Effect of *amurca* on olive oil quality during storage

Sana Janakat · Anas Al-Nabulsi · Fwzieh Hammad ·
Richard Holley

Revised: 6 August 2013 / Accepted: 15 August 2013 / Published online: 28 August 2013
© Association of Food Scientists & Technologists (India) 2013

Abstract Total phenolic compounds (TPC), antioxidant activity (AA), lipid peroxidation inhibition (percent) (LPOIP), free fatty acid and peroxide values were measured in olive oil samples over the period of 12 months in comparison with oil samples extracted from *amurca* (olive oil lees) and olive oil samples taken from the bottom of the canister (near *amurca*) after 12 months of storage. Olive oil samples taken over the period of 12 months possessed decreasing amounts of TPC, AA and LPOIP, which led to increased peroxide and free fatty acid values. In contrast, oil extracted from *amurca* and olive oil samples taken from the bottom of the container after 12 months of storage possessed significantly higher TPC, AA, LPOIP and consequently lower free fatty acid and peroxide values. These results show that the presence of naturally occurring *amurca* (sediment) in stored olive oil stabilizes olive oil quality during storage.

Keywords *Amurca* · Total phenolic compounds · Lipid peroxidation inhibition percent · Free fatty acid value · Peroxide value · Olive oil quality

Introduction

The term *amurca* refers to the watery bitter tasting and dark coloured sedimentation which settles at the bottom of olive oil containers over time (Niaounakis and Halvadakis 2006; Smith and Secoy 1975). Olive oil content of *amurca* varies

tremendously (12–460 mg/kg oil) depending on the type of mills used to extract olive oil (Koidis et al. 2008). The Jordanian specification for olive oil does not state a criterion for the maximum amount of *amurca* that is permitted in olive oil for local use (JISM 2009), and since the Jordanian consumer prefers the bitter taste and the aroma of *amurca*, olive oil produced for local consumption contains a high amount of *amurca*.

Although *amurca* was reported to be a very rich source of antioxidants (Frega et al. 1999; Lozano-Sanchez et al. 2010), internationally it is considered a negative factor affecting olive oil quality, and when present the oil is often discarded (Fregapane et al. 2006). Olive oil quality is affected by many factors such as: storage temperature (Gomez-Alonso et al. 2007), contact with atmospheric oxygen and type of container (Kanavouras and Coutelieris 2006). These factors stimulate lipid peroxidation (LPO) reactions. LPO refers to the oxidative degradation of lipids and formation of lipid free radicals (Gutteridge 1986), that lead to malondialdehyde formation, which is considered an endogenous source of DNA damage and yields off-flavour and other types of quality loss (e.g. changes in colour and taste) during storage which in turn can cause large economic losses (Marnett 2002).

Alba-Mendoza (2001) suggested that elimination of *amurca* might increase olive oil shelf life and avoid off flavour. However, Fregapane et al. (2006) reported that filtration decreases the rate of hydrolysis of triacylglycerol and consequently prolongs the shelf life of olive oil. In contrast, Tsimidou et al. (2005) demonstrated that water and small particles (*amurca*) in olive oil led to loss of stability and increased peroxide value.

In an earlier study *amurca* was shown to possess high total phenolic compounds, antioxidant activity, and anti-lipoperoxidative activity (Janakat and Hammad 2013). The objectives of this work were to determine the impact of *amurca* on olive oil oxidative stability during storage and to

S. Janakat (✉) · A. Al-Nabulsi · F. Hammad
Department of Nutrition and Food Technology, Jordan University of
Science and Technology, Irbid P.O. Box 3030, Jordan
e-mail: jana@just.edu.jo

R. Holley
Department of Food Science, University of Manitoba, Winnipeg,
Manitoba R3T 2N2, Canada

compare the oxidative stability of *amurca* and oil samples collected from the bottom of containers at the end of storage.

Materials and methods

Chemicals and reagents

Folin-Ciocalteu's phenol reagent and 2, 4, 6- tripyridyl- s- triazine (TPTZ) were purchased from Sigma (St. Louis, MO, USA), gallic acid, Tris-HCl and thiobarbituric acid (TPA) were purchased from Acros Organics (Fisher Scientific, Pittsburg, PA, USA), methanol was purchased from Medex (Naseby, UK), sodium dodecyl sulfate (SDS) was purchased from Scharlau (Barcelona, Spain), ascorbic acid was purchased from Gesellschaft Deutscher Chemiker, GDCh (Frankfurt, Germany) and ferrous chloride was purchased from AppliChem (Darmstadt, Germany).

Olive oil samples

Olive oil canisters containing 20 L were purchased from one of the olive oil mills in the province of Irbid (Northern Jordan) and which had been pressed in December 2009. Olive oil samples ($n=3$) were taken from the top of the canisters (about 3 cm below the surface) at 0 time (immediately after pressing), 1, 3, 5, 7, 9, and 12 months storage. Samples from the bottom of the canisters (about 3 cm above the *amurca* sediment) were also taken after 12 months of storage. All samples were stored at room temperature in the dark until use.

Amurca samples

Amurca samples were obtained from the same olive oil canisters. *Amurca* was removed from the olive oil by centrifugation at 4000 rpm (1252 X g) for 30 min and stored at -18°C until tested.

Oil extraction from *amurca*

Oil was extracted from *amurca* by soaking *amurca* samples in hexane (1:3) overnight, the mixture was centrifuged at 3,000 rpm (723 X g) for 20 min, the supernatant was collected, and hexane was evaporated using a rotary evaporator.

Preparation of olive oil and *amurca* extracts

Fifty grams of olive oil or *amurca* samples were diluted in 50 ml of hexane and the mixture was washed three times with 30 ml of methanol/water mixture (60:40). The mixture was shaken for 2 min before allowing the two phases to separate in

a separatory funnel. The methanolic extracts were then washed with 50 ml of hexane and finally brought up to 100 ml in a volumetric flask and stored at -18°C until use (Favati et al. 1995).

Total phenolic compounds

Total phenolic compounds of olive oil and *amurca* extracts were determined according to the Folin-Ciocalteu procedure adapted from Hajimahmoodi et al. (2008) at 725 nm. Gallic acid was used as the calibration standard and results were expressed as mg gallic acid equivalent (mg GAE/100 g fresh weight).

Antioxidant activity

Antioxidant activity of sample extracts were determined spectrophotometrically using a ferric reducing antioxidant power assay (FRAP) at 593 nm (Benzie and Strain 1999). For construction of the calibration curve, 6 concentrations of vitamin E (4, 6, 8, 10, 15 and 20 mg) were used and results were calculated as mg vitamin E equivalent (mg vitamin E equivalent/100 g fresh weight).

Free fatty acid and peroxide values

Free fatty acid and peroxide values were determined for olive oil samples and oil extracted from *Amurca* according to the AOAC (1984, 1997).

Determination of lipid peroxidation inhibition percent

Lipid peroxidation was determined by measuring the concentration of malondialdehyde (MDA) in rat liver homogenate using the thiobarbituric acid (TBA) reactive species assay according to methods by Ohkawa et al. (1979) and Lin et al. (1998). LPO inhibition (percent) was calculated according to the following equation (Toda et al. 2000).

$$\text{LPO inhibition percent} = \frac{\text{control} - \text{treatment}}{\text{control}} \times 100$$

where:

control	absorbance of the MDA/TBA complex in the absence of the extract
treatment	absorbance of the MDA/TBA complex in the presence of the extract

Statistical analysis

The data were statistically analyzed using the statistical package for social sciences (SPSS, version 15.0, 2007, Chicago, IL,

USA). One way analysis of variance (ANOVA) tests were performed to test the difference between treatments followed by Duncan's Analysis. Significance was declared at $p < 0.05$.

Results and discussion

Effect of storage time on total Phenolic compounds

Figure 1 shows the effect of storage time on total phenolic compounds of olive oil samples taken from the top of the container in comparison with total phenolic compounds of *amurca* and olive oil samples taken from the bottom of the container after 12 months of storage.

Total phenolic compounds decreased from $31.6(\pm 0.37)$ mg GAE/100 g oil in samples taken immediately after pressing (0 time) to $6.7(\pm 0.19)$ mg GAE/100 g in samples taken after 12 months storage, which is a 78.8 % decrease of phenolic compounds. These results are in agreement with those of Gomez-Alonso et al. (2007) who reported that the reduction of total phenolic compounds ranged from 43 % to 73 % during 21 months of storage. In the present work most of the total phenolic compound loss (62 %) occurred within the first month of storage. By 3 months an additional non-significant loss of 3.2 % occurred, but by 5 months a further significant loss of 10.2 % was observed. Between 5 and 12 months storage an additional non-significant loss of 3.3 % was found.

Olive oil samples taken from the bottom of the container (near the *amurca*) after 12 months of storage contained $17.1(\pm 0.30)$ mg GAE/100 g oil, which is a 45.8 % decrease in total phenolic compounds normally found in freshly

pressed olive oil. Sedimentation of *amurca* at the bottom of the container with time (Koidis et al. 2008) is likely why there were higher total phenolic compounds near the bottom of the container. A cloudy appearance of freshly pressed olive oil with higher total phenolic compounds that disappears during storage was reported earlier (Tsimidou et al. 2005). The cloudy appearance may persist for several months before *amurca* settles at the bottom of the container (Fregapane et al. 2006). The total phenolic compounds of oil samples extracted from *amurca* after 12 months of storage was 289 mg GAE/100 g of *amurca*, which was 9.1 times higher than freshly pressed olive oil and 16.9 times higher than that of olive oil taken from the bottom of the container (at 12 months) and 43.1 times higher than the total phenolic compounds of olive oil samples taken from the top of the container after 12 months of storage. This is a clear indication that *amurca* is a reservoir for phenolic compounds.

Antioxidant activity

Figure 2 depicts the effect of storage time on antioxidant activity of olive oil samples taken from the top of the container in comparison with that of *amurca* samples and olive oil samples taken from the bottom of the container after 12 months of storage. Antioxidant activity decreased significantly with time from $1.29(\pm 0.01)$ mg vitamin E equivalent/100 g oil in freshly pressed olive oil samples taken from the top of the container to $0.39(\pm 0.003)$ mg vitamin E equivalent/100 g oil ($p < 0.05$) in samples taken from the same container location after 12 months of storage. The antioxidant activity of samples taken from the bottom of the container after 12 months of storage was $1.12(\pm 0.09)$ mg vitamin E

Fig. 1 Effect of storage time on total phenolic compounds of olive oil samples taken from the top of the container (about 3 cm below the surface) in comparison with olive oil samples taken from bottom of the container (about 3 cm above *amurca* sediment) and *amurca* samples taken after 12 months of storage. Values are expressed as mean ($\pm$ S.E.M) ($n=3$).

(Asterisk) indicates that olive oil was taken from bottom of the container (about 3 cm above *amurca* sediment) after 12 months of storage); (Number sign) indicates 1:10 dilution. P -values were calculated using ANOVA test. Means with different superscripts a,b,c,d differ significantly ($p < 0.05$)

Fig. 2 Effect of storage time on antioxidant activity of olive oil samples taken from the top of the container (about 3 cm below the surface) in comparison with olive oil samples taken from bottom of the container (about 3 cm above *amurca* sediment) and *amurca* samples taken after 12 months of storage. Values are expressed as mean ($\pm$ S.E.M) ($n=3$).

(*Asterisk*) indicates that olive oil was taken from bottom of the container (about 3 cm above *amurca* sediment) after 12 months of storage; (*Number sign*) indicates 1:10 dilution. *P*-values were calculated using ANOVA test. Means with different superscripts a,b,c,d differ significantly ($p<0.05$)

equivalent/100 g), while the antioxidant activity of oil extracted from *amurca* samples after 12 months of storage was $22.3(\pm 0.16)$ mg vitamin E equivalent/100 g.

The correlation between total phenolic compounds and antioxidant activity of olive oil samples was found to be a linear positive relationship ($R^2=0.873$) (Fig. 3), which is in agreement with the findings of Hajimahmoodi et al. (2008) and Qusti et al. (2010). Frega et al. (1999) suggested that *amurca* dispersed in olive oil might have some antioxidant activity.

Lipid peroxidation (LPO)

Figure 4 shows the effect of olive oil storage time on LPO inhibition percent. LPO was expressed as malondialdehyde (MDA) formation in rat liver tissue using an ascorbate/ FeCl_2 model. All extracts (hexane/methanol/water) taken at 0 time to

9 months caused significant LPO inhibition percent in comparison with the control (containing all reagents except the sample extracts), which was correlated with phenolic compounds and antioxidant activity. *Amurca* extracts caused a $95.7(\pm 2.5)$ % LPO inhibition ratio, and this could be attributed to the fact that phenolic compounds and antioxidants inhibited MDA formation (Gavino et al. 1981; Janakat and Al-Thnaibat 2008). Moreover, there was a significant decrease in LPO inhibition percent over time, from $53.13(\pm 0.29)$ % in freshly pressed olive oil to $2.70(\pm 0.33)$ % in olive oil samples taken from the top of the container after 12 months of storage. This is believed to be due to the fact that *amurca* takes several months to settle at the bottom of the container (Fregapane et al. 2006). Olive oil samples taken after 12 months of storage (from the bottom of the container) caused $53.7(\pm 1.5)$ % LPO inhibition, while samples taken from the top container after 12 months of storage caused $2.7(\pm 0.33)$ % LPO inhibition percent. This could be attributed to the high total phenolic compounds and antioxidant activity of *amurca* at the bottom of the container (Frega et al. 1999).

Free fatty acid value

Table 1 depicts the effect of storage time on olive oil free fatty acid value in samples taken from the top of the container in comparison with that of olive oil samples taken from the bottom of the container and oil samples extracted from *amurca* after 12 months of storage. A significant increase in free fatty acid value was observed with time from $1.39(\pm 0.03)$ % for samples taken at 0 time from the top of the container to $3.99(\pm 0.08)$ % in samples taken after 12 months storage from the container location ($p<0.05$). The increase in free fatty acid value comes as a result of

Fig. 3 Linear correlation between total phenolic compounds measured according to the Folin-Ciocalteu procedure and antioxidant activity measured according to the FRAP assay of olive oil samples

Fig. 4 Effect of storage time of olive oil on LPO inhibition percent in comparison with LPO inhibition percent induced by oil extracted from *amurca* samples after 12 months of storage expressed as malondialdehyde (MDA) concentration at 532 nm. Values are expressed as mean ($\pm$ S.E.M) ($n=3$). (Asterisk) indicates that olive oil was taken from bottom of the container (about 3 cm above *amurca* sediment) after 12 months of storage; (Number sign) indicates 1:10 dilution. *P*-values were calculated using ANOVA test. Means with different superscripts a,b,c,d differ significantly ($p<0.05$)

hydrolysis of triglyceride to free fatty acids (Gutierrez and Fernaandez 2002; Pristouri et al. 2009; Ciafardini, and Zullo 2002). The Jordanian specification for olive oil requires that the free fatty acid value for olive oil produced for local use is $\leq 3.3\%$ (JISM 2009). Olive oil samples taken from the bottom of the container after 12 months of storage possessed a significantly ($p<0.05$) lower free fatty acid value ($2.61(\pm 0.01)\%$) than samples taken from the top of the container at the same time ($3.99(\pm 0.08)\%$). Furthermore, the free fatty acid value in oil extracted from *amurca* samples after 12 months of storage was lower at $1.62(\pm 0.03\%)$ ($p<0.05$), but was not significantly different from the free fatty acid value of oil samples taken at 0 time. This was due to the stabilizing role of suspended *amurca* against oxidative degradation (Frega

et al. 1999; Lozano-Sanchez et al. 2010). On the contrary, Fregapane et al. (2006) reported that freshly pressed olive oil which had a cloudy appearance, had a high free fatty acid value in the oil and that after filtration the rate of hydrolysis of the triglycerides decreased.

Peroxide value

Table 1 also depicts the effect of storage time on peroxide values of olive oil samples taken from the top of the container in comparison with peroxide value of olive oil samples taken from the bottom of the container, and the peroxide value of oil extracted from *amurca* after 12 months of storage. The peroxide values were lower than $20 \text{ meq O}_2/\text{kg oil}$ ($p<0.05$) in all samples except for those taken at 9 and 12 months from the top of container. Peroxide values were stable for 3 months and ranged between $11.69(\pm 0.01)$ to $12.72(\pm 0.33) \text{ meq O}_2/\text{Kg}$, then a significant increase was observed after 5 months of storage onwards. Peroxide values reached $16.51(\pm 0.61) \text{ meq O}_2/\text{Kg}$ at 5 months, $19.09(\pm 0.61) \text{ meq O}_2/\text{Kg}$ at 7 months, and $25.61(\pm 0.20) \text{ meq O}_2/\text{Kg}$ at 9 months which is consistent with many previous studies (Tsimidou et al. 2005; Pristouri et al. 2009; Mendez and Falque 2007).

Olive oil from the bottom of the container (about 3 cm above the *amurca* sediment) taken after 12 months of storage had a significantly ($p<0.05$) lower peroxide value $9.27(\pm 0.18) \text{ meq O}_2/\text{Kg oil}$ than samples taken from the top of the container (about 3 cm below the surface) at the same time ($25.6(\pm 0.20) \text{ meq O}_2/\text{Kg oil}$), which can be explained by the presence of high antioxidant activity at the bottom of the container which inhibits initiation of auto-oxidation of free fatty acids (Kahl and Hildebrandt 1986; Gutteridge 1986). This result is in accordance with the results of Fregapane et al. (2006) who reported that filtration of olive oil caused

Table 1 Effect of storage time on olive oil free fatty acid and peroxide values in comparison with that oil extracted from *amurca* after 12 months of storage

Storage Time	Free fatty acid value [Oleic Acid %]	Peroxide Value [meqO ₂ /Kg]
0 h	$1.39(\pm 0.03)^a$	$11.69(\pm 0.01)^c$
1 month	$3.58(\pm 0.16)^c$	$12.72(\pm 0.33)^c$
3 months	$3.31(\pm 0.14)^c$	$12.58(\pm 0.25)^c$
5 months	$3.33(\pm 0.13)^c$	$16.51(\pm 0.61)^d$
7 months	$3.35(\pm 0.15)^c$	$19.09(\pm 0.24)^e$
9 months	$3.66(\pm 0.18)^{c,d}$	$25.61(\pm 0.20)^f$
12 months	$3.99(\pm 0.08)^d$	$25.61(\pm 0.20)^f$
12 months*	$2.61(\pm 0.01)^b$	$9.27(\pm 0.18)^b$
<i>Amurca</i>	$1.62(\pm 0.03)^a$	$1.78(\pm 0.03)^a$

(*) indicates that olive oil was taken from bottom of the container (about 3 cm above *amurca* sediment) after 12 months of storage. *P*-values were calculated using ANOVA test. Means with different superscripts a,b,c,d differ significantly ($p<0.05$)

an increase in the rate of peroxide formation. Moreover, the peroxide value for oil extracted from *amurca* samples was $1.78(\pm 0.03)$ meqO₂/Kg oil which was significantly ($p < 0.05$) lower than the peroxide value of oil samples taken at 0 time. The high total phenolic compounds and antioxidant activity of *amurca* can be responsible for this low peroxide value.

Conclusions

Sedimentation of *amurca* during olive oil storage causes a significant decrease in total phenolic compounds as well as antioxidant activity and it causes some loss of olive oil antiliperoxidative activity, which yields increased acid and peroxide values leading to loss of olive oil quality during storage. Thus, *amurca*, which is a natural source of phenolic compounds and antioxidant activity in olive oil should not be removed from olive oil because this might reduce olive oil shelf life.

Acknowledgment We would like to thank the Deanship of Research at Jordan University of Science and Technology (JUST) for providing financial support for this project.

References

- Alba-Mendoza J (2001) Elaboración de aceite de oliva virgín. In: Barranco D, Barranco D, Fernandez-Escobar R, Rallo L (eds) El cultivo del olivo, 4th edn. Ediciones Mundi- Prensa, Madrid, pp 551–587
- Association of Official Analytical Chemists (AOAC) (1984) Official Method of Analysis. 14th ed. USA, Washington, DC
- Association of Official Analytical Chemists (AOAC) (1997) Official Method of Analysis. 14th ed. USA, Washington, DC
- Benzie I, Strain J (1999) Ferric reducing/antioxidant power assay: direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. *Methods Enzymol* 299:15–27
- Ciafardini G, Zullo B (2002) Microbiological activity in stored olive oil. *Int J Food Microbiol* 75:111–118
- Favati F, Caporale G, Monteleone E, Bertuccioli M (1995) Rapid determination of phenol content in extra virgin olive oil. *Dev Food Sci* 37(1):429–452
- Frega N, Mozzon M, Lercker G (1999) Effects of free fatty acids on oxidative stability of vegetable oil. *J Am Oil Chem Soc* 76(3):325–329
- Fregapane G, Lavelli V, Leon S, Kapuralin J, Salvador D (2006) Effect of filtration on virgin olive oil stability during storage. *Eur J Lipid Sci Technol* 108:134–142
- Gavino V, Miller J, Ikharabha S, Milo G, Cornwell D (1981) Effect of polyunsaturated fatty acids and antioxidants on lipid peroxidation in tissue cultures. *J Lipid Res* 22:763–769
- Gomez-Alonso S, Mancebo-Campos V, Salvador M, Fregapane G (2007) Evolution of major and minor components and oxidation indices of virgin olive oil during 21 months storage at room temperature. *Food Chem* 100:36–42
- Gutierrez F, Fernaandez J (2002) Determinant parameters and components in the storage of virgin olive oil. Prediction of storage time beyond which the oil is no longer of “extra” quality. *J Agric Food Chem* 50:571–577
- Gutteridge J (1986) Iron promoters of the fenton reaction and lipid peroxidation can be released from hemoglobin by peroxides. *FEBS Lett* 201(2):291–295
- Hajimahmoodi M, Sadeghi N, Jannat B, Oveisi M, Madani S, Kiayi M, Akrami M, Ranjba A (2008) Antioxidant activity, reducing power and total phenolic content of Iranian olive cultivar. *J Biol Sci* 8(4): 779–783
- Janakat S, Al-Thnaibat O (2008) Antiliperoxidative effect of three edible plants extracts; *Viscum album*, *Arum dioscoridis* and *Eminium spiculatum*. *J Food Qual* 31:1–12
- Janakat S, Hammad F (2013) Chemical Composition of *Amurca* Generated from Jordanian Olive Oil. *J Nutr Food Sci* 3:186. doi:10.4172/2155-9600.1000186
- Jordan Standards and Metrology Organization (JISM) (2009) Fats and oils Olive oil and olive pomace oil
- Kahl R, Hildebrandt A (1986) Methodology for studying antioxidant activity and mechanism of action of antioxidant. *Food Chem Toxicol* 24:1007–1014
- Kanavouras A, Coutelieres F (2006) Shelf-life predictions for packaged olive oil based on simulations. *Food Chem* 96:48–55
- Koidis A, Triantafyllou E, Boskou D (2008) Endogenous microflora in turbid virgin olive oils and the physicochemical characteristics of these oils. *Eur J Lipid Sci Technol* 110:164–171
- Lin C, Yen M, Lo T, Lin J (1998) Evaluation of the hepatoprotective and antioxidant activity of *Boehmeria nivea* var. *nivea* and *B. nivea* var. *tenacissima*. *J Ethnopharmacol* 60:9–17
- Lozano-Sanchez J, Cerretani L, Bendini A, Segura-Carretero A (2010) Filtration process of extra virgin olive oil: effect on minor components, oxidative stability and sensorial and physicochemical characteristics. *Trends Food Sci Technol* 21:201–211
- Marnett J (2002) Oxy radicals, lipid peroxidation and DNA damage. *Toxicology* 181(182):219–222
- Mendez A, Falque E (2007) Effect of storage time and container type on the quality of extra-virgin olive oil. *Food Control* 18:521–529
- Niaounakis M, Halvadakis C (2006) Olive processing waste management, 2edth edn. Elsevier Pub. Ltd., London
- Ohkawa H, Ohish N, Yagi K (1979) Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. *Anal Biochem* 95:351–358
- Pristouri G, Badeka A, Kontominas M (2009) Effect of packaging material headspace, oxygen and light transmission, temperature and storage time on quality characteristics of extra virgin olive oil. *Food Control* 21(4):412–418
- Qusti S, Abo-Khatwa A, Bin-Lahwa M (2010) Screening of antioxidant activity and phenolic content of selected food items cited in the holly Quran. *Eur J Biol Sci* 2(1):40–51
- Smith E, Secoy D (1975) Forerunners of pesticides in classical Greece and Rome. *J Agric Food Chem* 23(6):1050–1055
- Toda S, Yase Y, Shirataki Y (2000) Inhibitory effect of *Astragali Radix*, crude drug in oriental medicine on lipid peroxidation and protein oxidative modification of mouse brain homogenate by copper. *Phytother Res* 14:249–296
- Tsimidou M, Georgiou A, Koidis A, Boskou D (2005) Loss of stability of “veiled” (cloudy) virgin olive oils in storage. *Food Chem* 93:377–383