ECRONICON OPEN ACCESS

EC PHARMACOLOGY AND TOXICOLOGY

Research Article

The Effect of Repeated Heating on the Peroxidative Quantity of the Frying Oils

Sohayla M Attalla[1,2]*, Nadia E Atwan[3], Adel A Zalata[4], Essam M Ali[1] and Fatma A Kamel[1]

[1]*Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine, Mansoura University, Mansoura, Egypt*

[2]*International Medical School (IMS), Management and Science University (MSU), University Drive, Off Persiaran Olahraga, Shah Alam, Malaysia*

[3]*Pathology Department, Faculty of Medicine, Mansoura University, Mansoura, Egypt*

[4]*Biochemistry Department, Faculty of Medicine, Mansoura University, Mansoura, Egypt*

***Corresponding Author:** Sohayla M Attalla, Professor, Forensic Medicine and Clinical Toxicology Department, Faculty of Medicine, Mansoura University, Mansoura, Egypt and International Medical School (IMS), Management and Science University (MSU), University Drive, Off Persiaran Olahraga, Shah Alam, Malaysia.

Received: April 13, 2022; **Published:** December 29, 2022

Abstract

Deep fat frying is an important method of food preparation. Chemical reactions occur during frying and give rise to formation of complex products and oxidized fatty acids which are absorbed by the food. The objective of this study was to assess the effect of repeated heating on the peroxidative quality of the frying oils by measuring the Thio Barbituric Acid Reactive Substances "TBARS" content in fresh, heated and repeatedly heated studied oils (sunflower, cottonseed and mixed oils). Results revealed that the deteriorative effect of heat as indicated by the TBARS level in oil, increases by increasing the duration of oil use. The repetition of heating is much more destructive than the continuous use of the oil. Sunflower oil can tolerate heating better than cottonseed and mixed oil. It is recommended that frying is better to be avoided. Repeated use of the oil for frying must not occur even with short periods of use.

Keywords: *Frying; Heated Oils; Antioxidants; Tocopherols; Chromatography*

Introduction

Fat and oils are heated at high temperatures during baking, grilling and frying; however, deep fat frying is the most common method of high temperature treatment. Deep fat frying is a popular food preparation method produces the desirable fried food flavour, golden brown colour and crisp texture. Because of the great consumption of frying oils and fat, the effect of high temperature on oils and fat is of major concern both for product quality and nutrition [1]. Fast food and snacks which absorb substantial amounts of frying oils are being increasingly consumed [2] as they provide an appealing and quick option for those who have little time to dedicate to the preparation and/or consumption of their meals [3]. Fried foods contribute a significant proportion of the total fat consumed in the Western world [4]. In the U.S., in 1994, approximately 12 billion pounds of fat and oils were used with 5.5 billion pounds used for frying and baking. Fried snack foods accounted for 2.9 billion pounds of oil, whereas 2 billion pounds were used for frying in restaurants [1]. In Egypt, the deep-fried vegetable patties (Taamiah, Falafel, bean cake) form the staple food item in the diet and widely available at street level from vendors [5]. However, due to the absence of suitable frying oil quality sensor for restaurant situation, it is difficult to implement any regulation against the use of deteriorated frying oils [6].

Oxidation of lipids in food has received considerable attention because of possible adverse health effects related to consumption of oxidized lipids. The rate of lipid oxidation depends on a number of factors, including the polyunsaturated fatty acids content and the presence of antioxidants such as α-tocopherol [7]. In fact, polyunsaturated fatty acids are particularly susceptible to oxidation by free radicals during the storage, cooking and frying of foods, the potential risk of exposure to lipid degradation products is likely to have increased [2]. Also, it has been found that regular intake of foods with saturated fat raises the risk of coronary heart disease and the total mixed fat intake is associated with a higher incidence of the nutritionally linked cancers e.g. distal colon [8]. Many studies have been reported on the quality of continuously heated oils and fats, at high temperatures for many hours but reports on the domestic frying of foods are limited [9].

Aim of the Study

The aim of this work is to study the effect of heating on the formation of thermal oxidative products in different types of heated oils (the most widely used oils in Egypt).

Materials and Methods

A pilot study (cross sectional descriptive study) was carried out among females in Mansoura Faculty of Medicine. The questionnaire about the type of oil used in frying included 1200 females of different social categories (400 doctors, 400 employees and 400 workers). Table 1 shows the frequency of oil use by different female categories in Mansoura Faculty of Medicine.

	Doctors (n = 400)	Employees (n = 400)	Workers (n = 400)	Total (n = 1200)
Corn oil	30 (7.5%)	10 (2.5%)	10 (2.5%)	50 (4.17%)
Cottonseed oil	120 (30%)	150 (37.5%)	90 (22.5%)	360 (30%)
Mixed oil*	30 (7.5%)	170 (42.5%)	230 (57.5%)	430 (35.83%)
Olive oil	10 (2.5%)	0	0	10 (0.83%)
Palm oil	0	0	0	0
Soybean oil	0	0	0	0
Sunflower oil	210 (52.5%)	70 (17.5%)	70 (17.5%)	350 (29.17%)

Table 1: *The frequency of oil use by different female categories in Mansoura Faculty of Medicine.*

**Mixed oil is a blend of sunflower oil and cottonseed oil. It is the most used by street vendors in Egypt [5].*

Then, the most commonly used oils (sunflower, cottonseed and mixed oils) were chosen for the study and were prepared by deep frying potato chips in the fresh oil in aluminium containers for different periods (1/4, 1/2 and 1 hour) and also repeatedly used (2, 3, 4 times; 1/4 hour each and 2 times; 1/2 hour each) without any topping up (without replenishing the oil in the fryer with fresh oil) under conditions corresponding to the normal household frying practices (domestic frying).

The effect of heating on oils was determined by assessment of the Thio Barbituric Acid Reactive Substances "TBARS" in the fresh and heated studied oils [10,11].

Statistical analysis was done by using the Statistical Package for Social Science (SPSS) program. Non significant when $p > 0.05$. Significant when $p \leq 0.05$. Highly significant when $p \leq 0.01$. Extremely significant when $p \leq 0.001$.

Results

The effect of heating on oils (comparison of the TBARS content in fresh and heated studied oils) is shown in table 2. The effect of repetition of heating on oils (comparison of TBARS content in repeatedly heated oils) is shown in table 3. Comparison of the TBARS content in sunflower, cottonseed and mixed oils is shown in table 4. Comparison between the three studied oils is shown in table 5.

	Fresh	H 1/4	H 2/4	H 3/4	H 4/4	H 1/2	H 2/2	H 1
Mean	1.15	1.54	5.72	7.15	9.06	2.92	6.92	4.07
SD ±	0.029	0.15	0.088	0.038	0.059	0.075	0.106	0.007
Minimum	1.121	1.33	5.61	7.127	8.99	2.813	6.77	3.991
Maximum	1.171	1.7	5.81	7.213	9.12	2.973	6.999	4.147
t		4.78	8.12	10.1	20.1	5.1	9.5	7.1
P		0.017	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 2: *The statistical comparison of the TBARS content (nmol/ml) in the fresh and heated sunflower oil (H1/4 means heated once for 15 minutes. H2/4 means heated twice; each 15 minutes. H3/4 means repeatedly heated thrice; each 15 minutes. H4/4 means repeatedly heated 4 times; each 15 minutes. H1/2 means heated once for 30 minutes. H2/2 means heated twice; each 30 minutes. H1 means heated once for one hour).*

	Fresh	H 1/4	H 2/4	H 3/4	H 4/4	H 1/2	H 2/2	H 1
Mean	5.53	6.31	9.45	12.72	16.66	9.57	12.08	10.47
SD ±	0.023	0.14	0.92	0.15	1.69	0.18	0.068	0.004
Minimum	5.412	6.123	9.321	12.57	17.21	9.33	11.99	10.41
Maximum	5.812	6.473	9.521	12.91	17.6	9.76	12.14	10.51
t		5.22	8.95	10.23	12.19	8.1	10.1	9.1
P		0.014	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 3: *The statistical comparison of the TBARS content (nmol/ml) in the fresh and heated cottonseed oil (H1/4 means heated once for 15 minutes. H2/4 means heated twice; each 15 minutes. H3/4 means repeatedly heated thrice; each 15 minutes. H4/4 means repeatedly heated 4 times; each 15 minutes. H1/2 means heated once for 30 minutes. H2/2 means heated twice; each 30 min. H1 means heated once for one hour).*

	Fresh	H 1/4	H 2/4	H 3/4	H 4/4	H 1/2	H 2/2	H 1
Mean	1.5	5.62	7.54	11.45	11.72	5.98	7.55	6.95
SD ±	0.13	0.23	0.16	0.51	0.86	0.026	0.27	0.003
Minimum	1.321	5.321	7.32	10.81	11.99	5.95	7.322	6.913
Maximum	1.613	5.867	7.712	11.99	12.71	6.01	7.96	6.993
t		9.1	11.1	13.1	13.5	9.3	11.17	10.1
p		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 4: *The statistical comparison of the TBARS content (nmol/ml) in the fresh and heated mixed oil (H1/4 means heated once for 15 minutes. H2/4 means heated twice; each 15 minutes. H3/4 means repeatedly heated thrice; each 15 minutes. H4/4 means repeatedly heated 4 times; each 15 minutes. H1/2 means heated once for 30 minutes. H2/2 means heated twice; each 30 minutes. H1 means heated once for one hour).*

	Fresh	H 1/4	H 2/4	H 3/4	H 4/4	H 1/2	H 2/2	H 1
Mean	1.5	5.62	7.54	11.45	11.72	5.98	7.55	6.95
SD ±	0.13	0.23	0.16	0.51	0.86	0.026	0.27	0.003
Minimum	1.321	5.321	7.32	10.81	11.99	5.95	7.322	6.913
Maximum	1.613	5.867	7.712	11.99	12.71	6.01	7.96	6.993
t		9.1	11.1	13.1	13.5	9.3	11.17	10.1
p		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 4: *The statistical comparison of the TBARS content (nmol/ml) in the fresh and heated mixed oil (H1/4 means heated once for 15 minutes. H2/4 means heated twice; each 15 minutes. H3/4 means repeatedly heated thrice; each 15 minutes. H4/4 means repeatedly heated 4 times; each 15 minutes. H1/2 means heated once for 30 minutes. H2/2 means heated twice; each 30 minutes. H1 means heated once for one hour).*

	Sunflower oil		Cottonseed oil		Mixed oil	
	H4/4	H2/2	H4/4	H2/2	H4/4	H2/2
Mean	9.06	6.92	16.66	12.08	11.72	7.55
SD ±	0.059	0.106	1.69	0.068	0.86	0.27
Minimum	8.99	6.77	17.21	11.99	11.99	7.322
Maximum	9.12	6.999	17.6	12.14	12.71	7.96
t	12.21		3.21		5.1	
P	< 0.001		0.011		0.002	

Table 5: *Statistical comparison of TBARS content in the repeatedly heated oils for four times; each 1/4 hour (H 4/4) and the repeatedly heated oils two times each 1/2 hour (H 2/2).*

	Sunflower oil		Cottonseed oil		Mixed oil	
	H4/4	H 1	H4/4	H 1	H4/4	H 1
Mean	9.06	4.07	16.66	10.47	11.72	6.95
SD ±	0.059	0.007	1.69	0.004	0.86	0.003
Minimum	8.99	3.991	17.21	10.41	11.99	6.913
Maximum	9.12	4.147	17.6	10.51	12.71	6.993
t	15.1		4.23		6.12	
P	< 0.001		0.005		< 0.001	

Table 6: *Statistical comparison of TBARS content in the repeatedly heated oils for four times; each 1/4 hour (H 4/4) and the oils heated once for one hour (H 1).*

	Sunflower oil		Cottonseed oil		Mixed oil	
	H 2/2	H 1	H 2/2	H 1	H 2/2	H 1
Mean	6.92	4.07	12.08	10.47	7.55	6.95
SD ±	0.106	0.007	0.068	0.004	0.27	0.003
Minimum	6.77	3.991	11.99	10.41	7.322	6.913
Maximum	6.999	4.147	12.14	10.51	7.96	6.993
t	25.5		16.1		2.91	
P	< 0.001		< 0.00		0.025	

Table 7: *Statistical comparison of the TBARS content in the repeatedly heated oils for two times; each 1/2 hour (H 2/2) and the oils heated once for one hour (H 1).*

	Fresh	H 1/4	H 2/4	H 3/4	H 4/4	H 1/2	H 2/2	H 1
Comparison of sunflower oil versus cottonseed oil								
t	18.47	22.22	26.1	35.1	4.31	33.1	40.5	72.1
p	< 0.001	< 0.001	< 0.001	< 0.001	0.003	< 0.001	< 0.001	< 0.001
Comparison of sunflower oil versus mixed oil								
t	2.35	14.5	9.5	8.1	3.12	32.1	2.12	35.1
p	< 0.011	< 0.001	< 0.001	< 0.001	0.008	< 0.001	0.014	< 0.001
Comparison of cotton seed oils versus mixed oils								
t	18.1	3.51	9.5	2.71	3.7	16.1	15.1	52.1
p	< 0.001	0.003	< 0.001	0.012	0.002	< 0.001	< 0.001	< 0.001

Table 8: *Statistical comparison of TBARS content in the studied.*

Discussion

The role of dietary fat and oils in human nutrition is one of the important areas of concern and investigation in the field of nutritional science. The findings of these investigations have wide ranging implications for consumers, health care providers and nutrition educators, as well as food producers, processors and distributors. New evidence concerning the benefits and risks associated with aspects of dietary fat is constantly emerging in both the scientific literatures and the popular media. At times, controversies about these findings evolve [12].

Deep fat frying is an important, ubiquitous, and highly versatile process, which has been used since antiquity to cook a wide spectrum of products. Its unique contribution to sensory characteristics, together with the relatively low cost of large-scale frying, has made fried foods the staples of the ever-growing late 20th century fast food industry [4].

The use of oil remains one of the most popular methods for the preparation of foods. This is particularly true in Egypt and the majority of the Arab world where falafel (a deep-fried vegetable patty) forms the staple food item in the diet and is widely available at street level from vendors [5].

So, this work aimed to study the effect of heating on oils mostly used in Egypt.

Because of concern about the types of changes that take place in fat during oxidative and thermal deterioration and the effects the deterioratives could have on the consumer, many chemical and biological studies have been carried out. Experimental findings indicate that the potential danger to the consumer is relative to the severity of the overall treatment of the fat [13]. Malonaldehyde (TBARS) measurement is one of the oldest and most frequently used tests for measuring the lipid peroxidation of fatty acids because of the simplicity of the test, it has been widely applied to measure the lipid peroxidation [14].

Results of this study showed that there is an increase in the TBARS content of the studied heated oils which was more rising on increasing the duration of heating. It was found that the TBARS content of sunflower and cottonseed oils increased significantly in oils heated for 1/4 hour ($P < 0.05$) and extremely significantly in oils heated for 1/2 hour and one hour ($P < 0.001$). In mixed oil, TBARS increased extremely significantly ($P < 0.001$) in different durations of heating in comparison to the fresh oil. These results coincide with those observed in other studies on heated sunflower oil. TBARS content of sunflower oil heated for 48 hours at constant temperature 110˚C was 490 µmol/Kg compared to 8 µmol/kg in fresh oil [15].

Results of the present study coincide also with those observed in other studies. It was found that the TBARS content of cottonseed oil heated for 5 and 60 minutes was 0.201 and 0.712 nmol/ml respectively compared to 0.132 nmol/ml in the fresh oil. While sunflower oil heated for 5 and 60 minutes contained TBARS 0.170, and 0.647 nmol/ml respectively compared to 0.101 nmol/ml in the fresh oil [16]. It was also found that the repeatedly heated cottonseed oil in restaurants contained 98.9 ± 51.75 nmol/gm TBARS in contrast to 9.1 ± 3.69 nmol/gm in the fresh oil [17].

Results of the present work showed also that the repeatedly heated oils showed extremely significant increase ($P < 0.001$) in TBARS content in contrast to the fresh oils. Moreover, increasing the times of repetition of heating causes more rising in the level of TBARS in oils. During comparison of repeatedly heated oils four times; each 1/4 hour (H4/4) to those repeatedly heated twice; each 1/2 hour (H2/2), the former showed significant increase in TBARS content in all the studied oils (Table 4). During comparison of repeatedly heated oils four times; each 1/4 hour (H4/4) to those heated once for one hour (H1), the former showed significant increase in TBARS content in all the studied oils. Also, comparison of repeatedly heated oils twice; each 1/2 hour (H2/2) to those heated once for one hour (H1), the former showed significant increase in TBARS content in all the studied oils.

These results indicate that repetition of heating increases the level of TBARS more than the continuous heating. These results agree with previous study that predicted that repeated heating is more damaging to the oil more than continuous heating [18].

Alternative heating and cooling is more damaging than continuous heating. This may be explained by that at a high temperature (during continuous heating) the water is lost more quickly producing a steam blanket over the frying kettle and protect the fat against atmospheric oxygen [13]. FAO also stated that the continuous heating provides a protective water vapour blanket that protects against oxidation [12].

Results of the present work revealed that the TBARS content of fresh and heated cottonseed oils was significantly higher than the TBARS content of fresh and heated sunflower oils for comparable periods. The TBARS content of fresh and heated mixed oils was significantly higher than the TBARS content of fresh and heated sunflower oils for comparable periods. The TBARS content of fresh and heated cottonseed oils was significantly higher than the TBARS content of fresh and heated mixed oils for comparable periods. This means that the cottonseed oil was exposed to the deteriorative effect of heating more than the mixed oil and the sunflower oil. These results coincide with previous research that detected high levels of TBARS in cottonseed oil heated for 5 or 60 minutes than in sunflower oil heated for comparable periods [16].

Based on the fact that sunflower oil contains more polyunsaturated fatty acids than cottonseed oil and taking into consideration that oxidation products of frying oil differ according to the fatty acid content of the oil and the oxidative stability of vegetable oils was traditionally related to the degree of unsaturation of their fatty acids [19], it may be predicted that heated sunflower oil contains more TBARS than cottonseed oil but results of this study revealed that sunflower oil contains TBARS less than cottonseed oil. This agree with the concept that fat high in monoenes may be considerably more toxic than more highly unsaturated fats when heated under the same conditions [13] and also support the opinion that fatty acid unsaturation of dietary oils is not the only determining factor of the antioxidant capacity. Therefore, the optimal balance between the content of unsaturated fatty acids and natural antioxidants in dietary oils appear to be of major importance [20].

It was published that the degree of unsaturation of an oil has little, if any, effect on its smoke point (smoke point is the temperature at which smoke is first detected from the heated oil). Oils containing fatty acids of low molecular weight have lower smoke points than others of comparable fatty acids content. Moreover, recent work suggest that the benefits occurred by lowering polyunsaturated fatty acids could be lost if the levels of antioxidants such as tocopherols are reduced [19]. So, the present study agrees with Cabrini's study who attributed the high total radical trapping antioxidant parameters in sunflower oil to the very high amount of α-tocopherol in the oil [21].

Moreover, supplementation of the frying oil with vitamin E was found to increase the stability of the oil under prooxidant conditions and its intake increases the *in vivo* protection against lipid peroxidation [22]. So, in terms of thermal stability during frying, the overall results showed an improved behaviour and quality of the treated oils (mixed with antioxidant) than of the pure oils [23].

So, it must be taken into account that the evaluation of the frying performance of oil is a complicated task suggesting that more than one parameter should be measured to follow changes that take place in the oil. Clearly the fatty acid composition of the oil is not the only factor determining the frying stability of oil. The presence of minor components such as tocopherols in the oil as well as processing effects (temperature, addition of citric acid) and the frying practices used (addition of antifoaming agent, replenishing of the oil) all play an important role in influencing the stability of an oil [24]. During frying, changes take place in oil due to thermal degradation, oxidation, and hydrolysis. The rate of decomposition depends on the composition of the oil, the temperature and period of frying, whether continuous or intermittent frying is used, the type of food fried, and whether or not fresh oil is added to replenish the frying oil [25,26].

Conclusion

Assessing the effect of heating on oils by measurement of the TBARS content in the studied oils, revealed that the deteriorative effect of heat increases by increasing the duration of oil use (e.g. TBARS content of oils heated for 1 hour was more than that in oils heated for 1/2 hour and much more than that in oils heated for 1/4 hour). Moreover, the repetition of heating was much more destructive than the continuous use of the oil (e.g. TBARS content of oils used for one hour frying session was less TBARS content of oils used for two sessions; each 1/2 hour and was much less than TBARS content of oils used for four sessions; each 1/4 hour). It was shown also that heating increases the TBARS content in the cottonseed oil more than the mixed oil and the sunflower oil. So, it is concluded that frying is better avoided (especially for long periods) and repeated use of the oil for frying must be avoided even with short periods of use because repeated heating of the oil produced much more TBARS than the continuous heating.

Bibliography

1. Warner K. "Impact of high temperature food processing on fats and oils". *Advances in Experimental Medicine and Biology* 459 (1999): 67-77.

2. Donnelly JK and Robinson DS. "Free radicals in foods". *Free Radical Research* 22.2 (1995): 147-176.

3. Mc Savage J and Trevisan S. "The use and abuse of frying oil". *Food Service Technology* 1.2 (2001): 85-94.

4. Saguy IS and Dana D. "Integrated approach to deep fat frying: engineering, nutrition, health and consumer aspects". *Journal of Food Engineering* 56 (2003): 143-153.

5. Tewfik IH., *et al*. "The effect of intermittent heating on some chemical parameters in refined oils used in Egypt. A public health nutrition concern". *International Journal of Food Sciences and Nutrition* 49.5 (1998): 339-342.

6. Paul S and Mittal GS. "Regulating the use of degraded oil/fat in deep-oil/fat food frying". *Critical Reviews in Food Science and Nutrition* 37.7 (1997): 635-662.

7. Lopez Bote CJ., *et al*. "Dietary vegetable oils and α tocopherol reduce lipid oxidation in rabbit muscle". *Journal of Nutrition* 127.6 (1997): 1176-1182.

8. Weisburger JH. "Eat to live, not live to eat". *Nutrition* 16.9 (2000): 767-773.

9. Andrikopoulos NK., *et al*. "Deterioration of natural antioxidant species of vegetable edible oils during the domestic deep frying and pan frying of potatoes". *International Journal of Food Sciences and Nutrition* 53.4 (2002): 351-363.

10. Ohkawa H., *et al*. "Assay for liquid peroxides in animal tissue by thiobarbituric acid reaction". *Analytical Biochemistry* 95 (1979): 351-358.

11. Draper HH., *et al*. "Comparative evaluation of thiobarbituric acid methods for the determination of malonaldehydes in biological materials". *Free Radical Biology and Medicine15* (1993): 353-363.

12. FAO. "Fats and oils in human nutrition". Report of a joint expert consultation organized by the Food and Agriculture Organization of the United Nations and the World Health Organization, 19 – 26 October. Rome, Italy (1994).

13. Alexander JC. "Chemical and biological properties related to toxicity of heated fats". *Journal of Toxicology and Environmental Health* 7 (1981): 125-138.

14. Halliwell B and Gutteridge JMC. "The antioxidants of human extracellular fluids". *Archives of Biochemistry and Biophysics* 280 (1990): 1-8.

15. Eder K and Stangl G. "Plasma thyroxin and cholesterol concentrations of miniature pigs are influenced by thermally oxidized dietary lipids". *The Journal of Nutrition* 130 (2000): 116-121.

16. Abdel Khalek SM and Abdel Rahman MK. "Natural vitamins as antioxidants". *Egyptian German Society of Zoology* 19 (1996): 55-68.

17. El-Mehallawi I., *et al*. "Peroxidative damage and cancer colon risk in animals fed repeatedly heated cottonseed oil". *Mansoura Journal of Forensic Medicine and Clinical Toxicology* 8.2 (2000): 191-212.

18. Andrikopoulos NK., *et al*. "Quality assessment of frying oils and fats from 63 restaurants in Athens, Greece". *Food Service Technology* 3.2 (2003): 49-57.

19. Botha I., *et al*. Effect of cultivar and location on fatty acids and tocopherols in regular and genetically modified soybean oils". 94th AOCS annual meeting and expo., Kansas city, Missouri, USA (2003).

20. Scaccini C., *et al*. "Effect of dietary oils on lipid peroxidation and on antioxidant parameters of rat plasma and lipoprotein fractions". *Journal of Lipid Research* 33 (1992): 627-633.

21. Cabrini L., *et al*. "Antioxidants and total peroxyl radical trapping ability of olive and seed oils". *Journal of Agricultural and Food Chemistry* 49 (2001): 6026-6032.

22. Quiles JL., *et al*. "Vitamin E supplementation increases the stability and the in vivo antioxidant capacity of refined olive oil". *Free Radical Research* 31 (1999): 129-135.

23. Goburdhun D and Jhurree B. "Effect of deep fat frying on fat oxidation in soybean". *International Journal of Food Sciences and Nutrition* 46.4 (1995): 363-371.

24. Petukov I., *et al*. "Frying performance of genetically modified canola oils". *Canola Oil* 28 (1993): 287-296.

25. Blumenthal MM. "A new look at the chemistry and physics of deep fat frying". *Food Technology* 45 (1991): 68-71.

26. Melton SL., *et al*. "Review of stability measurements for frying oils and fried food flavor". *Journal of the American Oil Chemists' Society* 71 (1994): 1301-1308.

Volume 11 Issue 6 June 2023