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Comparative studies on three vegetable oils commonly consumed in Egyptian local markets

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Abstract: The present study was carried out to compare the chemical composition, fatty acids profile and antioxidant activity of three vegetable oils (soybean, sunflower and palm) commonly consumed in Egyptian local markets. The highest total phenolic content was obtained in soybean oil (SBO, 1.49 ± 0.36 mg GAE.100 g^{-1}). Palm oil (PO) was characterized by the lowest total phenolic compounds content (1.08 ± 0.17 GAE.100 g^{-1}). The methanolic extracts of the oils were characterized by statistically significant differences in their antioxidant activity measured by both DPPH and Folin-Ciocalteu methods. The highest antioxidant activity was displayed by the extract obtained from sunflower oil (SFO, 17.96 ± 2.08 of DPPH scavenged) followed by SBO (12.78 ± 3.71) and PO (9.04 ± 2.52). PO has a balanced fatty acid composition in which the level of saturated fatty acids (SFA's) is almost equal to that of the unsaturated fatty acids (USFA's). Palmitic acid (43.18%) and oleic acid (38.97%) are the major component acids along with linoleic acid (11.32%) and only a trace amount of linolenic acid (0.25%). In conclusion, the results of this study confirm the expansion of the use of soybean and sunflower oils in various food applications, as opposed to palm oil.

Keywords: soybean oil**,** sunflower oil, palm oil, phenolics, antioxidant activity, fatty acids.

Introduction

Vegetable oils are the most important source of fat in the human diet. They in particular are natural products of plant origin consisting of ester mixtures derived from glycerol with chains of fatty acid contain about 14 to

20 carbon atoms with different degrees of unsaturation. Vegetable oil is very common, affordable and used by majority of people across the globe especially in the tropics. Its use as antidote to prevent some oxidative stress related diseases and a complication is advocated (Frank, 2002).

Soybean is the dominant oilseed produced in the world, due to its favorable agronomic characteristics, its high-quality protein, and its valuable edible oil. It contributes over a half of all oilseeds produced worldwide (Frank, 2002). Soybean oil is classified as polyunsaturated oil which includes about 15 % saturates, 24 % monounsaturates and 61 % polyunsaturates of which 53.2 % is linoleic acid while the linolenic acid content is about 7.8 % (*Ercument et al.,* 2011). The nutritional advantages of this composition and it's effects in regulating the plasma lipid and eicosanoids bio - synthesis are reviewed on the basis of results from several human clinical trials and studies (Frank, 2002). These studies have shown that soybean oil effective in lowering the serum cholesterol and LDL levels, and likely can be used as potential hypocholesterolemic agent if used as a dietary fat and ultimately help prevent atherosclerosis and heart diseases.

Sunflower oil is the fourth largest vegetable oils in the world, after soybean, palm, and canola (edible rapeseed) (Frank, 2002) . It is used in the food industry and in various commercial products, and it has been shown to have significant potential for biodiesel production (Arkansas Bio-Fuels Enterprises, 2007; National Sunflower Association, 2009). Previous studies have demonstrated that sunflower oil comprises up to 90% unsaturated fatty acids (combined oleic and linoleic) and approximately 10% saturated fatty acids (palmitic and stearic) (Steer and Seiler, 1990 and Frank, 2002) In general, the fatty acids profile of vegetable oils determines their nutritional properties and specific uses (Burton *et al.,* 2004). So, demand for sunflower oil increased sharply in the mid-eighties when high polyunsaturated fatty acid (PUFA) margarine became the desired table margarine for health reasons. Also, sunflower oils with high oleic acid content are considered healthy (Jing *et al.,* 1997) and they have high stability during frying and extended shelf life, which makes them preferable for the 3 billion kg $year^{-1}$ frying oil market in the United States (Warner *et al.,* 2003). Sunflower oil has been used topically on the skin to promote wound healing and heal certain skin conditions. Researchers states that there is evidence suggesting that the use of sunflower oil in the diet instead of olive oil may lower LDL cholesterol (http://www.webmd.com). Furthermore, sunflower oil contains large amounts of Omega 6 linoleic acid; when not counteracted with Omega 3, it can aggravate hyperinsulinemia and possibly lead to non-insulin-dependent diabetes (Iszatt, 1999-2012).

Palm oil contains approximately an equal amount of saturated and unsaturated fatty acids. Amongst the former, palmitic and stearic acid account for 45% and 5% of the total fatty acids, respectively. Palm oil has a wide range of applications and it is commonly fractionated into olein and stearin (Annonymous 2007). The different properties of palm oil and it's fractions allow the products to be used for different purposes. Palm olein oil, a liquid fraction obtained from the refining of palm oil, is rich in oleic acid (42.7– 43.9%), β-carotene and vitamin E (tocopherols and tocotrienols) (Abdul Gapor, 1990). It is rich in tocotrienol which has been reported to be natural inhibitors of cholesterol synthesis. Tocopherols are very important minor components of oils and fats because of their antioxidant properties (Eqbal *et al.,* 2013).

All of the previous studies indicated that the chemical composition and different properties of the vegetable oils were affected by many factors including, location, agricultural services for seed production, processing technology etc. Changes in chemical composition and different properties of the vegetable oils could be affected on the nutritional and healthy status of the human. Therefore, the present study was carried out to compare the chemical composition, fatty acids profile and antioxidant activity of three vegetable oils (soybean, sunflower and palm) commonly consumed in Egyptian local markets

Materials and methods

Materials

Selected oilseeds from soybean (*Glycine max* L.), sunflower (*Helianthus annus* L.) and palm (*Elaeis guineensis L*.) oils were purchased from local grocery stores in Port Saied, Egypt in the year, 2015.

Chemicals: Folin-Ciocalteu reagent, *O*-phosphoric acid, serine borate buffer (SBB), *N*-1-(pyrenyl) maleimide (NPM), dithiothreitol (DTT) and gallic acid were obtained from Sigma Chemical Co., St. Louis, Mo.All organic solvents and other chemicals were of analytical grade were purchased from El-Ghomhorya Trade Company for Drugs, Chemicals and Medical Instruments, Cairo, Egypt.

Methods

Preparation of oils extract

Methanol extracts of the selected oils were prepared according to the method of Amin *et al.,* (2004) with some modifications. In brief, 20 g from oil +180 ml methanol [80% (v/v)] were homogenized and transferred to a beaker and stirred at 200 rpm in an orbital shaker (Unimax 1010, Heidolph

Instruments GmbH & Co. KG, Germany) for 1 h at room temperature. The extract was then separated from the residue by filtration through Whatman No. 1 filter paper. The remaining residue was re-extracted twice, and then the two extracts were combined. The residual solvent of methanolic extract was removed under reduced pressure at 55°C using a rotary evaporator (Laborata 4000; Heidolph Instruments GmbH & Co. KG, Germany). The yield of the extracts were weighted and used for biological experiments.

Chemical characteristics of vegetable oils

Acid value (mg KOH/ 100 gm oil), peroxide value (millieq. peroxide/ kg oil), saponification value (mg KOH required to saponify 1 gm oil) and iodine value (gm iodine/100 gm fat) were determined using the methods of the A.O.A.C. (1985).

Fatty acids composition

Individual fatty acids were determined by gas chromatography (GC-4CM Shimodzu) according to the methods mentioned by Farag *et al*., (1986). The operation parameters can be summarized in the following: column, S.G.L, 10 mm; temp., 150 – 240 ^{0}C; temp rate, 5 0C/min; packing, SE-30; wt., 5%; support, EMES; mesh, 60-80; carrier gas, N2; flow rate, 20 ml/min; inlet press, 6 kg/cm2; detector, F.I.D.; range, 16 mv; sensitivity, 10 –3; temp, 270 ^{0}C; recorder chart speed, 5 mm/min.

Total phenolic compounds content

The content of total phenolic compounds in methanolic extracts was determined by the Folin–Ciocalteu reagent according to method of Singleton and Rossi, (1965). An aliquot (0.2 mL) of the methanolic extract was placed in a volumetric flask (10 mL). Diluted Folin-Ciocalteu reagent (0.5 mL) was added. After 3 min, saturated sodium carbonate (1 mL) was added. The flask was filled with water up to 10 mL. After 1 h, absorbance at lmax 725 nm against a reagent blank was measured using a UV–VIS spectrophotometer (Beckman DU-50). Total phenolic compounds were determined after preparation of a standard curve, and on that basis, total phenolic compounds were expressed as gallic acid equivalent (GAEs).

Antioxidant Activity Determination

The method consisted of spectrophotometric measurement of the intensity of the color change in solution depending on the amount of 2,2-diphenyl-1-picrylhydrazyl (DPPH). The reaction was initiated by mixing 1 mL of the methanolic extract with 3 mL methanol and then by adding 1 mL

of DPPH• (0.012 g/100 mL). The absorbance at lmax 517 nm (UV–vis spectrophotometer SP 8001, Metertech Inc.) was checked at 0, 0.5 and every 0.5 min until the reaction reached a steady state. This plateau was reached within 15 min. The activity of the extract in scavenging DPPH• was calculated as follows:

$$\%\text{DPPH}^{\cdot}\ \text{scavenging} = \left[\frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}}\right]$$

The amount of sample needed to decrease the initial DPPH concentration by 50%, *EC*50, was calculated graphically. The antiradical power (ARP) of extracts calculated as Suja *et al.*, (2005):

$$ARP = \frac{1}{(EC_{50})}$$

Antioxidant activity

Antioxidant activity of the selected oils extract and standards (α-tocopherol, BHA, ans BHT; Sigma Chemical Co., St. Louis, Mo) was determined according to the *β*-carotene bleaching method following a modification of the procedure described by Marco (1968). Antioxidant activity was expressed as antioxidant activity (AA) and calculated as percent inhibition relative to control using the Al-Saikhan *et al.*, (1995) equation.

Statistical Analysis

All measurements were done in triplicate and recorded as mean±SD. Statistical analysis was performed with the Student *t*-test and MINITAB 12 computer program (Minitab Inc., State College, PA).

Results and Discussion

Total phenolics of selected vegetable oils methanolic extract

The total phenolics content of selected vegetable oils methanolic extract was shown in Table (1). The highest total phenolics content was obtained in SBO (1.49 ± 0.36 mg GAE.100 g^{-1}). PO was characterized by the lowest total phenolics compound content (1.08 ± 0.17 GAE.100 g^{-1}). In similar study, Haiyan *et al.* (2007) determined low level of total phenolics content in soybean oil (0.227 mg.100g^{-1}) compared with the date of the present study. On the other side, Parry *et al.* (2006) determined higher levels of total phenolics contents ranged 98-335 mg GAE.100g^{-1} for other vegetable oils including onion, parsley, cardamom, mullein, roasted pumpkin and milk thistle processed by cold-pressed technology. The differentiation in all of those data could be attributed to one or/and more of the following reasons: 1) the type of the vegetable oil, 2) the technology used for oil extraction and preparation, and 3) method of analysis. In this attention, Earl *et al.*, (2005)

and Leong *et al.*, (2015) reported that during refining, the bleaching and steam deodorisation processes partially/completely remove some of the valuable components including phenolics. The amounts retained in the refined oils depend on the conditions of refining.

Table 1. Total phenolics of selected vegetable oils methanolic extract

Oil sample	Total phenolic compound content (mg GAE.100 g^{-1})*
Soybean (SBO)	1.49 ± 0.36
Sunflower (SFO)	1.26 ± 0.23
Palm (PO)	1.08 ± 0.17

Values (means ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$); GAE, Gallic acid equivalent

Antioxidant activity of selected vegetable oils methanolic extract

The percentage of DPPH scavenged by antioxidants contained in oil extracts is shown in Table (2). From such data it could be noticed that all of the studied oil extracts scavenged DPPH. The methanolic extracts of the oils were characterized by statistically significant differences in their antioxidant activity measured by both DPPH and Folin-Ciocalteu methods. The highest antioxidant activity was displayed by the extract obtained from SFO (17.96 ± 2.08 of DPPH scavenged) followed by SBO (12.78 ± 3.71) and PO (9.04 ± 2.52). PO methanolic extract possessed the lowest ARP calculated from the amount of sample needed to decrease the initial DPPH concentration by 50% ($1.79x10^{-2}$) while the best ARP was exhibited by the extract obtained from SFO ($3.59\ x10^{-2}$). The same behavior was recorded for the all oil extracts when their antioxidant activities were measured by another method i.e. Folin-Ciocalteu reagent method.

Table 2. Antioxidant activity of selected vegetable oils methanolic extract.

Oil sample	DPPH scavenging (%)	EC50 (µg)	Antiradical powder (ARP)	Antioxidant activity (AA, %)
Soybean (SBO)	12.78 ± 3.71	28.38 ± 4.09	$2.31x10^{-2}$	44.17±4.11
Sunflower (SFO)	17.96 ± 2.08	14.74 ± 2.11	$3.59\ x10^{-2}$	49.78±3.98
Palm (PO)	9.04 ± 2.52	31.53 ± 3.58	$1.79x10^{-2}$	37.56±4.67

* Values (means ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$); ARP, antiradical power; *EC*50, the amount of sample needed to decrease the initial DPPH concentration by 50%, AA measures by Folin–Ciocalteu reagent method.

The data of the present study with the others indicated that the antioxidant activities of different vegetable oils was affected by many factors including type of oil, extraction media/conditions and the type/ molecular

structure of phenolics content. For the type of oil, Ramadan and Moersel (2006) compared, using the same per-weight basis, the antiradical performance of oils with respect to DPPH radical. The order of effectiveness of oils in inhibiting free radicals was as follows: coriander> black cumin> cottonseed> peanut> sunflower> walnut> hemp seed> linseed> olive> niger seed. The extraction conditions used in oil extracts preparation were affect effectively on their antioxidant activities. In this direction, Espin *et al.* (2000) examined the ARP of plant oils, e.g., SBO and SFO, in both lipid and methanolic fractions, and reported that free radical scavenging capacity on DPPH in polar fraction was not significant. Regarding the type of phenolics content, Sroka and Cisowski (2003) reported that the ARP to scavenge DPPH by phenolic compounds extracted from rapeseeds also depended on the number of hydroxyl groups in the aromatic ring of the studied compounds. Also, the molecular structure of phenols is important for their antioxidant activity, as this activity is enhanced by the presence of a second hydroxyl or a methoxy group in the *ortho*- or *para*-position .

Chemical characteristic/fat constants of selected vegetable oils

The chemical characteristics (fat constants) of selected vegetable oils were shown in Table (3). The highest fat constants i.e. AV, PV and SN were obtained in PO which recorded 3.89 ± 0.13 mg KOH/g oil, 1.02 ± 0.16 meq/kg oil and 197.30 ± 3.07 mg KOH/g oil, respectively. SFO was characterized by the lowest fat constants i.e. AV, PV and SN 3.12 ± 0.17 mg KOH/g oil, 0.74 ± 0.11 meq/kg oil and 183.76 ± 5.76 mg KOH/g oil, respectively. The fat constants (AV, PV and SN) determined in different selected vegetable oils could be arranged as follows: PO> SBO> SFO. The opposite direction was observed for the IV. The present data are in accordance with that observed by Serag El-Din, (2001) and El-Sharkawy (2011).

Table 3. Chemical characteristics/fat constants of selected vegetable oils

Oil sample	Acid value (AV, mg KOH/g oil)	Peroxide value (PV, meq/kg oil)	Iodine value (IV, Hanus solution)	Saponification number (SN, mg KOH/g oil)
Soybean (SBO)	3.41 ± 0.77	0.85 ± 0.09	132.11 ± 2.76	189.55 ± 4.21
Sunflower (SFO)	3.12 ± 0.17	0.74 ± 0.11	123.54 ± 5.19	183.76 ± 5.76
Palm (PO)	3.89 ± 0.13	1.02 ± 0.16	60.72 ± 4.11	197.30 ± 3.07

* Values (means ±SD) with different superscript letters are statistically significantly different ($P \leq 0.05$).

The IV is usually used as a measure of the degree of unsaturation of oils. This difference in IV could be attributed to the difference in their content of unsaturated fatty acids (USFA's). Such as mentioned by Earl *et*

al., (2005), palm oil is a saturated fat i.e. rich in saturated fatty acids subsequently recorded the lowest value of IV. Also, SBO and SFO are rich in USFA's (Serag El-Din, 2001 and El-Sharkawy, 2011). Studies have shown that the oxidation rate of USFA is much higher than that of the SFA, which oxidize quickly and are the major contributors to the poor stability of these oils (White, 2000). Furthermore, the highest SN recorded for PO due to its high content of short chain fatty acids compared with the SBO and SFO.

Fatty acids composition of selected vegetable oils

Gas-liquid chromatographic analysis for the methyl ester of selected vegetable oil samples were carried out to indicate their fatty acid composition related to the type of oil. The obtained data were illustrated in Table (4). PO has a balanced fatty acid composition in which the level of saturated fatty acids (SFA's) is almost equal to that of the unsaturated fatty acids (USFA's). Palmitic acid (43.18%) and oleic acid (38.97%) are the major component acids along with linoleic acid (11.32%) and only a trace amount of linolenic acid (0.25%). The low level of linoleic acid and virtual absence of linolenic acid make the oil relatively stable to oxidative deterioration (Frank, 2002). On the other side, SBO and SFO are not saturated fat, their total saturated fatty acid composition are only 13.10 and 16.59%, respectively. The major saturates in SBO and SFO are palmitate and stearate. Palmitate is responsible for about 70% and 50% of the total saturated fat in SBO and SFO, respectively. Also, SBO and SFO contain 22.05 and 19.04% and 61.18 and 67.66%, of the monounsaturate oleate and PUFA's, respectively.

Table 4. Fatty acids composition of edible oils

Fatty acids (%)		Soybean	Sunflower	Sunflower
Lauric	12.0	0.00	0.43	0.21
Myristic	14.0	0.12	0.19	1.34
Palmitic	16.0	12.01	7.22	43.18
Stearic	18.0	3.91	4.93	4.02
Arachidic	20.0	0.41	0.33	0.39
Behenic	22.0	0.14	0.00	0.00
Lignoceric	24.0	0.00	0.00	0.00
Total SFA		16.59	13.10	49.14
Palmitoleic	16:1	0.18	0.20	0.32
Oleic	18:1	22.05	19.04	38.97
Linoleic	18:2	53.70	67.05	11.32
Linolenic	18:3	7.48	0.61	0.25
Gadoleic	20:1	0.00	0.00	0.00
Eicosadienoic	20:2	0.00	0.00	0.00
Total MUFA		22.23	19.24	39.29
Total PUFA		61.18	67.66	11.57
Total USFA		83.41	86.90	50.86
SFA/USFA ratio		5.03	6.63	1.04

The obtained data are relatively in accordance with that obtained by Serag El-Din (2001) who found that SFO and SBO were characterized by having higher ratio of USFA's in particular oleic (C18:1) and linoleic (C 18:2) acids. From a nutritional point of view, Ingestion of approximately 1–2% of daily calories as linoleate is widely accepted as the amount needed to meet the essential fatty acid requirement of rodent species and humans (Frank, 2002). The 8% linolenate of soybean oil, makes it not only an excellent source of essential fatty acids, but also a member of the n-3 fatty acid group (the third carbon atom from the terminal end of the hydrocarbon chain is involved in a double bond) (Lands, 1986 and DeMan, 1992). A number of health benefits have been associated with the consumption of foods or oils that contain n-3 fatty acids including decreased blood pressure, likelihood of thrombosis, plasma TG concentrations, tumor cell growth and survival and inflammation, and improved vascular reactivity, immune function and insulin sensitivity, and optimized visual signaling (Philip, 2012).

In conclusion, the results of this study confirm the expansion of the use of soybean and sunflower oils in various food applications, as opposed to palm oil. As soybean and sunflower oils are the major edible oils consumed in Egypt, lowering their saturated fat could help reduce liver and heart diseases in this country, even though their total saturated fatty acids composition are only in small quantities.

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دراسة مقارنة على ثلاثة من الزيوت النباتية الشائعة الإستهلاك فى الأسواق المحلية المصرية

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الملخص العربى:

أجريت الدراسة الحالية بهدف مقارنة التركيب الكيميائى وصورة الأحماض الدهنية والنشاط المضاد للأكسدة لثلاثة من الزيوت النباتية (فول الصويا، عباد الشمس، النخيل) الشائعة الإستهلاك فى الأسواق المحلية المصرية. ولقد سجلت أعلى المحتوى من الفينولات الكلية فى زيت فول الصويا (1.49 ± 0.36 mg GAE.100 g^{-1}) فى حيت سجل زيت النخيل أقل المستويات (1.08 ± 0.17 GAE.100 g^{-1}). كما سجلت الخواص المتعلقة بالمستخلصات الميثانولية للزيوت إختلافات معنوية فيما يتعلق بالنشاط المضاد للأكسدة ، حيث سجلت أعلى المستويات لزيت عباد الشمس (17.96 ± 2.08 of DPPH scavenged) يتبعها فى ذلك زيت فول الصويا (12.78 ± 3.71) ، وزيت النخيل (9.04 ± 2.52). كما سجل زيت النخيل تركيبا متوازنا فيما يتعلق بالأحماض الدهنية والذى يعنى أن مستوى الأحماض الدهنية المشبعة يعادل غالبا مستوى الأحماض الدهنية الغير مشبعة. كما سجل حمض البالميتيك (43.18%) ، حمض الأوليك (38.97%) ، وحمض الينوليك (11.32%) أعلى الأحماض الدهنية بينما يوجد أثار من حمض البينولينيك (0.25%). وفى النهاية تؤكد نتائج الدراسة أفضلية إستخدام زيت فول الصويا وزيت عباد الشمس فى مختلف التطبيقات الغذائية على عكس الحال فى زيت النخيل.

الكلمات المفتاحية: زيت فول الصويا، زيت عباد الشمس، زيت النخيل، الفينولات، النشاط المضاد للأكسدة، الأحماض الدهنية.