsaturated/saturated “P/S” (samples had P/S ratio from 0.16 to 0.57) and Omega-6/Omega-3 “n-6/ n-3” (ratio ranged from 22.14 up to 95.28). Local legislations should set clear limits regarding saturated fats and trans fats content in fried foods. Moreover, routine supervision of fried food restaurants and street shops should be adopted to monitor their commitments towards those legislations.

Keywords | Fatty acids, Saturated fat, Trans fat, Fried food, Gas chromatography

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INTRODUCTION

The current availability of low-cost high energy fast foods sold by restaurants and street food shops leads to increase total energy intake among low-income populations (FAO, 2011). However, fried foods have a suboptimal nutritional quality, they attain a great acceptance among people particularly children and youth (Santos et al., 2018). This acceptance could be regarded to the effect of frying process that gives fried foods many consumer desired sensory features (Ghidurus et al., 2010). French fries, falafel, eggplant, chicken, fish and nuggets are popular fried food items that sold in many Egyptian restaurants and street

shops (Megahed et al., 2011). Knowing that, most of these restaurants and street food shops expose food to deep oil frying during cooking process (Santos et al., 2018). Hence, researchers started to pay more attention to the worldwide fried foods consumption and its health effect (Camire et al., 2009).

During deep-frying, the frying oil temperature reaches to 170-200°C causing many deteriorative changes which directly lowers the fried food nutritional quality (Ghidurus et al., 2010). These changes include loss and/or degradation of some food components such as moisture and essential vitamins. Moreover, new compounds are developed

as a result of fat oxidation such as trans fatty acids (TFA) (Camire et al., 2009). The formed compounds not only remain in the oil but also, absorbed by the fried food to be consumed (Ghidurus et al., 2010).

Naturally, the basic structure of fat and oil is either mono-unsaturated (MUFA), polyunsaturated (PUFA), saturated fatty (SFA) acids or a combination of them. PUFA normally are in the *Cis*-configuration (the same side). However, under certain condition this configuration may be changed into *Trans*-configuration (the opposite side) resulting in formation of trans fats or trans fatty acids (TFA) (Dhaka et al., 2011; Pérez-Farinós et al., 2016; Chavasit et al., 2018). The change in configuration occurs either naturally through dehydrogenation process by rumen bacteria (TFA accumulate in meat and milk) or artificially through incomplete hydrogenation of unsaturated vegetable oils to produce partially hydrogenated vegetable oils (PHVO) (Ghidurus et al., 2010; Pérez-Farinós et al., 2016). Production of PHVO resulted in formation of more saturated, solid and stronger fat consistency than the normal vegetable oils consistency. Moreover, PHVO became widely used on the commercial scale in food manufacturing industries as well as the restaurants and street food shops for food processing and food frying (Chavasit et al., 2018; Santos et al., 2018; Stender, 2020). It worth to mention that the main source of TFA in consumer daily diets was regarded to consumption of foods fried using PHVO, where TFA is much higher in PHVO compared to the animal meat and byproducts (Dhaka et al., 2011). Food processors and fast-food restaurants prefer using PHVO as it is relatively inexpensive, solid at room temperature, has a longer shelf life and of low oxidation rate beside that it gives the fried food technical criteria preferred by consumers. That's why many unlicensed fast-food shops may re-use frying oils several times or even buy the previously used oil of frying snacks, coated meat products and potato chips factories to be a very cheap source of fat in the frying process, which unfortunately is rich in TFA content (Dhaka et al., 2011; Stender, 2020). Additionally, chicken skin and mechanically deboned meat (MDM) are extensively used in processing of many meat products leading to major difference in its fat composition as well as nutritional quality (Malak et al., 2020). Meanwhile, consumer awareness about the nutritional and health effect of TFA consumption is very low (Zhang et al., 2015; Santos et al., 2018). Despite that TFA is not synthesized inside human body, their absorption, and metabolization results in many serious health problems including change in the body lipid profile by increasing the harmful cholesterol known as low density lipoprotein (LDL), triglycerides, insulin levels. On the contrary, TFA lowers the level of beneficial cholesterol known as high density lipoprotein (HDL) which increases the risk of incidence of coronary heart disease (CHD), breast can-

cer, lower pregnancy period, diabetes, cancer of colon, several allergic reactions and obesity (Choudhary and Grover, 2013; Chavasit et al., 2018; Astrup et al., 2020; Amorim et al., 2020; Stender, 2020). Food and drug administration (FDA), world health organization (WHO) and some countries (USA, Canada, Thailand and India) mandated to mention the amount of existing TFA on the food label. Moreover, the nutritional fact sheet should link between SFA and TFA content (Wayland, 2015; Costa et al., 2016; Gupta et al., 2016; WHO, 2016a,b). Many countries still have neither accurate data concerning the status of TFA content in their market foods nor any legal regulation recommending the limit of existence of TFA in fried foods. So, this study was designed to evaluate the current status of major fried street foods sold in the Egyptian market through quantitation and identification of its individual fatty acids content using gas-liquid chromatography (GC), measuring the concentration of fatty acids indices (SFA, PUFA and TFA) and highlighting the nutritionally important ratios (P/S and $n-6/n-3$) which may affect human health.

MATERIAL AND METHODS

SAMPLE COLLECTION

A total of 110 fried food samples were collected from the most commonly consumed fried foods in Egypt including; chicken wings, broasted chicken, nuggets, fish, shrimp, octopus, potato fingers (French fries), mashed potato, falafel (tameya), eggplant and onion rings ($n=10$ each). All samples were purchased from random restaurants and fast-food outlets located in the great Cairo, Egypt. Samples were transferred inside cooled ice-box immediately into the laboratory for further examination.

ANALYSIS OF FATTY ACIDS

Total lipid extraction: Total lipids from each of the examined samples were extracted (in duplicate) with hexane at 1:50 (wt/vol) ratio in each extraction operation (Romero et al., 1998).

Preparation of fatty acids methyl esters (FAME): FAME were prepared from previously extracted lipids using rapid method of IUPAC (1992a). Whereas, fat saponified for 30 min at 60°C with 40 ml/g 0.5 N NaOH in methanol, then boron trifluoride-methanol complex was added to achieve complete conversion of fatty acids into their methyl esters form.

Separation and identification of fatty acids methyl esters by Gas-liquid chromatography (GC): The prepared FAME were separated and quantified according to IUPAC (1992b) guidelines by using gas-liquid chromatography (Agilent 6890 series) equipped with a flame ionization detector (FID) using a 60 m x 0.32 mm x 0.25 μ m DB-

23 capillary column. Temperatures set for injector (230 °C) and detector (250 °C). Carrier gas used was hydrogen (flow rate of 40 ml/min.) and temperature program was (150-170°C at 10°C/min) then (170-192°C at 5°C/min), holding for five min then (192-220°C during 10 min). Standards was similarly chromatographed with each sample to confirm samples FAME identity. Each individual FAME were identified by comparison to known standards. Through Fatty acid peaks we could calculate amounts of fatty acids according to Slover and Lanza (1979).

STATICAL ANALYSIS

Each fried food type was chromatographed in three replicates (n=10) and the collected data were analyzed using SPSS program for statistics v23 for windows (SPSS Inc., Chicago, IL, USA). To determine the least significant difference (LSD) ($P < 0.05$) among the obtained mean values, ANOVA procedures was used. All results were reported as mean \pm SD.

RESULTS AND DISCUSSION

During frying process, many chemical changes occur in the fried food depending on frying time, frying temperature, initial moisture content of food, surface coating of food, amount and quality of absorbed oils (Kita et al., 2007). These changes may be attributed to starch gelation, protein denaturation and drying of the outer surface of the fried food as a result of the migration of moisture of food and replaced by oil particularly in the presence of the coating layer as in nuggets. This coating may also absorb a larger amount of oil during the frying process increasing the whole fried food fat uptake (Ngadi et al., 2009; Oke et al., 2018). Consequently, the initial fatty acid content and fat saturation level in the food before frying affects the final fatty acid profile of fried food products so, the final fatty acid composition varies completely among different fried food items.

SATURATED FATTY ACIDS (SFA) IN EXAMINED FRIED FOODS

Fractionation of fatty acids (Table 1) showed that fatty acid content varied among the examined samples. Where the saturation level was linked to the high concentration of palmitic fatty acid (C16:0) followed by stearic fatty acid (C18:0). Also results in Table (2) revealed that the highest saturation level was obtained from chicken wings (49.55%), broasted chicken (49.29%) and mashed potato (47.85%). Furthermore, Nearly the same proportion (44%) of SFA values was obtained from nuggets, shrimp, octopus and onion rings. However, lower results reported by Czech et al. (2015) for fried shrimp (36.28%) and fried octopus (33.9%) and higher SFA (48.9%) of nuggets was reported Atta et al. (2010). Additionally, in this study the low-

est saturation percentage was retrieved from French fries (31.56%) which is nearly similar to Atta et al. (2010) findings of SFA in French fries. Moreover, Vieira et al. (2018) reported similar results for SFA level of fried fish.

Generally, lowering SFA level in the daily food intake is associated with decreasing the incidence of cardiovascular diseases (Kris-Etherton et al., 2018). This means that depending on SFA results both chicken wings, broasted chicken and mashed potato may have the highest detrimental effect upon consumption and potentially to have a high risk to human health.

UNSATURATED FATTY ACIDS (UFA) IN EXAMINED FRIED FOODS

The highest monounsaturated fatty acids (MUFA) percentage was recovered from French fries (46.04) while the lowest percentage (37.22) were from fried eggplant (Table 2). These results are related to the high oleic fatty acid (C18:1) content (Table 1) which is the main fatty acid forming MUFA.

Regarding polyunsaturated fatty acids (PUFA) results (Table 2), it was noticed that fried chicken wings, fish and mashed potato had the lowest PUFA value (8.21, 8.77 and 8.67, respectively). Moreover, linoleic fatty acid (C18:2) had the largest share in PUFA content (Table 1). Frying process also known to reduce PUFA content in the fried food items (Suliman et al., 2006). Increasing PUFA intake known to be associated with lowering heart and cardiovascular diseases (Kris-Etherton et al., 2018). Correspondingly, total unsaturated fatty acids (UFA) (sum of MUFA+PUFA) recorded the lowest proportions in fried chicken wings (50.01%) and broasted chicken (50.42%) (Table 2). Undoubtedly, oleic fatty acid (C18:1) and linoleic fatty acid (C18:2) were the main constituents of the UFA (Table 1). Therefore, most of the examined fried samples represent a high risk to health upon its consumption due to its high content of saturated fatty acids compared to the polyunsaturated fatty acids.

TRANS FATTY ACIDS (TFA) IN EXAMINED FRIED FOODS

Regulations regarding trans fatty acids (TFA) content of marketed food in Egypt is not mandated to be mentioned on the labeling data of food product. However, some countries as Denmark clearly limited TFA percentage to below 2% of total product fat content (Trattner et al., 2015). During the current study samples of falafel, eggplant, fish and French fries showed a high shooting level of 5.3%, 4.9%, 4.7% and 4.2% respectively for TFA (Table 2). Deep frying as well as repetitive use of frying oil for several cooking cycles is a major source for TFA formation in fried foods (Chen et al., 2014). Based on previous studies, those types of fried foods contain high levels of TFA and considered most likely to be deleterious for health upon their consum-

Table 1: Individual fatty acid contents (fatty acids%) of examined fried food samples (n=10)

	Chicken wings	Broasted chicken	Nuggets	Fish	Shrimp	Octopus	French fries	Mashed potato	Falafel	Egg-plant	Onion rings
C8:0	0.195 ±0.01 ^{a*}	0± 0.00 ^b	0± 0.00 ^b	0.162± 0.03 ^c	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0.166± 0.05 ^c	0± 0.00 ^b	0± 0.00 ^b
C10:0	0.043 ±0.00 ^a	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b	0± 0.00 ^b
C12:0	0.442 ±0.02 ^a	0± 0.00 ^b	0.219± 0.00 ^c	0.418± 0.01 ^a	0± 0.00 ^b	0.221± 0.01 ^c	0± 0.00 ^b	0.406± 0.06 ^a	0.218± 0.03 ^c	0± 0.00 ^b	0± 0.00 ^b
C14:0	1.408 ±0.05 ^a	1.038 ±0.04 ^b	0.955± 0.00 ^c	1.090± 0.02 ^b	0.918± 0.00 ^c	0.951± 0.08 ^c	0.727± 0.05 ^c	1.064± 0.09 ^b	0.950± 0.01 ^c	0.984± 0.06 ^c	0.963± 0.04 ^c
C16:0	41.69 ±0.21 ^a	43.08 ±0.10 ^b	38.70± 0.44 ^c	40.71± 0.71 ^a	37.97± 0.30 ^c	38.78± 0.86 ^c	30.12± 0.51 ^d	40.69± 0.48 ^a	38.167± 0.74 ^c	41.35± 0.53 ^a	38.78± 0.64 ^c
C16:1	0.601 ±0.03 ^a	0.189 ±0.01 ^b	0.184± 0.01 ^b	0.269± 0.03 ^b	1.544± 0.08 ^c	0.196± 0.05 ^b	0.183± 0.03 ^b	0.315± 0.01 ^b	0.845± 0.07 ^a	0.171± 0.02 ^b	0.190± 0.05 ^b
C17:0	0.194 ±0.00 ^a	0.089 ±0.00 ^b	0.093± 0.00 ^b	0.118± 0.02 ^a	0.111± 0.01 ^a	0.093± 0.00 ^b	0.099± 0.00 ^b	0.251± 0.03 ^c	0.113± 0.00 ^a	0.100± 0.04 ^a	0.094± 0.02 ^b
C17:1	0.047 ±0.04 ^a	0.023 ±0.00 ^b	0.026± 0.00 ^b	0.032± 0.01 ^{a,b}	0.038± 0.00 ^{a,b}	0.027± 0.00 ^b	0.033± 0.00 ^{a,b}	0.020± 0.00 ^b	0.035± 0.00 ^{a,b}	0.024± 0.00 ^b	0.027± 0.02 ^b
C18:0	4.991 ±0.40 ^a	4.623 ±0.14 ^a	4.405± 0.09 ^a	0± 0.00 ^b	5.353± 0.05 ^a	4.443± 0.02 ^a	0± 0.00 ^b	4.629± 0.01 ^a	0± 0.00 ^b	0± 0.00 ^b	4.465± 0.13 ^a
C18:1T	0.308 ±0.07 ^a	0.081 ±0.07 ^b	0± 0.00 ^c	4.659± 0.84 ^d	0.114± 0.04 ^b	0± 0.00 ^c	4.068± 0.71 ^d	0± 0.00 ^c	5.207± 0.00 ^d	4.735± 0.00 ^d	0± 0.00 ^c
C18:1	41.01 ±0.15 ^a	39.11 ±0.36 ^a	43.22± 0.72 ^b	42.922± 0.58 ^b	38.89± 0.70 ^a	43.48± 0.38 ^b	45.53± 0.61 ^c	42.78± 0.30 ^b	41.14± 0.29 ^a	36.89± 0.48 ^c	43.25± 0.19 ^b
C18:2T	0.129 ±0.03 ^a	0.193 ±0.04 ^b	0.131± 0.01 ^a	0.123± 0.00 ^a	0.185± 0.01 ^b	0.135± 0.08 ^a	0.146± 0.04 ^a	0.156± 0.01 ^{a,b}	0.135± 0.01 ^a	0.205± 0.02 ^b	0.123± 0.00 ^a
C18:2	8.039 ±0.06 ^a	10.58 ±0.37 ^b	11.13± 0.48 ^b	8.589± 0.51 ^a	13.61± 0.73 ^c	10.76± 0.32 ^b	17.42± 0.80 ^d	8.281± 0.65 ^a	11.79± 0.63 ^b	14.68± 0.47 ^c	11.10± 0.52 ^b
C18:3n6	0.016 ±0.00 ^a	0.052 ±0.00 ^b	0.034± 0.01 ^d	0.019± 0.00 ^a	0.105± 0.03 ^c	0.038± 0.00 ^c	0.055± 0.00 ^b	0.018± 0.01 ^a	0.052± 0.03 ^b	0.042± 0.00 ^c	0.032± 0.02 ^d
C18:3n3	0.150 ±0.01 ^a	0.288 ±0.06 ^{b,c}	0.294± 0.01 ^b	0.165± 0.02 ^a	0.619± 0.06 ^d	0.274± 0.03 ^c	0.721± 0.02 ^c	0.369± 0.05 ^f	0.519± 0.05 ^g	0.155± 0.02 ^a	0.366± 0.01 ^f
C20:0	0.404 ±0.08 ^a	0.373 ±0.07 ^a	0.383± 0.04 ^a	0.404± 0.01 ^a	0.291± 0.00 ^a	0.381± 0.07 ^a	0.381± 0.05 ^a	0.764± 0.18 ^b	0.369± 0.02 ^a	0.373± 0.06 ^a	0.384± 0.05 ^a
C20:1	0.149 ±0.00 ^a	0.185 ±0.03 ^a	0.155± 0.07 ^a	0.195± 0.03 ^a	0.198± 0.08 ^a	0.159± 0.04 ^a	0.299± 0.06 ^b	0.191± 0.02 ^a	0.204± 0.02 ^b	0.140± 0.01 ^a	0.156± 0.03 ^a
C22:0	0.178 ±0.06 ^a	0.089 ±0.00 ^b	0.070± 0.00 ^b	0.129± 0.04 ^a	0.050± 0.00 ^b	0.064± 0.00 ^b	0.227± 0.03 ^c	0.048± 0.00 ^b	0.096± 0.00 ^{a,b}	0.143± 0.05 ^a	0.064± 0.00 ^b

* ^{a-f}Values with different superscripts within the same raw are significantly ($P < 0.05$) different.; Data represent average of three independent readings ± standard deviation

ption causing systemic inflammation, diabetes, breast cancer and coronary disease (Atta et al., 2010; Chavasit et al., 2018; Astrup et al., 2020; Stender, 2020). Similar high TFA results were obtained by Mashal et al. (2012) who reported TFA values of 4.08% and 3.6% for falafel and French fries, respectively. While lower results were detected by Flores et al. (2018), where all the fried food samples collected from street vendors did not exceed the 2% limit of TFA contents that ranged from 0.6 to 1.7%.

It was noticed that upon frying of fish the PUFA level was lowered (8.7%) and TFA level was elevated (4.9%) despite

the fact that raw fish is known to have high PUFA content. This could be explained that raw fish has a high PUFA content in normal *Cis*- configuration but this *Cis*- configuration was changed into *Trans*- configuration when raw fish was subjected to prolonged deep-frying process on high temperatures resulting in accumulation of high levels of TFA. (Bansal et al., 2009; Ghidurus et al., 2010).

OMEGA 3 (n3) AND OMEGA 6 (n6) FATTY ACIDS IN EXAMINED FRIED FOODS

Both n3 and n6 are essential fatty acids i.e., they cannot be

Table 2: Fatty acids indices and nutritionally important ratios of examined fried food samples (n=10)

	Chicken wings	Broasted chicken	Nuggets	Fish	Shrimp	Octopus	French fries	Mashed potato	Falafel	Eggplant	Onion rings
SFA **	49.55± 0.83 ^a	49.29± 0.35 ^{a,b}	44.83± 0.75 ^c	43.03± 0.84 ^{d,e}	44.69± 0.36 ^{c,e}	44.93± 1.04 ^c	31.56± 0.64 ^f	47.85± 0.85 ^b	40.08± 0.85 ^g	42.96± 0.74 ^d	44.75± 0.88 ^c
MUFA	41.81± 0.22 ^{a,b}	39.51± 0.4 ^c	43.59± 0.8 ^d	43.41± 0.65 ^{a,d}	40.68± 0.86 ^{b,c}	43.87± 0.47 ^d	46.04± 0.7 ^e	43.31± 0.33 ^{a,d}	42.22± 0.38 ^{a,b,d}	37.22± 0.51 ^f	43.63± 0.29 ^d
PUFA	8.21± 0.07 ^a	10.92± 0.43 ^b	11.46± 0.5 ^b	8.77± 0.53 ^a	14.34± 0.82 ^c	11.08± 0.35 ^b	18.20± 0.82 ^d	8.67± 0.71 ^a	12.36± 0.71 ^b	14.88± 0.49 ^c	11.50± 0.55 ^b
TFA	0.437± 0.01 ^a	0.273± 0.011 ^a	0.130± 0.01 ^a	4.781± 0.84 ^{b,c}	0.299± 0.05 ^a	0.134± 0.08 ^a	4.213± 0.75 ^b	0.156± 0.01 ^a	5.342± 0.01 ^c	4.94± 0.02 ^{b,c}	0.123± 0.00 ^a
UFA	50.01± 0.29 ^a	50.42± 0.83 ^{a,b}	55.04± 1.30 ^c	52.19± 1.18 ^d	55.01± 1.68 ^c	54.93± 0.82 ^c	64.24± 1.52 ^c	51.98± 1.04 ^{b,d}	54.58± 1.09 ^c	52.10± 1 ^{b,d}	55.12± 0.84 ^c
P/S ratio	0.1656± 0.01 ^a	0.221± 0.02 ^b	0.255± 0.05 ^c	0.203± 0.03 ^d	0.320± 0.01 ^e	0.246± 0.06 ^c	0.576± 0.06 ^f	0.181± 0.05 ^a	0.308± 0.01 ^c	0.346± 0.00 ^g	0.256± 0.08 ^c
<i>n3</i>	0.1502± 0.01 ^a	0.288± 0.06 ^{b,c}	0.294± 0.01 ^b	0.165± 0.02 ^a	0.619± 0.06 ^d	0.273± 0.03 ^c	0.721± 0.02 ^e	0.369± 0.05 ^f	0.519± 0.05 ^g	0.154± 0.02 ^a	0.366± 0.01 ^f
<i>n6</i>	8.055± 0.06 ^a	10.63± 0.37 ^b	11.16± 0.49 ^b	8.61± 0.51 ^a	13.72± 0.76 ^c	10.79± 0.32 ^b	17.48± 0.81 ^d	8.30± 0.66 ^a	11.84± 0.66 ^b	14.71± 0.48 ^c	11.52± 0.53 ^b
<i>n9</i>	0.148± 0.00 ^{a,b}	0.185± 0.03 ^c	0.155± 0.07 ^{a,b}	0.195± 0.03 ^{c,d}	0.198± 0.08 ^{c,d}	0.158± 0.04 ^b	0.299± 0.06 ^c	0.190± 0.02 ^{c,d}	0.204± 0.02 ^d	0.140± 0.01 ^a	0.153± 0.03 ^b
<i>n6/n3</i>	53.61± 0.05 ^a	36.86± 0.12 ^b	37.97± 0.47 ^{b,c}	52.09± 0.26 ^a	22.14± 0.11 ^d	39.45± 0.11 ^c	24.23± 0.63 ^c	22.44± 0.60 ^d	22.79± 0.58 ^{d,c}	95.28± 0.37 ^f	30.38± 0.48 ^g

* a-g Values with different superscripts within the same raw are significantly ($P < 0.05$) different.; Data represent average of three independent readings ± standard deviation

** Saturated fatty acid (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), trans fatty acids, Total unsaturated fatty acids (UFA) = MUFA+PUFA, polyunsaturated fatty acids / saturated fatty acids (P/S) ratio, trans fatty acids (TFA), Omega 3 (*n3*), Omega 6 (*n6*)

synthesized inside the human body and must be supplemented through the daily dietary intake (Simopoulos, 2016). Results of *n3* fatty acid (Table 2) revealed that, all examined samples had a lowered *n3* content. while, the lowest percentages were obtained from chicken wings (0.1502), eggplant (0.1546) and fish (0.1635). These results agreed with findings of Gladyshev et al. (2007) who obtained *n3* values ranged from 0.479 to 0.941 from two different types of fried fishes. Moreover, Kalogeropoulos et al. (2006) recorded *n3* level of 0.6 for pan fried eggplant.

Regarding *n6* level, the lowest values were detected in chicken wing (8) while higher percentages were detected in fried shrimp (13.7) and octopus (10.7). Moreover, the highest level was recorded from French fries (17.48). Results (Table 1 and 2) displayed that content of the *n3* was mainly regarded to presence of α -Linolenic acid (C18:3n3) while *n6* content was mainly linked to linoleic acid (C18:2). These results were in accordance with those reported by Kalogeropoulos et al. (2006) for fried eggplant (6.7%) and Czech et al. (2015) for octopus (9.3%) and shrimp (16.2%).

Traces of Omega 9 (*n9*) were recorded in all samples (0.1-0.2 of total fatty acids) which mainly consisted of gondoic

fatty acid (C20:1). Knowing that, *n9* is not needed in the daily intake as human body able to synthesize it (Simopoulos, 2008). However, consuming diet rich in *n9* may have many health benefits through improving insulin sensitivity as well as decreasing the inflammation reactions (Finucane et al., 2015).

FATTY ACIDS NUTRITIONAL RATIOS OF MAJOR IMPORTANCE

Calculating ratios of nutritional importance was carried out for example: P/S ratio (polyunsaturated/saturated fatty acids or polyene index) and *n6/n3* ratio. Prolonged deep-frying process known to decrease the P/S ratio due to lowering of PUFA content (Ma et al., 2015). Department of health and social security of London suggested that healthy food is the food which contains P/S ratio greater than 0.45 (Lopes et al., 2015). In current study all examined samples (Table 2) had a very low P/S ratio that ranged from 0.16 to 0.34 whereas all samples were below recommended ratio = 0.45 except French fries which had a slightly higher value (0.57) than the recommended level. It's worth to mention that P/S ratio of 1 to 1.5 helps in maintaining a good functionality of cardiovascular system and reduces the oxidative stress (Kang et al., 2005).

Both $n6$ and $n3$ are essential fatty but unfortunately, they aren't inter-convertible (cannot be converted to each other), and both of them compete on the desaturation enzymes during metabolism inside the body resulting in production of many byproducts (Simopoulos, 2016). The $n6/n3$ ratio is recommended to be below 10 to help in reducing cardiovascular diseases, colorectal and breast cancers, suppress inflammation and decrease incidence of asthma (Simopoulos, 2008, 2016). Neither of the examined samples met the recommended level of $n6/n3$ instead of that high values were obtained ranged from 22.14 in fried shrimp up to 95.28 in eggplant which reflected the risk of consuming those types of fried foods. Similarly, Czech et al. (2015) reported an $n6/n3$ ratio of 20 and 15 for fried shrimp and octopus, respectively. Moreover, Kalogeropoulos et al. (2006) recorded an $n6/n3$ ratio of 12 for fried eggplant.

CONCLUSION

Through studying the fatty acid profile of fried foods, we concluded that cooking using deep-frying may be favorable to consumers from the sensorial point of view but, unfortunately it causes several deleterious changes to the fried food fatty acids content. Among these changes is the increase in both levels of saturated fats and trans fats. Consequently, these changes badly interfere the human health status and causes many heart and cardiovascular diseases. Most of fried foods sold in in unlicensed food shops and unmonitored restaurants don't adhere to the international guidelines regarding nutritional indices of fatty acids. Therefore, Local authorities should mandate a clear regulation concerning fatty acid content of fried foods restaurants especially the saturated fat and trans fatty acid content.

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CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

AUTHORS CONTRIBUTION

All authors had an equal contribution during designing, performing and writing the final manuscript of this study

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