Peels of Some Citrus Fruits As Source of Antioxidants for Use with Different Vegetable Oils

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ABSTRACT

The present study was conducted on peels of three citrus fruits; namely, orange peel (OP), mandarin peel (MP) and lemon peel (LP) to evaluate their bioactive compounds for use in some vegetable oils as antioxidants. The total phenolics content in OP, MP and LP were 818.86, 996.8 and 956.86, respectively as mg gallic acid equivalent / 100 g and total flavonoids content in OP, MP and LP were 476.56, 517.38 and 406.23, respectively as mg rutin equivalent / 100 g. Two analytical methods were used to determine the antioxidant activity 2, 2- diphenyl-1- picrylhydrazyl (DPPH) and ferric reducing antioxidant power (FRAP). Separation of phenolic compounds of peel extracts by HPLC revealed the identification of 24 compounds whose concentrations varied in the three types of peels. The oxidative stability of palm olein, soybean and sunflower oils containing each of OP, MP and LP and their extracts as novel sources of antioxidants versus butylated hydroxytoluene (BHT) as a synthetic antioxidant were evaluated by measuring their induction periods (IPs) using the Rancimat method. The ethanolic extracts of the peels were added at two levels; 1000 and 2000 ppm, individually, while the whole peels (OP, MP and LP) were added in different quantities according to the extract yield percentage of each. The data revealed that citrus peel extracts, especially orange peels, are considered as potent antioxidants and thereby can be applied to prolong the storage periods of the three vegetable oils under study instead of BHT since there is a concern about its use from the safety point of view.

Keywords: Orange peels, mandarin peels, lemon peels, bioactive compounds.

INTRODUCTION

Citrus processing industry, leaves peels, seeds and pulps after juice extraction, which are corresponding to about 50 % of the raw processed fruit. Such components are usually disposed as industrial wastes, despite they are considered a potential source of valuable plant metabolites and essential oils, that are used in cosmetic and medical uses (Andrea *et al.*, 2003, Khan, 2005, Li *et al.*, 2006, Tejada-Ortigoza *et al.*, 2018, Inglese & Sortino, 2019, Shehata *et al.*, 2021).

Processing of citrus wastes is likely to be a valuable source of phenolic compounds and dietary fiber. Those wastes due to their easy availability, are capable of offering significant low cost nutritional dietary supplements and bioactive residues besides a friendly environment platform (Tejada-Ortigoza *et al.*, 2018).

Citrus peels are considered as wastes although they contain a wide variety of secondary compounds that have valuable antioxidants activity compared with other parts of the fruit (Manthey & Grohmann, 2001). Antioxidants can terminate radical chain reactions *in vivo* which can damage nucleic acids and proteins. Antioxidant activity towards these radicals has been traced in phenolic compounds and flavonoids which depend mainly on their structural characteristics (the number and the position of phenolic hydroxyl, other groups and conjugation). Peels contain the highest concentrations of flavonoids in the citrus fruit (Anagnostopoulou *et al.*, 2006). Moreover citrus flavonoids have antioxidant, anti-inflammatory, anti-carcinogenic and antiatheroslerosis activities (Chen *et al.*, 2017).

Currently, antioxidants like butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are employed to retard the formation of compounds that result in a decrease in the sensory and nutritional quality of foods. Some studies have reported that these synthetic antioxidants are sometimes toxic using clinical trials on rats which showed that the aforementioned antioxidants stimulate the development of cancerous cells. Therefore, researchers as well as consumers prefer using natural food additives than their synthetic analogs uses. Wastes of food processing industries can have

high added value by identification and isolation of their bioactive compounds (Rafiq *et al.*, 2018).

The present work aimed to use the peels of some citrus fruits. Moreover, the work aimed to evaluate the antioxidants activity of citrus peels and their extracts to protect some vegetable oils against oxidative rancidity.

MATERIALS AND METHODS

Materials:

Citrus fruits: About 20 kg of each of orange, mandarin and lemon fruits were collected from a farm at Hosh Essa in Al Beheira Governorate, Egypt, during February and March, 2018.

Refined oils: Refined bleached and deodorized (RBD) sunflower, soybean and palm olein oils (free from antioxidant- packed under inert gas conditions) were kindly provided by Oleo Misr for Oil and Detergents 2nd Industrial Zone, Sadat City, Egypt "Oleo Misr Company "and Arma Oil Industries, 10 th of Ramadan City, Egypt.

Methods:

The freshly collected fruits (orange, mandarin and lemon) were washed with tap water followed by distilled water and peeled by hand using a knife. Thereafter, fresh citrus peels were lyophilized in a lyophilizer (Vir Tis SP SCIENTIFIC–sentry 2.0) at – 80°C at pressure of 14 m torr for 80 hr. The lyophilized samples were packed in glass jars and stored at -18°C until used.

Total phenolics content:

Total phenolics were determined according to Folin-Ciocalteus method as described by Singleton *et al.* (1974). A volume of 0.2 ml of each extract was pipetted into different test tubes, then 0.8 ml of Folin-Ciocalteus reagent was added. Two ml of sodium carbonate solution 7.5% were added and vigorously mixed, then, 7 ml of deionized water were added. Mixtures were left for 2 hr, then the absorbance was measured at a wave length of 756 nm using UV- Vis Spectrophotometer (Laxco-Alpha-1102, Suite). The total phenolics content was expressed as gallic acid equivalent (GAE) from a calibration curve of gallic acid.

Total flavonoids content:

The flavonoid compounds were extracted according to Zarina & Tan (2013). Two ml of the sample ethanolic extract was accurately transferred into a 10 ml volumetric flask and 0.6 ml of sodium nitrite solution of 5%, were added before the mixture was shaken and left for 6 min. Secondly, 0.5 ml of aluminium nitrate (10 %) solution, was added to the volumetric flask, shaken and left to stand for 6 min. Finally, 3.0 ml of the sodium hydroxide solution 4.3% was added to the volumetric flask, followed by addition of water up to the mark, shaken and left to stand for 15 min before determination. A blank sample solution without colouration was used as a reference and absorbance was measured at a wave length of 500 nm. The sample solution was used to determine the content of flavonoids in the sample by UV- Vis Spectrophotometer (Laxco-Alpha-1102, Suite). The total flavonoid content of each extract was calculated, based on a standard curve of rutin and was expressed as mg of rutin equivalent (RE) per 100 g of dry weight.

Antioxidant activity assay:

The DPPH· method

Antioxidant activity of the lyophilized citrus peels was determined by evaluating the free radical scavenging activity of the 2,2-Diphenyl-1-picryl-hydrazyl (DPPH) radical according to a modified method described by Brand-Williams *et al.* (1995). Briefly, 0.3 ml ethanolic extract was added to 2.7 ml DPPH 0.1 mmol in methanol solution. The reaction mixture was vortex mixed well and incubated for 30 min at room temperature in the dark. Absorbance was measured at 517 nm using Spectrophotometer (Laxco-Alpha-1102 Suite). Antioxidant activity was expressed as a percentage of inhibition of DPPH radical and calculated from the following equation:

$$\text{Inhibition (\%)} = [(\text{A DPPH} - \text{A Sample}) / \text{A DPPH}] \times 100$$

Where: A Sample is the absorbance of the sample and A DPPH is the absorbance of the control DPPH solution. The IC_{50} value is defined as the concentration of total antioxidant necessary to decrease the DPPH radical concentration by 50 %. L- ascorbic acid was used as a positive control.

Ferric ions (Fe^{3+}) reducing antioxidant power (FRAP) assay:

The ability of orange, mandarin and lemon peel extracts to scavenge hydrogen peroxide was determined according to the method mentioned by Gulcin *et al.* (2012). Different concentrations of

citrus peels extract in 1 ml of distilled water were mixed with 2.5 ml sodium phosphate buffer (0.2 M, pH 6.6) and 2.5 ml potassium ferricyanide (1%). The mixture was incubated at 50 ° C for 20 min. Aliquots (2.5 ml) of trichloroacetic acid (10%) were added to the mixture. Then, 2.5 ml of this solution was mixed with 2.5 ml distilled water and 0.5 ml ferric chloride (0.1%) and the absorbance was measured at 700 nm in a Spectrophotometer (Laxco-Alpha-1102, Suite). Increased absorbance of the reaction mixture indicates an increase in reduction capability.

Separation of total phenolic compounds by HPLC:

Sample (1g) was placed in quick fit conical flask and 20 ml of 2 M NaOH was added and the flasks were flushed with N_2 and the stopper was replaced. The samples were shaked for 4 hr at room temperature. The pH was adjusted to 2 with 6 M HCl. The samples were centrifuged at 1500 xg for 15 min, (Centrifuge Equipment, Damon/ IEC-Division international equipment Co. CAT No 783) and the supernatant was collected. Phenolic compounds were extracted twice with 50 ml diethyl ether and ethyl acetate 1:1. The organic phase was separated and evaporated at 45°C and the samples were dissolved in 2 ml methanol (Kim *et al.*, 2006).

HPLC analysis was carried out using Agilent Technologies 1100 series liquid chromatograph equipped with an auto sampler and a diode-array detector. The analytical column was a Eclipse XDB-C18 (150 X 4.6 µm; 5 µm) with a C18 guard column (Phenomenex, Torrance, CA). The mobile phase consisted of acetonitrile (solvent A) and 2% acetic acid in water (v/v) (solvent B). The flow rate was kept at 0.8 ml/min for a total run time of 70 min and the gradient programme was as follows: 100% B to 85% B in 30 min, 85% B to 50% B in 20 min, 50% B to 0% B in 5 min and 0% B to 100% B in 5 min. The injection volume was 50 µl and peaks were monitored simultaneously at 280 and 320 nm for the benzoic acid and cinnamic acid derivatives, respectively. All samples were filtered through a 0.45 µm Acrodisc syringe filter (Gelman Laboratory, MI) before injection. Peaks were identified by congruent retention times and UV spectra and compared with those of the standards

Preparation of citrus peels extract:

Citrus peel extracts were prepared using 80% ethanol. Fifty g of each of orange, mandarin and lemon lyophilized peel powders were individually blended with the solvent at a ratio 1:10 (w/v). Pyrex tightly closed bottles covered with aluminium foil were used for extracting at room temperature. The extraction was carried out twice then the content was centrifuged at 1500 xg for 15 min, (Centrifuge Equipment, Damon/ IEC-Division international equipment Co. CAT No 783). The combined extracts were collected, and the solvent was removed using vacuum rotary evaporator (IKA.Com BIMA RCB) at 50°C, then the extracts were lyophilized. The lyophilized extracts were placed in tightly closed brown bottles and stored at (–18°C) until use. Yield percentage was calculated using the following equation:

%Yield = extract (g) x 100 / sample (g)

Oil sample preparation for the oxidative stability:

Refined, bleached and deodourized (RBD) sunflower, palm olein and soybean oils, free from any additives, were used as the substrate for oxidative stability studies. Oil samples containing 1000 and 2000 ppm orange, mandarin and lemon lyophilized peels and their counterparts of their ethanolic extracts were separately prepared. BHT (200 ppm) was used as a reference and blank. Sunflower, palm olein and soybean oils (neither extracts nor peels were added) have been considered as the control. The peels of citrus were blended with 100 ml of each oil in dry brown tightly closed bottles and stored for 10 days in a cool, dark and dry place to avoid any oxidation. Thereafter, oils were filtered to remove any residue and used directly for oxidative stability test.

Rancimat test:

The oxidative stability was determined with the Rancimat apparatus in Food Science and Technology Research Institute, Cairo, Egypt, according to Laubli & Bruttel, (1986). All samples were studied at the same temperatures 110°C/ hr under a constant air flow (20 L/hr). The induction times (hr) were printed automatically by the apparatus software with an accuracy of 0.005 (Maszewska *et al.*, 2018).

Statistical analysis:

The determinations were carried out in triplicates and data were reported as mean values ±

standard deviation (SD). The data were analyzed using SAS program ver. 9.1 (2009) as a factorial experiment with three replications according to Gomez & Gomez (1984). Means were compared using the least significant difference at 0.05 level of probability.

RESULTS AND DISCUSSION

Total phenolic and flavonoid contents:

The peels of the three citruses under study exhibited considerable amounts of phenolics as shown in Table (1), thus the MP and LP had 996.8 and 956.86 mg gallic acid equivalent / 100 g, respectively. However, OP had 818.86 mg /100 g , being higher than the result found by Awad *et al.* (2008) for OP and MP (670 and 780 mg /100 g, respectively). The present result is close to the results reported by Yassari & Yassari (2013). The MP contained significantly ($p \leq 0.05$) the highest amount of flavonoid content (517.38 mg /100 g), whereas OP and LP had only 476.56 and 406.23 mg /100 g, respectively as shown in Table (1). Ibrahim & Hamed (2018) reported that total flavonoids content of dried orange peels extracted with methanol and ethanol extracts were 365.4 and 273.82 mg / 100 g, respectively while the total flavonoids content for LP were higher being 469.08 and 390.75 mg / 100 g, respectively.

Table 1: Total phenolic and flavonoid contents of orange, mandarin and lemon peels

Citrus peel	Total phenolic content as gallic acid (mg /100 g)	Total flavonoids content as rutin (mg /100 g)
Orange peels	818.86 ± 0.0 [b]	476.56 ± 2.08 [b]
Mandarin peels	996.8 ± 13.42 [a]	517.38 ± 2.77 [a]
Lemon peels	956.86 ± 0.00 [a]	406.23 ± 8.34 [c]

Samples were analyzed in triplicate. The results are expressed as mean values ± SD.
Means were compared using the least significant difference at 0.05 level of probability.
The values having different letters within the same column are significantly ($P \leq 0.05$) different.

Antioxidant activity of three citrus peels

In the present study, two analytical methods were used to determine the antioxidant activity of OP, MP and LP along with ascorbic acid (AA) as a reference antioxidant. The analytical methods were 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical assay and ferric reducing antioxidant power (FRAP) assay and the data are given in Table (2). It was obvious that the significantly ($P \leq 0.05$) highest IC_{50} was 22.69 mg / ml for LP followed by MP (7.49 mg / ml) then OP (6.59 mg / ml). The results are in agreement with the result reported by Anagnostopoulou *et al.* (2006) who found that the antioxidant activity of OP ranged from 97 to 275 µg dry extract/ml. The result of IC_{50} of DPPH was higher than that reported by Chen *et al.* (2017), the OP extract ranged from 0.51 to 0.68 mg / ml and Singh *et al.* (2020) reported that IC_{50} values of DPPH for different citrus peels methanol extracts ranged from 1.1 to 5.15 mg / ml.

Table 2: The DPPH and FRAP assay in orange, mandarin and lemon peels

Citrus peel	DPPH inhibition (%)	IC_{50} (mg / ml)	FRAP (Absorbance)
Orange peel	89.29±0.14[b]	6.59±0.01[c]	0.34±0.01[b]
Mandarin peel	90.22±0.14[a]	7.49±0.01[b]	0.52±.01[a]
Lemon peel	88.14±0.14[c]	22.69±0.02[a]	0.56±0.01[a]

Samples were analyzed in triplicate. The results are expressed as mean values ± SD..
Means were compared using the least significant difference at 0.05 level of probability.
The values having different letters within the same column are significantly ($P \leq 0.05$) different.

Phenolic compound profile

It is worth to mention that Shehata *et al.* (2021) investigated the antioxidant and antimicrobial activities as well as the polyphenolic profile of Egyptian sweet orange peel extracts. The authors could identify and determine 22 (aqueous extract) and 32 (ethanolic extract) compounds identified by UPLC-ESI-MS/MS. As shown in Table (3) using the HPLC, ferulic acid, vanillic acid, syringic acid, gallic acid and sinapic acid were the main phenolic compounds in OP being 1239.173, 605.878, 463.815, 367.04 and 361.459 µg / g, respectively, also, the same phenolic compounds in MP were 915.606, 446.353, 245.635, 339.988 and 9.089 µg / g, respectively, whereas, apigenin, hesperidin, naringin, sinapic acid and gallic acid were the main phenolic compounds in LP being 1603.230, 1199.429, 334.949, 228.816 and 231.863 µg / g, respectively. In contrast, Ibrahim & Hamed (2018) reported that hesperidin, naringin, rutin acid, catachine, qurcetin and cinnamic acid were the main phenolic compounds in orange and lemon peel extracts. Singh *et al.* (2020) reported that the levels

of caffeic, *p*-coumaric, ferulic and sinapic acids in sour orange peels were 0.229, 0.193, 1.580 and 0.954 mg/g. Moreover, the extract of bitter orange identified ferulic acid as the most abundant (102.13 µg/g), whereas, caffeic acid as the least value (2.43 µg/g) in the peel extract. Lemon peel contained higher amounts of ferulic, sinapic, p-coumaric and caffeic acids (44.9, 42.1, 34.9 and 14.2 mg/100 g) than orange peel (39.2, 34.9, 27.9 and 9.5 mg/100 g) and grapefruit (32.3, 31.9, 13.1 and 5.6 mg/ 100 g). Ferulic, sinapic acids and their ester derivatives (dihydroxycoumarin, dihydroxycoumarin-O-sinapoyl-glucose ester, and feruloyl glucoside ester) were identified in orange peel. In the case of kumquat peels, the primary identified phenolic acids were *p*-hydroxybenzoic acid, vanillic, protocatechuic, chlorogenic and sinapic acids. As shown in Table (3), OP and MP contain comparable amount of gallic, syrigic, vanillic and ferulic acids and they were the main phenolic acids in both peels, whereas, LP was completely different from OP as well as MP, and hesperidin, apigenin as well as naringin were the main phenolic acids in it.

Table 3: HPLC fractionation of phenolic compound of orange, mandarin and lemon peels.

Phenolic compound	Orange peel (µg/g)	Mandarin peel (µg/g)	Lemon peel (µg/g)
Gallic acid	367.040	339.988	231.863
Protocatechuic acid	3.220	6.506	3.221
p-hydroxybenzoic acid	40.787	14.244	53.544
Gentisic acid	N.D.	N.D.	N.D.
Cateachin	87.988	17.691	7.335
Chlorogenic acid	91.419	22.675	6.173
Caffeic acid	N.D.	70.996	17.911
Syringic acid	463.815	245.635	4.152
Vanillic acid	605.878	446.353	66.688
Scopoletin	N.D	N.D.	N.D.
Ferulic acid	1239.173	915.606	34.544
Sinapic acid	361.459	9.089	228.816
Rutin	1.919	6.076	29.087
p-coumaric acid	5.070	10.984	6.490
Naringin	172.867	59.442	334.949
Hesperidin	91.683	76.639	1199.429
Apigenin-7-glucoside	N.D.	N.D.	N.D.
Rosmarinic acid	N.D.	N.D.	N.D.
Cinnamic acid	31.035	1.133	14.130
Qurecetin	41.979	12.120	6.576
Naringinin	N.D.	N.D	N.D
Apigenin	N.D	45.527	1603.230
Kaempferol	12.631	32.953	67.683
Chrysin	N.D.	N.D.	N.D.

N.D: Not detected.

Oxidative stability of oils:

The oxidative stability of palm olein, soybean and sunflower oils containing each of OP, MP and LP and their extracts as suggested novel sources of antioxidants versus BHT as a synthetic antioxidant were studied and evaluated by measuring their induction periods (IPs) using the Rancimat method. The ethanolic extracts of the peels were added at two levels; 1000 and 2000 ppm, individually, while the aforementioned whole peels (OP, MP and LP) were added at different quantities according to their extract yield percentage, containing the equivalent amount.

Oils treated with orange peel (OP) and its extract (OPE):

Fig. (1) shows that addition of OPE at 2000 ppm exhibited the highest oxidative stability for palm olein (60 hr), soybean (7 hr) and sunflower oils (16 hr) compared to all the other treatments, followed by the addition of OP at 2000 ppm. Both of the treatments of OPE and OP at 2000 ppm were more powerful than using BHT at 200 ppm and exhibited higher oxidative stability for palm olein and soybean oils. On the other hand, sunflower oil didn't show the same trend.

The fatty acid profile is generally recognized as the most decisive parameter influencing the oxidation stability of oils (Macciola & De-Leonardis, 2012). Several authors have reported that fat oxidation decreases by increasing the levels of saturated fatty acids (Verardo *et al.*, 2013). Even though the OPE at both concentrations 1000 and 2000 ppm showed more oxidative stability than the addition of OP at the same concentration for all the studied oils. Palm olein oil showed the highest oxidative stability compared to the other two oils, as mostly it is characterized by its high content of saturated fatty acids (Verardo *et al.*, 2013).

Oils treated with mandarin peels (MP) and its extract (MPE):

Fig. (2) shows that the addition of mandarin

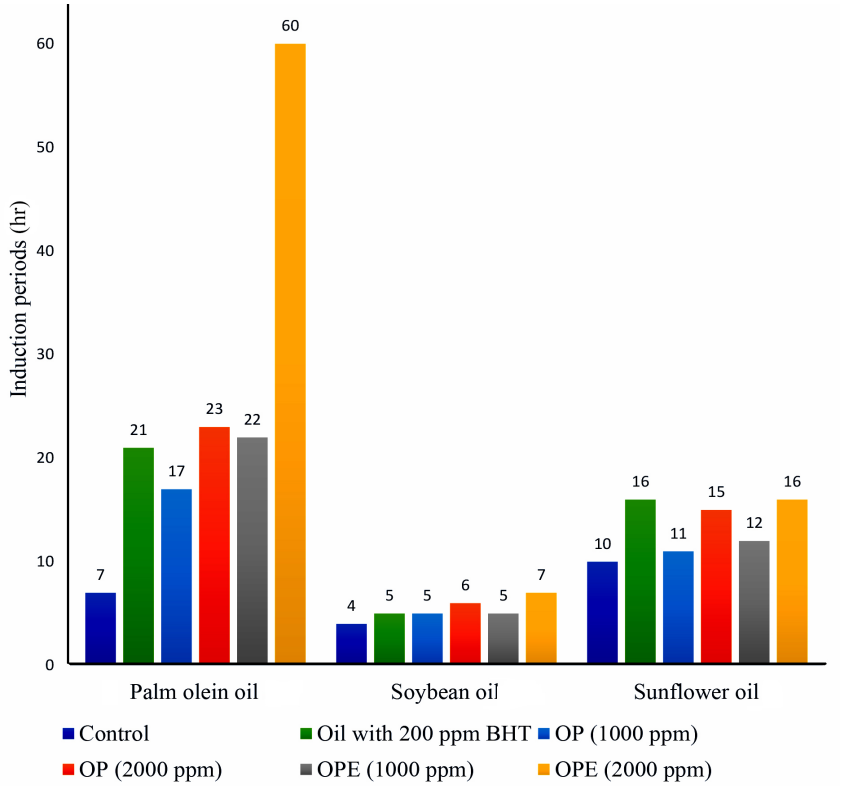

Fig. 1: The induction periods of the three oils containing orange peel and orange peel extract as measured by the rancimat apparatus

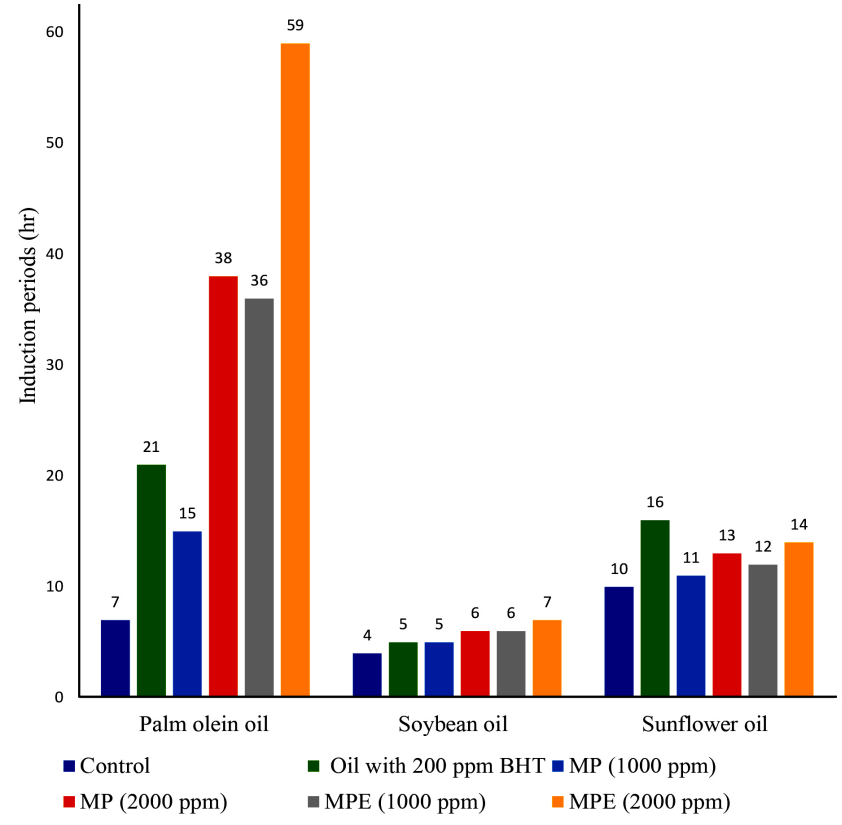

Fig. 2: The induction periods of the three oils containing mandarin peel and mandarin peel extract as measured by the rancimat apparatus

peel extract (MPE) at 2000 ppm exhibited significantly ($P \leq 0.05$) the highest oxidative stability for palm olein (59 hr), soybean (7 hr) and sunflower oils (14 hr) compared to all the other additions. Also, as in OP, both treatments of MPE and MP at 2000 ppm were more powerful than using BHT at 200 ppm and exhibited higher oxidative stability for palm olein and soybean oils, whereas for sunflower oil using BHT was more powerful (16 hr) compared to the two other treatments; namely, MPE (14 hr) and MP (13 hr).

The results show that the addition of MP and MPE to palm olein, soybean and sunflower oils increased the oxidative stability of those oils compared to the control. Moreover, the MPE had more oxidative stability than MP at the same concentration (1000 and 2000 ppm) when added to the aforementioned three oils. Furthermore, the addition of MPE at both concentrations as well as addition of MP at 2000 ppm elevated the oxidative stability of palm olein and soybean oils as compared with synthetic antioxidant BHT, although, sunflower oil did't follow the same trend.

Oils treated with lemon peels (LP) and its extract (LPE):

Fig. (3) shows that the addition of lemon peel extract (LPE) at 2000 ppm exhibited significantly ($P \leq 0.05$) the highest oxidative stability for palm olein (45 hr), soybean (20 hr) and sunflower oils (29 hr) compared to all the other additions. Also, as in OP and MP, both treatments (LPE and LP) at 2000 ppm were more powerful than using BHT at 200 ppm and exhibited higher oxidative stability for palm olein, soybean oils and sunflower oils.

In conclusion, it was obvious that addition of LP and LPE at both concentrations (1000 and 2000 ppm) to palm olein and soybean oils were more powerful and increased the oxidative stability of the three oils under study compared to the addition of BHT. In contrast, the addition of BHT to sunflower oil was more powerful and exhibited higher oxidative stability for sunflower oil compared with the addition of LP at concentration 1000 ppm, although, the addition of LPE at 1000 and 2000 ppm to sunflower oil was still more powerful and exhibited higher oxidative stability than the addition of BHT to sunflower oil.

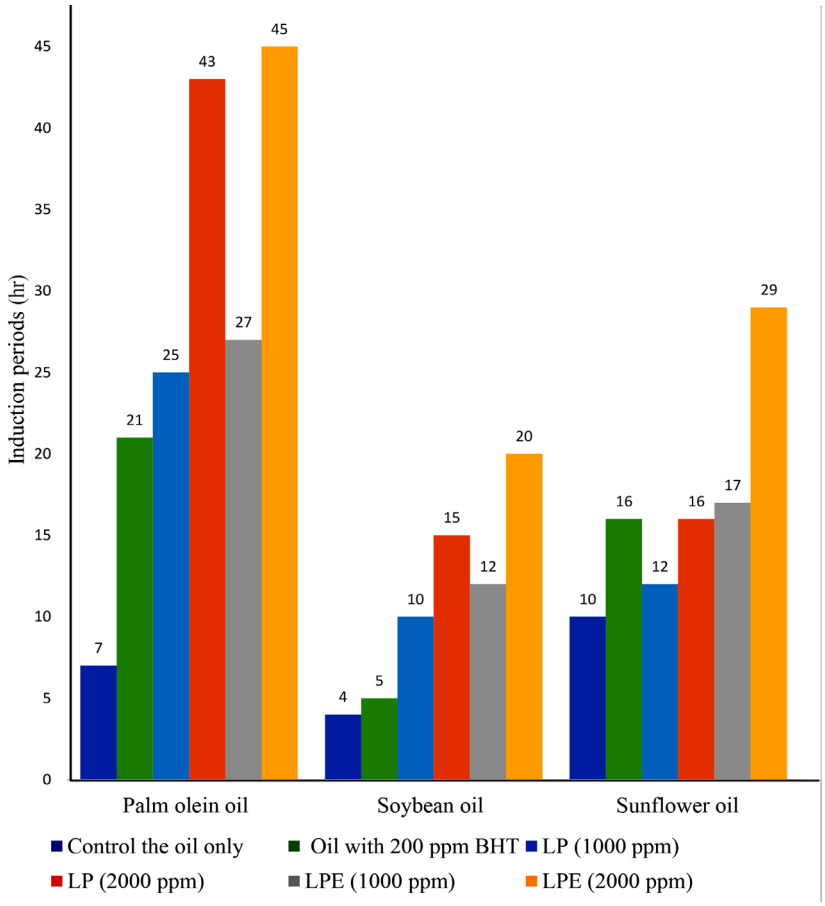

Fig. 3: The induction periods of the three oils containing lemon peel and lemon peel extract as measured by the rancimat apparatus

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قشور بعض ثمار الموالح كمصدر لمضادات الأكسدة للاستخدام مع زيوت نباتية مختلفة

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أجريت هذه الدراسة على قشور ثمار كل من البرتقال واليوسفي والليمون وتمت المقارنة بين المستخلصات الإيثانولية لهذه القشور كمصدر لمضادات الأكسدة الطبيعية واختبار كفاءتها في ثلاثة أنواع من زيوت الطعام وهى أوليين النخيل ، فول الصويا و دوار الشمس. وكان محتوى الفينولات الكلية في قشورالبرتقال واليوسفي والليمون (٨١٨,٨٦ ، ٩٩٦,٨ ، ٩٥٦,٨٦ ملجم حامض جاليك / ١٠٠ جم) على الترتيب، وكان محتوى الفلافونويدات الكلية في قشور البرتقال واليوسفي والليمون (٤٧٦,٥٦ ، ٥١٧,٣٨ ، ٤٠٦,٢٣ ملجم روتين / ١٠٠ جم) على الترتيب. تم استخدام طريقتين تحليليتين لتحديد النشاط المضاد للأكسدة وهما طريقة الـ DPPH وطريقة الـ FRAP. أوضح تركيب المستخلصات من المركبات الفينولية بواسطة HPLC التعرف على ٢٤ مركبًا تفاوتت تركيزاتها في الأنواع الثلاثة من القشور.

تمت دراسة وتقييم الثبات التأكسدي لزيوت أوليين النخيل وفول الصويا وعباد الشمس التي تحتوي على كل من قشور البرتقال واليوسفي والليمون ومستخلصاته كمصادر جديدة لمضادات الأكسدة مقابل الـ BHT كمضاد أكسدة صناعي من خلال قياس الفترات التمهيدية باستخدام طريقة الرانسيمات حيث تم إضافة المستخلصات الإيثانولية للقشور على مستويين هما ١٠٠٠ و ٢٠٠٠ جزء في المليون منفردة ، بينما تمت إضافة القشور الكاملة للموالح بكميات مختلفة حسب نسبة العائد لكل مستخلص. أوضحت النتائج أن مستخلصات قشور الموالح وخاصة قشور البرتقال تعتبر مضادات أكسدة طبيعية واعدة وآمنة في آن واحد ، يمكن استخدامها لإطالة الفترات التخزينية للزيوت النباتية الثلاثة موضع الدراسة ، بدلاً من مركب BHT الصناعي حيث يوجد قلق بشأنه من وجهة نظر مدى السلامة المرتبطة بالمضافات الصناعية.