***Minireview Article***

# Towards greener preservation of edible oils, A mini-review

.


## ABSTRACT

Edible oils like sunflower oil, rapeseed oil, soybean oil, cotton seed oil and olive oil are necessary components in human diet and are extensively utilized in the food trade. Safe storage of edible oils has perpetually been a haul within the food industry since the oils can easily endure oxidative deterioration. Studies specializing in polyphenols as a supply of natural antioxidants of plant origin to delay oxidative deterioration of food products have enlarged worldwide. Both natural and synthetic antioxidants are widely used in protecting oils against oxidative deterioration. Natural antioxidants are greener preservatives because they are known to be safer than their synthetic counterparts. Currently there is an increased interest in sources of natural antioxidants to enrich oils towards shelf life enhancement. This review highlights some research works in which natural antioxidants from plant materials have been used to preserve edible oils. Most of the natural compounds extracted from medicinal plants were found to be able to preserve edible oils against oxidative deterioration. The potential of most of the natural antioxidants from plant materials to preserve edible oils was found to be comparable to that of synthetic antioxidants in all the reviewed researches. Use of natural antioxidants from plant materials for preservation of edible oils is a promising approach that can be adopted by edible oil manufacturers.



*Keywords: Edible oil, polyphenols, antioxidants, preservation, medicinal plants*


## 1. INTRODUCTION

Herbal products have always been helpful to man since long back. Traditional herbs are gaining much attention in both developing and developed countries mainly due to the fact that they proved to have little or no known side effects. The use of traditional herbs has now gained vital importance the world over [40]. Medicinal plants in general have been used and are still being used in a number of ways by man. Man has exploited these special plants as medicines for various ailments, food and as food additives.

Use of herbs as sources of preservatives for food and other products is an emerging area which has attracted the attention of many researchers. Plants are being used as sources of preservatives for edible oils, meat, milk, bread, beverages and other different food products. This review will look at the application of phytochemicals in the preservation of edible oils.

Medicinal plants, additionally known as ancient herbs, are discovered and utilized in ancient medication practices since prehistoric times [2]. Plants are known to synthesize many advanced chemical compounds for various functions which include defense against inclement weather, insects, fungi, diseases, and phytophilous mammals [3, 16, 31]. Various phytochemicals with potential or established biological activities are known in medicinal plants [14, 25]. Medicinal plants are now in wide use among non-industrialized societies, primarily as a result of their availability and being cheaper than fashionable medicines. However, the developed communities have additionally recently turned to greener and safer product from plants for safety reasons [35].

The helpful effects of plant products are primarily attributed to their phytochemical composition. Phytochemicals are complex biologically active chemical compounds found in plants. Amongst these phytochemicals are plant secondary metabolites such as alkaloids, anthocyanins, flavonoids, phenolic acids, terpenes, lignans, seroids and saponins [50]. Different phytochemicals are known to exhibit varying biological activities in-vivo and in-vitro [40]. Among the commonest biological activities exhibited by some phytochemicals include antioxidant, antibacterial, antihypertensive, anticancer and antiviral.

Edible oils are prone to oxidative deterioration. During oil purification and food processing, heat or chemicals are used and this can result in weakening or loss of valuable nutrients including tocopherols, sterols, and important antioxidant compounds [37]. Oxidation reactions of lipids and oil based food products have significant concerns in the food processing industry [10]. Moreover, on exposure to oxygen, light and high temperatures under storage or in use, oils and oil containing foods are at risk of oxidative deterioration reactions leading to changes in their organoleptic properties, shelf life, nutritional value and safety [16, 22, 27].

The oxidative inhibitory property of phytochemicals is very important in food preservation. The utilization of artificial antioxidants in macromolecule based foods to keep up oxidative stability has been condemned because they are considered carcinogenic [24, 25]. The common artificial antioxidants employed in the oil and food trade embody butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertiary-butyl hydroquinone (TBHQ), all of which have been reported to cause and promote harmful effects to human health [7, 33, 36]. Use of traditional herbs as natural antioxidants to prolong the shelf life of edible oils and food therefore becomes a more preferable option among food manufacturers [14, 38].

## 2. NATURAL AND SYNTHETIC FOOD PRESERVATIVES

Food preservatives are chemical substances that are used to inhibit the deterioration of food under prevailing conditions. Besides preserving the food, preservatives can also perform other functions in food that includes improving food texture, enhancing the flavor, improving its appearance, and prolonging its shelf life [39]. To provide edible oils of acceptable quality, food manufacturers need to use preservatives. Quite a number of natural and synthetic preservatives are available for food preservation.

BHA and BHT have been used as synthetic antioxidant preservatives in edible oils and other different food products that contain oil or fat [39]. TBHQ is another synthetic antioxidant used in edible oils and a variety of other food products. The aforementioned antioxidants are wholly synthetic compounds produced in laboratories. Although BHT, BHA and TBHQ are known to be effective preservatives, they have a number of drawbacks. Several health concerns and/or adverse reactions have been found to be associated with BHA, BHT and TBHQ. Even if the majority of studies have been carried out on animals, there is still quite a large body of research that has identified problems with these synthetic antioxidants for humans [10, 39]. Adverse reactions which include dermatitis, vasomotor rhinitis, headache, flushing, asthma, conjunctival suffusion, allergies and angioedema have been reported in humans upon exposure to BHA, BHT and/or TBHQ [11, 12]. A number of people have been found to be allergic to BHA [18]. Haas and Levin noted that BHT irritates the liver and kidneys in humans [17]. Exposure to the vapors of TBHQ has been found to be associated with eye irritation and skin irritation in man [48].

Ascorbic acid (Vitamin C) and Tocopherols (Vitamin E) are plant derived antioxidants that are in wide use within the food and the edible oil industry. Vitamin C happens naturally in several fruit and vegetables and may even be factory-made synthetically. Vitamin C salts specifically sodium ascorbate and calcium ascorbate can be synthesized from vitamin C and used as food antioxidants. Tocopherols are naturally found in plant tissues particularly in nuts, vegetable oils, fruits and vegetables. Tocopherols are naturally found in plant tissues especially in nuts, vegetable oils, fruits and vegetables. Vitamin C and tocopherols are the most typical natural antioxidants utilized in edible oils and food products. Though they are added to food, they can be found naturally in most food products including edible oils. Their concentrations are

sometimes lower in processed foods since they are lost through processing. Their concentrations are usually lower in processed foods since they are lost during processing. Vitamin C and tocopherols are comparatively weak antioxidants compared to the artificial phenolic antioxidants and have restricted carry through properties [26]. Vitamin C and tocopherols are usually seen as being safe for human use and there are virtually no reports on their health issues in humans [39].

There are quite a variety of alternative oxidative inhibitor compounds derived from plant polyphenols. The major categories of polyphenols embody phenolic resin acids, flavonoids, stilbenes and lignans [34, 46]. Antioxidants derived from plant polyphenols, have been found to be effective preservatives for edible oils [10, 16, 42]. Use of antioxidant compounds derived from plant polyphenols in edible oil preservation is a new area which is showing a great potential to bring a healthier and greener future for edible oil manufacturers and their consumers. Antioxidant compounds derived from plant polyphenols are generally seen as being safe for human use and there are virtually no reports of adverse reactions to date [39].

## 4. LIPID OXIDATION

Lipid oxidation is a complex process which involves a number of factors and occurs in almost every biological system [37]. Lipid oxidation occurs through three main pathways namely: non-enzymatic chain auto-oxidation induced by free radicals, enzymatic oxidation and non-radical photoxidation [47, 49]. The free radical evoked pathway is thought to cause the bulk of macromolecule reaction reactions in edible oils and most food products [28]. Fotina [13] outlined the initiation step of lipid oxidation, in which a hydrogen atom (H•) is abstracted from an unsaturated fatty acid (R) by oxygen to form an alkyl radical as shown below:

RH + O=O + Initiator → R• (Alkyl radical) + HOO•

Autoxidation then proceeds through the normal free radical reaction pathway. The reaction proceeds through propagation steps in which more fatty acids are attacked by free radicals ultimately forming lipid hydroperoxides (ROOH). The reaction proceeds as a chain reaction which is terminated when two radicals combine. Heat, metal ion catalysis or light can cause hydroperoxide decomposition.

The lipid oxidation products, lipid hydroperoxides are characterized by lack of taste and odor which ultimately affects the oil or food. Lipid hydroperoxides can also decompose to products that are responsible for off-odors and off-flavors in edible oils and foods [45]. Figure 1 below summarizes the reaction mechanism for lipid oxidation.

Initiation Stage

$R\bullet + LH \rightarrow R\text{-}H + L\bullet$

Propagation Stage

$L\bullet + O_2 \rightarrow LOO\bullet$

$LOO\bullet + O_2 \rightarrow LOOH + L\bullet$

$A\text{-}H + L\bullet \rightarrow A\bullet + L\text{-}H$

$A\text{-}H + LOO\bullet \rightarrow A\bullet + LOO\text{-}H$

Termination Stage

$LOO\bullet + LOO\bullet \rightarrow LOOH + O_2$

$LOO\bullet + L\bullet \rightarrow LOOL$

**Figure 1: Summary of Lipid oxidation reaction [43]**

*R• = Alkyl radical, L = lipid, A= Antioxidant present*

## 4. ACTION OF ANTIOXIDANTS

An antioxidant is a compound that can considerably inhibit or stop the oxidation of a substance when available in smaller amounts as compared to the substrate being oxidized [32]. Antioxidants can be categorized into primary and secondary antioxidants depending on the mechanism of action in relieving oxidative stress [43].

Primary antioxidants react directly with free radicals by either trapping carbon-centered radicals in competition with oxygen to terminate the propagation step of lipid oxidation or by donating electrons to radicals, resulting in scavenging of radicals before they propagate oxidation reactions [9]. Primary antioxidants are referred to as radical scavengers and can prevent oxidation by two mechanisms [44]. They can function in the initiation stage by scavenging reactive oxygen species (ROS) before they react with lipids or they can function in the propagation stage where they will scavenge lipid propagators such as peroxide radicals (LOO•).

Secondary antioxidants control the initiation of new chain reactions by destroying hydrogen peroxides through chelation of transition metals, which would give rise to other radicals [49]. Secondary antioxidants are known to function as metal chelators or serve to restore other antioxidants [49]. Metal chelating compounds which can act as pro-oxidants, also serve as important antioxidants by making metals unavailable to initiate lipid oxidation [30].

### 4.1 Plant derived antioxidant compounds as oil preservatives

The quality and stability of edible oils are the most factors influencing its acceptableness and value [4]. One of the most important indicators of the storage quality of edible oil is its oxidative stability [47]. The oxidative stability of edible oils is thought to rely upon temperature, light, oxygen, metals, enzymes, the presence of antioxidants or pro-oxidants, fatty acid composition, and the use of oxygen permeable packages [1, 37]. Changes in oil quality during processing, use and storage are a major issue from the health perspective.

The potential of various extracts of different plants in preventing oxidative deterioration of edible oils has been investigated by different researchers [3, 6, 7, 10, 16, 21, 23, 31]. Attributable to their antioxidant activity and antimicrobial properties, plant extracts rich in polyphenols are helpful in conserving food merchandise from aerophilic deterioration, microorganim spoilage, and also the growth of pathogens [35]. Antioxidants, which are components of polyphenols, inhibit lipid oxidation and retards oxidative deterioration of fats and foods [19].

Gazwi, [16] studied the oxidative stability of sunflower oil as affected by *Carica papaya* leaf extracts during accelerated oxidative storage conditions. *Carica papaya* leaf extracts positively showed the presence of polyphenolic compounds that includes phenols, flavonoids and tannins [16]. Gazwi, [16] discerned that *Carica papaya* leaf extracts have a protective effect against oxidation of sunflower oil that is comparable to that of synthetic antioxidants. From the findings, Gazwi [16] concluded that *Carica papaya* leaf extracts can serve as substitutes for synthetic antioxidants in oil and food preservation.

Ali and co-researchers, [3] investigated the oxidative stability of a mix of canola, rapeseed and sunflower oils stabilized with leaf extracts of *Eucalyptus citriodora* under accelerated oxidative storage conditions. The ethanolic extract of *Eucalyptus citriodora* which yielded a total phenolic content and total flavonoid content of 5.23 ±0.19 and 1.18 ±0.04 g/100g dry weight respectively was found to be effective in maintaining the oxidative stability of blended vegetable oils [3].

*Eucalyptus citriodora* extracts stabilized the vegetable oil blend for a duration of 6 months, which was longer as compared with control oil samples. The oil stabilizing power of *Eucalyptus citriodora* extracts is largely attributed to its high total phenolic content and total flavonoid content. The work shows that phenolic compounds and flavonoids from *Eucalyptus citriodora* have antioxidant potential that is capable of preserving the edible oils.

Kozlowska and Zawada, [23] evaluated the oxidative stability of sunflower and rapeseed oils enriched with herb extracts using Electron Paramagnetic Resonance Spectroscopy (EPR). [23] found out that the herb extracts generally improved radical scavenging properties of sunflower and rapeseed oils. In other words, the herb extracts improved the oxidative stability of the two edible oils.

Chen [7] investigated the inhibitory effects of *Rosemary* extracts on sunflower oil compared with artificial antioxidants. The findings by [7] showed that *Rosemary* extracts exhibited considerable antioxidant activity almost equal to that of synthetic antioxidants BHA and BHT. Jaber and co-researchers [21] did a similar research in which the stabilization of refined olive oil enriched with plant chlorophyll pigments extracted from *Chemlali olive* leaves was investigated. Based on the Rancimat method, Jaber and co-researchers [21] found out that olive oil samples with added leaf pigment extract were the most stable and had the lowest peroxide values as compared to those without leaf pigment extract added.

The table below summarizes some more findings on the effect of different plant extracts on the stability of different edible oils.

**Table 1: Summary of findings on the effect of different plant extracts on the stability of different edible oils**

| Plant extract used | Edible Oil studied | Author(s) | Year | Findings |
|---|---|---|---|---|
| *Garcinia mangostana Linn* | Sunflower oil | [8] | 2015 | Extract exhibited inhibitory effect against both primary and secondary oxidation up to 24 days under accelerated storage conditions. |
| *Nephelium lappaceum L* | Sunflower Oil | [29] | 2014 | Extract worked more effectively than the synthetic antioxidant (BHA) |
| *Temnocalyx obovatus* | Soya oil and Sunflower oil | [10] | 2012 | Extracts showed better protection against oil oxidation than TBHQ. |
| *Rosmarinus officinalis* | Sunflower oil | [6] | 2010 | Antioxidant activity of herbs was comparable to that of a commercial rosemary extract and BHA. |
| *Garlic* | Sunflower oil | [20] | 2007 | *Garlic* extract found to be a potent antioxidant as compared to BHA and BHT. |
| *Rosmarinus officinalis* | Sunflower oil (In a dressing mix) | [15] | 2005 | Sunflower oil dressing revealed no rancidity over 6 days of storage at 50°C. |

| | | | | |
|---|---|---|---|---|
| *Ginger* | Sunflower oil | [41] | 2003 | *Ginger* extract exhibited very strong antioxidant activity, almost equal to that of synthetic antioxidants (BHA and BHT). |

## 4. CONCLUSION

Quite a number of medicinal plant extracts exhibited potent antioxidant effects in edible oils. Medicinal plants are novel sources of antioxidant compounds that can be used as preservatives in the edible oil and food industries. A number of medicinal plant extracts have been found to have preservative effects against lipid oxidation that are better than or compare very well with synthetic antioxidants. There is need to isolate antioxidants compounds from medicinal plants and make them available to food and edible oil manufacturers. Use of plant derived antioxidants is a promising greener approach in edible oil and food processing that can be adopted by edible oil manufacturers. Promoting use of natural antioxidants in food preservation is key to providing effective substitutes for toxic synthetic antioxidants and addressing the health concerns of man. Due to the preservative properties against food deterioration of their extracts, medicinal plants such as *Garcinia mangostana Linn, Nephelium lappaceum L, Temnocalyx obovatus and Rosmarinus officinalis* need to be preserved and their cultivation should be increased. Moreover, the potential applications of these medicinal plants in other fields such as beverages, cosmetics, polymers and pharmaceuticals need to be studied. There is need to investigate the possibility of using extracts from other underutilized medicinal plants as food preservatives.

## COMPETING INTERESTS

Author declared that there are no competing interests.

## REFERENCES


1. Ahmad T, Atta S, Zeb AU, Gul SA. Effect of saturation and micro nutritional status on stability of dietary oils under photooxidative stress condition. Journal of the Chemical Society of Pakistan. 2011;33(3):343-350.
2. Ahn K. The worldwide trend of using botanical drugs and strategies for developing global drugs. BMB reports. 2017;50(3):111.
3. Ali S, Chatha SA, Ali Q, Hussain AI, Hussain SM, Perveen R. Oxidative stability of cooking oil blend stabilized with leaf extract of Eucalyptus citriodora. International Journal of Food Properties. 2016;19(7):1556-1565.
4. Almeida DT, VIana TV, Costa MM, Silva CD, Feitosa S. Effects of different storage conditions on the oxidative stability of crude and refined palm oil, olein and stearin (Elaeis guineensis). Food Science and Technology. 2019;39(1): 211-217.
5. ALMEIDA DT, Curvelo FM, Costa MM, Viana TV. Oxidative stability of crude palm oil after deep frying akara (Fried Bean Paste). Food Science and Technology. 2018;38(1):142-147.
6. Babović N, Žižović I, Saičić S, Ivanović J, Petrović S. Oxidative stabilization of sunflower oil by antioxidant fractions from selected lamiaceae herbs. Chemical Industry and Chemical Engineering Quarterly/CICEQ. 2010;16(4):287-293.
7. Chen X, Zhang Y, Zu Y, Yang L, Lu Q, Wang W. Antioxidant effects of rosemary extracts on sunflower oil compared with synthetic antioxidants. International Journal of Food Science & Technology. 2014;49(2):385-391.
8. Chong YM, Chang SK, Sia WC, Yim HS. Antioxidant efficacy of mangosteen (Garcinia mangostana Linn.) peel extracts in sunflower oil during accelerated storage. Food bioscience. 2015;1(12):18-25.
9. Dauqan EM, Abdullah A, Sani HA. Natural antioxidants, lipid profile, lipid peroxidation, antioxidant enzymes of different vegetable oils. Advance Journal of Food Science and Technology. 2011;3(4):308-316.
10. Dzomba P, Togarepi E, Musekiwa C, Chagwiza CJ. Improving oxidative stability of soya and sunflower oil using Temnocalyx obovatus extracts. African Journal of Biotechnology. 2012;11(50):11099-11103.
11. Fisherman EW, Cohen GN. Aspirin and other cross-reacting small chemicals in known aspirin intolerant patients. Annals of allergy. 1973;31(10):476-484.

12. Fisherman EW, Cohen G. Chemical intolerance to butylated-hydroxyanisole (BHA) and butylated-hydroxytoluene (BHT) and vascular response as an indicator and monitor of drug intolerance. Annals of allergy. 1973;31(3):126.
13. Fotina AA, Fisinin VI, Surai PF. Recent developments in usage of natural antioxidants to improve chicken meat production and quality. Bulgarian Journal of Agricultural Science. 2013;19(5):889-896.
14. Muanda NF, Dicko A, Soulimani R. Chemical composition and biological activities of Ficus capensis leaves extracts. Journal of Natural Products. 2010;3(1):147-60.
15. Frutos MJ, Hernandez-Herrero JA. Effects of rosemary extract (Rosmarinus officinalis) on the stability of bread with an oil, garlic and parsley dressing. LWT-Food Science and Technology. 2005;38(6):651-655.
16. Gazwi, H. Oxidative stability of sunflower oil as affected by Carica papaya leaves extracts during accelerated oxidative storage. International Journal of Biosciences. 2017; 1(11): 116-126.
17. Haas E, Levin B. Staying healthy with nutrition, rev: the complete guide to diet and nutritional medicine. Celestial Arts; 2012.
18. Hanssen M. E for Additives. Thorsons 1991.
19. Indrasena WM, Barrow CJ. Oxidation and stability of food-grade fish oil: role of antioxidants. Handbook of seafood quality, safety and health applications. 2010;317-334.
20. Iqbal S, Bhanger MI. Stabilization of sunflower oil by garlic extract during accelerated storage. Food Chemistry. 2007;100(1):246-254.
21. Jaber H, Ayadi M, Makni J, Rigane G, Sayadi S, Bouaziz M. Stabilization of refined olive oil by enrichment with chlorophyll pigments extracted from Chemlali olive leaves. European journal of lipid science and technology. 2012;114(11):1274-1283.
22. Katragadda HR, Fullana A, Sidhu S, Carbonell-Barrachina ÁA. Emissions of volatile aldehydes from heated cooking oils. Food Chemistry. 2010;120(1):59-65.
23. Kozłowska M, Zawada K. Evaluation of oxidative stability of vegetable oils enriched with herb extracts by EPR spectroscopy. Chemical Papers. 2015;69(7):950-957. doi: 10.1515/chempap-2015-0102.
24. Lafka TI, Sinanoglou V, Lazos ES. On the extraction and antioxidant activity of phenolic compounds from winery wastes. Food Chemistry. 2007;104(3):1206-1214.
25. Lapornik B, Prošek M, Wondra AG. Comparison of extracts prepared from plant by-products using different solvents and extraction time. Journal of food engineering. 2005;71(2):214-22.
26. Madhavi, D. L., R. S. Singhal, and P. R. Kulkarni. "Technological aspects of food antioxidants." In Food antioxidants, pp. 173-280. CRC Press, 1995.
27. Maforimbo E. Evaluation of capsicum as a source of natural antioxidant in preventing rancidity in sunflower oil. Journal of Food Technology in Africa. 2002;7(2):68-72.
28. Jalosinska M, Wilczak J. Influence of plant extracts on the microbiological shelf life of meat products. Polish Journal of Food and Nutrition Sciences. 2009;59(4):303-308.
29. Mei W, Ismail A, Esa N, Akowuah G, Wai H, Seng Y. The effectiveness of rambutan (Nephelium lappaceum L.) extract in stabilization of sunflower oil under accelerated conditions. Antioxidants. 2014;3(2):371-386.
30. Mitra J, Guerrero EN, Hegde PM, Wang H, Boldogh I, Rao KS, Mitra S, Hegde ML. New perspectives on oxidized genome damage and repair inhibition by pro-oxidant metals in neurological diseases. Biomolecules. 2014;4(3):678-703.
31. Nderitu SM, Nawiri MP, Nyambaka HN. Fortification of sunflower and palm oils using beta carotene extracted from Asystasia mysorensis and Solanum nigrum. Food Research. 2018;2(5):437-442.
32. Orhan C, Sahin N, Akdemir F, Markiewicz-Zukowska R, Borawska MH, Isidorov VA, Hayirli A, Sahin K. The effect of Cirsium arvense extract on antioxidant status in quail. British poultry science. 2013;54(5):620-626.
33. Özcan MM, Arslan D. Antioxidant effect of essential oils of rosemary, clove and cinnamon on hazelnut and poppy oils. Food Chemistry. 2011;129(1):171-174.
34. Pandey KB, Rizvi SI. Plant polyphenols as dietary antioxidants in human health and disease. Oxidative medicine and cellular longevity. 2009;2(5):270-278.
35. Papuc C, Goran GV, Predescu CN, Nicorescu V, Stefan G. Plant polyphenols as antioxidant and antibacterial agents for shelf-life extension of meat and meat products: classification, structures, sources, and action mechanisms. Comprehensive Reviews in Food Science and Food Safety. 2017;16(6):1243-1268.
36. Pimpa B, Kanjanasopa D, Boonlam S. Effect of addition of antioxidants on the oxidative stability of refined bleached and deodorized palm olein. Kasetsart J (Nat Sci). 2009;43:370-377.

37. Pristouri G, Badeka A, Kontominas MG. Effect of packaging material headspace, oxygen and light transmission, temperature and storage time on quality characteristics of extra virgin olive oil. Food control. 2010;21(4):412-8.
38. Racanicci Aline MC, Danielsen Bente Jos, Fernando M, Menten Marisa AB, Regitano-d'Arce, Leif H, Skibsted. Antioxidant effect of dittany (Origanum dictamnus) in pre-cooked chicken meat balls during chill-storage in comparison to rosemary (Rosmarin.us officinalis). Eur. Food. Res. Technol. 2004;218(1):521–524
39. Race S. Antioxidants. The truth about BHA, BHT, TBHQ and other antioxidants used as food additives. 2009.
40. Rai R, Nath V. Use of medicinal plants by traditional herbal healers in Central India. Indian Forester. 2005;131(3):463-468.
41. Salariya AM, Habib F. Antioxidant activity of ginger extract in sunflower oil. Journal of the Science of Food and Agriculture. 2003;83(7):624-9.
42. Salta FN, Mylona A, Chiou A, Boskou G, Andrikopoulos NK. Oxidative stability of edible vegetable oils enriched in polyphenols with olive leaf extract. Food Science and Technology International. 2007;13(6):413-421.
43. Sampels, Sabine. "Oxidation and antioxidants in fish and meat from farm to fork." In Food industry. IntechOpen, 2013.
44. Sehwag S, Das M. Antioxidant Activity: An Overview. Research & Reviews: Journal of Food Science & Technology. 2013;2(3):1-11.
45. Siddiq A, Anwar F, Manzoor M, Fatima A. Antioxidant activity of different solvent extracts of Moringa oleifera leaves under accelerated storage of sunflower oil. Asian Journal of Plant Sciences. 2005;4(6):630-635.
46. Spencer JP, El Mohsen MM, Minihane AM, Mathers JC. Biomarkers of the intake of dietary polyphenols: strengths, limitations and application in nutrition research. British Journal of Nutrition. 2008;99(1):12-22.
47. Tan CH, Ariffin AA, Ghazali HM, Tan CP, Kuntom A, Choo AC. Changes in oxidation indices and minor components of low free fatty acid and freshly extracted crude palm oils under two different storage conditions. Journal of food science and technology. 2017;54(7):1757-64.
48. Winter RA. Food Additives: A consumer's dictionary. Fifth edition. Three Rivers Press; 1999.
49. Wsowicz E., Anna G., Marzanna H., Henryk H., Maria M., Sylwia M. R., Urszula S., Renata Z. Oxidation of lipids in food, Polish journal of food and nutrition sciences, Pol. J. Food Nutr. Sci. 2004;13(54): 87–100.
50. Zohra SF, Meriem B, Samira S, Muneer MA. Phytochemical screening and identification of some compounds from mallow. J Nat Prod Plant Resour. 2012;2(4):512-6.