RESEARCH ARTICLE

Blending of Soybean Oil with Selected Vegetable Oils: Impact on Oxidative Stability and Radical Scavenging Activity

Yang Li[1], Wen-Jun Ma[1], Bao-Kun Qi[1], Sami Rokayya[1,2], Dan Li[1], Jing Wang[1], Hong-Xia Feng[1], Xiao-Nan Sui[1], Lian-Zhou Jiang[1]*

Abstract

Background: Soybean oil may protect against cancer of the breast and prostate. It may also exert beneficial influence in combination with other oils. Here, blends (20%, v/v) of sea buckthorn oil (SEBO), camellia oil (CAO), rice bran oil (RBO), sesame oil (SEO) and peanut oil (PEO) with soybean oil (SBO) were formulated. Materials and Methods: Oxidative stability (OS) and radical scavenging activity (RSA) of SBO and blends stored under oxidative conditions (60°C) for 24 days were studied. By blending with different kinds oils, levels of polyunsaturated fatty acids (PUFA) decreased, while monounsaturated fatty acid (MUFA) content increased. Progression of oxidation was followed by measuring peroxide value (PV), p-anisidine (PAV), conjugated dienes (CD) and conjugated trienes (CT). Results: Inverse relationships were noted between PV and OS at termination of storage. Levels of CD and CT in SBO, and blends, increased with increase in time. The impact of SEO as additives on SBO oxidation was the strongest followed by RBO, CAO, SEBO and PNO. Conclusions: Oxidative stability of oil blends was better than SBO, most likely as a consequence of changes in fatty acids and tocopherols' profile, and minor bioactive lipids found in selected oils. The results suggest that these oil blends could contribute as sources of important antioxidant related to the prevention of chronic diseases associated to oxidative stress, such as in cancer and coronary artery disease

Keywords: Vegetable oil blends - soybean oil - oxidative stability - antiradical properties

Asian Pac J Cancer Prev, **15 (6)**, 2583-2589

Introduction

Soybean consumption is associated with reduced risk of cancer of the breast and prostate and may enhance survival (Zhu et al., 2011; Kang et al,., 2012; Zhang et al., 2012; Sugiyama et al., 2013). It is conceivable that its effects could be enhanced by mixing with other vegetable products, for example in oils. Commercial oils today are mainly extracted using a hexane solvent, which has environmental and safety problems, so that it is necessary to develop alternative methods to hexane extraction. Enzyme-assisted aqueous extraction processing (EAEP) has been studied, which uses water as an extraction and separation medium. EAEP has been applied to extract oil from several kinds of oil-bearing seeds, such as soybean, corn germ, rapeseed and peanut. Soybean oil with high levels of polyunsaturated fatty acids (PUFA) is the main oil used for cooking and frying. Soybean oil is considered superior to many vegetable oils, but it is inferior in thermal stability at high temperatures.

Oil oxidation is an autocatalytic reaction generating hydroperoxides from unsaturated acylglycerols. Oxidation of polyunsaturated food lipids often affect on development of unpleasant tastes and odors, characteristic of rancid fats and oils, as well as degradation of functional and nutritional properties. Lipid oxidation can directly reflect shelf life of a product. Environmental factors, such as air, light and temperature, accelerate oxidative reactions which might end in the production of off-flavors and odors associated with low molecular weight volatiles, discoloration (Navarro et al., 2012). Also, oxidation induce important chemical changes of the oils that may affect directly the quality of the edible oil, generates radical oxygen species that may cause irreversible damages when reacting with biological molecules such as DNA, proteins or lipids (Bansal et al., 2010; Cabiscol et al., 2010). Lipid oxidation has harmful effects on both food quality and human health. Then efforts must be made to minimize oxidation and improve oxidative stability of lipid products.

The kind of oils and their oxidative stability are very important indicators which can help to know how long oils can be used. To overcome the problem of poor oxidative stability (OS) of soybean oil, ways of modifying fatty acid composition and increasing natural antioxidants were sought, such as combining high-oleic sunflower oil with corn oil or hydrogenated soybean oil with soybean oil (Abdulkarim et al., 2010; Naghshineh et al., 2010) or combining palm-olein with soybean oil (Warner and

*[1]Department of Food Science, Northeast Agricultural University, Harbin, Heilongjiang, China, [2]Department of Home Economics, Faculty of Education Quality, Mansoura University, Mansoura, Dakahlia, Egypt *For correspondence: jlzname@yeah.net*

Gupta, 2005).

Blending of two or more oils with different characteristics is one of the simplest procedures to make new specific products. Mixing different kinds of vegetable oils not only can change fatty acids profile, but also increase the levels of bioactive lipids and natural antioxidants in the blends and give better quality oils, as well as improved nutritional value at affordable prices (Marmesat et al., 2012; Aladedunye and Przybylski, 2013).

There is an urgent need for widely usable and easily available bioactive lipids and natural antioxidants (Gupta et al., 2013). The sea buckthorn (*Hippophae rhamnoides* L), known as Siberian pineapple, sea berry, sandthorn and swallowthorn, has a long history of application as a food and medicinal ingredient in eastern countries. Both seeds and the soft parts (fruit flesh and peel) of the berry are rich in lipids, vitamins, minerals, flavonoids and antioxidants both aqueous and lipophilic (Dhyani et al., 2007; Shah et al., 2007).

Camellia oil (also known as tea seed oil), mainly extracted from Camellia oleifera, has a lower content of saturated fatty acids (SFA). Tea seed oil is rich in oleic acid similar to olive oil contains 75-80 % oleic acid (C18:1), which have shown functional effects against several degenerative pathologies, including cardiovascular diseases and cancer (Lee and Yen, 2006).

Antioxidant compounds in rice bran oil have professed health benefits such as improving the storage stability of foods (Chotimarkorn and Silalai, 2008). Also, it has been determined that the amount of cholesterol lowering occurs to a greater extent than expected from the fatty acid composition of the oil, suggesting that besides fatty acids, other components in the oil were responsible for the cholesterol lowering effect. Oryzanol has been reported to be used in the cure of nerve imbalance and disorders of menopause (Iqbal et al., 2005).

Sesame seed (sesamum indicum L.) is one of the world's most important and oldest oilseed crops with a high level content of antioxidant known to human health. It is highly valued for its unique and pleasant flavor (Latif and Anwar, 2011). Oxidative stability of sesame oil is superior to that of other vegetable oils although it contains nearly 85% unsaturated fatty acids (Abou-Gharbia et al., 2000).

About two-thirds of the world peanut crop is used for oil. Peanut oil, with delicate fragrance and rich nutrition, is a glyceride mixture of about 80% unsaturated fatty acid and 20% saturated fatty acid. Peanut oil has been demonstrated to reduce cardiovascular risk and risk factors in epidemiological and clinical studies (Stephens et al., 2010).

As food habits of most countries are based on fried foods, oxidative-resistant oils are needed. Therefore, the use of more stable frying oils of comparatively low price would be desirable. To overcome the problem of poor stability of traditional soybean, ways of enhancing the levels of bioactive lipids and natural antioxidants were sought. Blending different kinds of vegetable oils can modify the physicochemical characteristics of vegetable oils and fats besides enhancement in oxidative stability. The present study, therefore aims to investigate the effects of blending selected oils with soybean oil on the oxidative stability and radical scavenging activity of high-linoleic soybean oil at an accelerated oxidative condition. The degradation of oxidized oils and blends was also investigated. Results from this study will aid the program of selecting unique oil blends for improved nutritional value and will provide insight into the mechanisms of the antioxidant.

Materials and Methods

Samples and reagents

Full-fat soybean flakes, sea buckthorn oil, camellia oil, rice bran oil, sesame oil and peanut oil were obtained from a local market (Harbin, China). Protease 6L (2.4 AU/g, from Bacillus licheniformis) was purchased from Novo-Nordisk A/S (Bagsvaerd, Denmark). The fatty acid methyl ester (FAME) standards and 1, 1-Diphenyl-2-picrylhydrazyl (DPPH, approximately 90%) were purchased from Sigma (St. Louis, MO, USA). All solvents and reagents from various suppliers were of the highest purity needed for each application and used without further purification.

Extraction of vegetable oils

The Enzyme-assisted aqueous extraction processing was performed with minor modifications (Li et al., 2013). The extruded seed mixtures were collected into a beaker, and additional water was added to achieve a 1:6 solid:water (wt/vol) ratio. The beaker was then incubated at 55°C in a water bath, and the pH of the slurry was adjusted to 9 by the addition of 2 N NaOH. The enzyme dosage of Alcalase 2.4 L was 1.85 % (v/w, based on the dry weight of the samples). A continuous-stirring device was used to disperse the mixture during the enzymatic hydrolyze process. The reactions were maintained at the stable temperature and pH mentioned above for 3 h.

At the end of the EAEP, the slurry was centrifuged in a 50 mL centrifuge tube at multiples of the force of gravity and express as 2, 372 g (TGL-16G, China) for 20 min at 20°C. Four distinct layers (oil, cream, skim and insoluble) were obtained after the centrifugation. The cream layer is an oil rich fraction (oil-in-water emulsion), whereas the skim fraction is an oil-lean and protein and sugar-rich soluble aqueous fraction. The insoluble layer is a fiber-rich insoluble fraction. The cream was collected in centrifuge tube and stored in refrigerator for 12 h, then centrifuged. The upper oil layer was carefully collected using a Pasteur pipette.

Blending of vegetable oils

The vegetable oil blends were formulated by blending with preheated (60°C) soybean oil (SBO) in proportions of 80:20 (w/w). The oils were thoroughly mixed to form uniform blends. Quality evaluation of the oil blends was by employing storage ability and thermal stability tests.

Fatty acid composition analysis

The fatty acid methyl esters (FAMEs) were prepared by the following two steps: (1) oils were saponified with 0.5 M KOH; (2) later methylated with 40% BF3 in methanol

(Li et al., 2012). Gas chromatography mass spectrometry (GC/MS) analysis was carried out with an Agilent 6890-5973 (Agilent Technologies, CA, USA) instrument. Separating procedure was achieved on an Agilent HP-88 capillary column (100×0.25 mm i.d., film thickness 0.2 μm). The operating conditions were as follows: carrier gas pressure, 100 kPa; carrier gas, helium; split ratio was 1:30; injection temperature, 250°C; scanning scope: 50-550 amu; ionization voltage: 70 eV. Oven temperature was programmed as follows: held at 80°C for 5 min, and then rising to 150°C at 10°C/min, and held for 2 min at 150°C; then continuously rising to 230°C at 5°C/min and held for 10 min. The individual fatty acids were identified and quantified by comparing their retention times with external standards.

Accelerated oxidation

SBO and oil blends were placed in a series of dark glass bottles having a volume 50 ml each. The bottles were completely filled with SBO, oil blends and sealed. No headspace was left in the bottles. The oxidation reaction was accelerated in a forced draft air oven, set at 60±2°C for up to 0, 4, 8, 12, 16, 20 and 24 days. Immediately after storage period, oil samples were withdrawn for triplicate analyses.

Determination of peroxide value (PV)

Accurate weigh of oil (300 mg) was dissolved in 9.9 ml of chloroform: methanol (7:3, v/v), then added 50 μL of 10 mM xylenol orange and 50 μL of iron (II) chloride solution (Pegg, 2001). The mixture solution was incubated at room temperature for 5 min and then centrifuged at 1000 g for 5 min at 5°C. The supernatant was used for measurement of absorbance at 560 nm with (EZ201, USA) spectrophotometer. The iron (III) chloride solution was used as standard curve.

Determination of p-anisidine value (PAV)

P-anisidine value of oxidized oil were determined according to AOCS Recommended Practice Ti la-64 (1998). Accurate weigh of oil (100 mg) was dissolved in 25 ml and measured at 350 nm. This solution (2.5 ml) was mixed with 0.5 ml of 0.5% (w/v) p-anisidine in acetic acid for 10 min.

Determination of the absorptive values

The absorptivity values at 232 and 270 nm were recorded by spectrophotometry (UV-260, Japan), following the analytical methods described by IUPAC (1979), method II.D.23. The contents of conjugated diene (CD) and conjugated trienes (CT) were expressed as absorptivities of the 1% oil in 2, 2, 4-trimethylpentane.

Determination of free radical scavenging activity (DPPH) assay

Radicals were dissolved in toluene according to the procedure described in (Ramadan et al., 2010). Radical Scavenging Activity (RSA) and the presence of hydrogen donors in SBO and the oil blends were examined by reduction of DPPH in toluene during the accelerated oxidation test. Toluene solutions of DPPH radicals were freshly prepared at concentrations of 10-4 M. The radical, in the absence of antioxidant compounds, was stable for more than 2 h of normal kinetic assay. For evaluation, 10 mg of SBO or oil blends sampled during the Shaal oven test (in 100 μL toluene at room temperature) was mixed with 390 μL toluene solution of DPPH radicals and the mixture was vortexed for 20 sec. at ambient temperature. The decrease in absorption at 515 nm was measured after 60 min against a toluene blank (without DPPH) in 1 cm quartz cells using a UV-260 visible recording spectrophotometer (Shimadzu, Kyoto, Japan).

Statistical analysis

Samples of pure oils and various blends were taken in triplicate. Data from the replications of all kinds were subjected to a variance analysis (ANOVA) using SPSS 16.0 for Windows. Significant differences between the means were determined by Duncan's new multiple range test ($P<0.05$). The correlation between all the studied parameters was determined by the principal component analysis (PCA) using XLSTAT software.

Results and Discussion

Fatty acid composition

An examination of FAME derivatives showed thirteen fatty acids (Table 1). The total saturated fatty acids, monounsaturated fatty acids and polyunsaturated fatty acids (PUFA) showed significant variation in their contents. Linoleic acid was the major fatty acid in soybean oil, followed by oleic acid (22.68%) and palmitic acid (16.66%). Similar fatty acid profiles for these oils have been also shown in several works (Reena and Lokesh, 2007; Haiyan et al., 2007; Sharif et al., 2009). Except SEO all selected oils under study contained more PUFA than MUFA.

Fatty acid composition of SBO and oil blends is presented in (Table 1). Blending of selected oils with SBO non-significantly changed the kind of main fatty acids in the blends. While major changes were noted in the contents of oleic acid (C18:1) and linoleic acid (C18:2) of blended oils. SBO had the highest percentage of PUFA and the lowest MUFA. Blending with selected oil didn't lead to significant modification in SFA. Several studies mentioned the effect of blending oils; Mariod et al., (2004) found that blending of sunflower kernel oil with Sclerocarya birrea oil could modify the fatty acid profile of the blends. Farooq et al., (2007) reported that blending Moringa oleifera oil with sunflower oil and soybean oil in different proportions can result in an increase in oleic acid and reduction of lionleic acid. Ramadan and Wahdan, (2012) studied that blending black cumin seed oil and coriander seed oil with corn oil could change the fatty acid profile of the blends; while blending with coriander seed oil has the distinguished impact. In general, it could be noted that the impact of blending SBO with CAO and SFO on fatty acid profile was more marked than that of the blending with others.

Principal component analysis

Principal Component Analysis was then carried out

Table 1. Fatty Acid Composition (%).

Fatty acid	Myristic acid (C14:0)	Palmitic acid (C16:0)	Palmitoleic acid (C16:1)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Linolenic acid (C18:3)	Arachidic acid (C20:0)	Gadoleic acid (C20:1)	Arachidic acid (C20:2)	Behenic acid (C22:0)	Lignoceric acid (C24:0)	Total SFA	Total MUFA	Total PUFA
SBO	0.16±0.02d	16.66±0.21e	0.21±0.03b	7.08±0.12f	22.68±0.34a	53.02±0.50e	0.05±0.01a	0.50±0.04b	0.32±0.04a	0.09±0.01b	N.D.	N.D.	24.40±0.16e	23.21±0.21a	53.16±0.45e
SEO	0.09±0.02c	9.94±0.13a	0.22±0.03c	5.77±0.05e	30.60±0.24b	47.60±0.38d	4.99±0.11e	0.30±0.01a	0.43±0.03b	N.D.	0.61±0.02b	N.D.	16.71±0.12a	31.25±0.33b	52.59±0.47d
RBO	0.67±0.02e	19.50±0.14f	0.83±0.05d	1.86±0.05a	43.20±0.35e	32.00±0.28b	1.12±0.04c	N.D.	0.94±0.02c	N.D.	0.34±0.03a	0.20±0.01a	22.57±0.23d	44.97±0.45e	33.12±0.33b
PNO	0.03±0.01a	12.11±0.10c	0.09±0.01a	3.97±0.11d	41.07±0.57d	32.88±0.35b	0.08±0.01a	1.93±0.04c	1.31±0.04d	0.03±0.01a	4.16±0.09e	1.95±0.04a	24.41±0.06f	42.49±0.25d	33.12±0.12b
SEBO	0.08±0.01b	9.99±0.12b	6.46±0.06e	2.97±0.11b	32.20±0.26c	34.60±0.39c	1.60±0.05d	2.78±0.06d	2.31±0.05e	0.46±0.02c	3.32±0.12d	N.D.	19.14±0.17b	40.97±0.34c	36.66±0.35c
CAO	N.D.	16.50±0.14d	N.D.	3.34±0..5c	56.97±0.34f	22.17±0.14a	0.30±0.01b	0.53±0.01b	N.D.	N.D.	1.02±0.03c	N.D.	21.40±0.12c	56.97±0.83f	22.47±0.27a
SBO	0.16±0.02a	16.66±0.09d	0.21±0.36a	7.08±0.12e	22.68±0.34a	53.02±0.50e	0.05 ±0.01b	0.50±0.04c	0.32±0.04a	0.09±0.01b	N.D.	N.D.	24.40±0.16d	23.21 ±0.21a	53.16 ±0.45f
SBO:SEO#	0.15±0.13a	15.48±0.02b	0.28 ±0.08b	6.83±0.01d	26.17±0.01d	48.36±0.12d	0.12±0.02c	0.48±0.25b	0.35±0.30b	0.08±0.11ab	0.47±0.23b	N.D.	23.41±0.25a	26.80±0.30e	48.56±0.11d
SBO:RBO#	0.22±0.32c	17.41±0.04e	0.34±0.09c	5.91±0.01a	24.47±0.83c	46.84±0.11c	0.14±0.34d	0.55±0.28d	0.41±0.03c	0.08±0.01b	0.06±0.01a	0.04±0.03	24.19±0.32c	25.22±0.09d	47.06±0.83c
SBO:PNO#	0.13±0.04a	15.75±0.01c	0.19±0.02a	6.45±0.10a	26.36±0.01d	48.99±0.01d	0.056±0.32b	0.79±0.09e	0.52±0.01d	0.08±0.01b	0.83±0.01d	0.39±0.01	23.70±0.01b	23.91±0.02b	50.53 ±0.06e
SBO:SEBO#	0.16±0.01a	15.30±0.76a	0.38±0.12d	7.1±0.81f	24.39±0.38b	46.24±0.66	0.03±0.01a	0.51±0.01c	0.34±0.02b	0.09±0.01b	0.59±0.04c	N.D.	23.69±0.17b	25.11±0.16c	46.36±0.03b
SBO:CAO#	0.16±0.02a	17.10±0.58f	0.27±0.01 b	6.53±0.23 b	30.38±0.75e	44.74±1.15a	0.14±0.01 d	0.44±0.01 a	0.54±0.11 d	0.07±0.01a	0.52±0.21c	N.D.	24.75±0.13e	31.19±0.12f	44.95±0.64a

*Mean values within each row followed different letters (a, b, c, etc.) are significantly ($P<0.05$); #(80:20 V/V)

according to fatty acid contents. Figures 1 and 2, present the plots of the scores and the correlation loadings respectively. Inertia percentage and correlated variables with axes 1 and 2 are displayed in (Table 2). Axes 1 explained 72.21% of the total inertia. Axes 2 explained 28.32% of the inertia and was made positively by Stearic acid. The inertia was made negative by Myristic, Palmitic, Oleic and Linoleic acids. Plots of the scores had been performed in (Figure 2), indicating that the data cloud was mainly bi-dimensional. With regards to the explanatory variables, (Figure 1) showed two clusters of varieties. The first cluster included (SBO and SEO). The second cluster (RBO, SFO and SEBO) were individualized.

Oxidative stability

Peroxide value: The initial PV of SBO was 2.34 meq O2/kg oil, results were in agreement with (Moura et al., 2013). The PV for EAEP-extracted SBO was significantly higher than hexane extracted oil (Table 3). It can be observed that a significant increase in PV, for thermal treatments promoted oxidation. Meanwhile, PVs of SBO and blends increased with increase in storage period. SBO and blends follow the pattern that a higher rate of increment during early storage, then the rate decreases. The difference in PV under the treatment was observed after 16th day, which was mainly associated with the rate of hydroperoxides decomposition. Unstable hydroperoxides formed in the initial stage of storage decomposed result in the formation of secondary products of oxidation. Except blending with SFO, the blends showed a marked decline in their PV during storage, thus result in enhancement of the OS of SBO. Padmavathy et al., (2001) reported that blending vegetable oils not only improve sensuous quality, also enhance the storage stability of the edible oils (Gulla et al., 2010). On the basis of PV, the OS of SBO and oil blends varied significantly, while the blends enriched with SEO being most stable. At the end of storage period, SBO control was oxidized rapidly and had the highest PV (28.33 meq/kg).

P-anisidine value: Unstable hydroperoxide occurs with β-scission readily decomposed to alkoxy radicals, resulting in formation of unsaturated aldehydes, nonvolatile aldehydes, ketones, acids, esters, alcohols and short-chain hydrocarbons at high temperature (Choe and Oh, 2013). These compounds produce rancid odors and flavors. Table 4 presents the changes in the level of PAV in SBO and oil blends after 24 days of storage under oxidation conditions. PAVs of SBO and blends increased with the increase of storage period. The PAV of SBO was in a range of (4.75 to 44.07 mg/g). The PAVs of EAEP oils were much higher than those of blends over storage up to 24th day, indicating that lipid oxidation was more extensive in EAEP oil (with higher levels of polyunsaturated fatty acids). PAVs of SBO and SEO blend were significantly higher than other blends without treatment, which attributed to roasted sesame oil originally contains many volatiles such as aldehydes, ketones, alcohols, pyrazines, furans and pyrroles (Chung et al., 2006). At the end of storage period, PAV recorded 27.13 and 26.23 mg/g for SBO blends enriched with RBO and SEO, respectively. Jissang al. investigated the effects of adding sesame oil to soybean oil on the development of PAV during 160°C frying and storage in the dark and found that the addition of sesame oil to soybean oil at 10% and 20% (v/v) improved the lipid oxidative stability of fried products during storage in the dark (Choe and Min, 2007). Results indicate that PAV of oil samples increased with increase of storage period. SBO was the strongest followed by PNO, SEBO, CAO, RBO and SEO. All blends seem to be successful in reducing the formation of p-anisidine reactive substances to a certain degree.

Ultraviolet absorptive: Nonconjugated double bonds in unsaturated acylglycerols are isomerized to more stable conjugated double

bonds when reacting with oxygen during storage at 60°C , indicating the quality status of SBO and blends (Mohdaly et al., 2010). The changes in UV absorbance at 232 and 268 nm, quantified by K232 and K268 have been used to evaluate the occurrence and extension of oxidative reactions. The uptake of oxygen and formation of peroxides in the early stages of lipid peroxidation reactions, as well as with the degradation of linoleic and linolenic acids lead the increase in K232 and K268.A significant negative correlation between oxidative stability and absorptivity at 232 and 268 nm in all oils (Zhu et al., 2013). K232 and K268 of SBO and blends during storage in the dark at 60°C (Figures 3a, b). The inhibition of CD and CT by addition of selected oils achieved by means of preventing the subsequent formation of reactive lipid radicals, and extending the induction period of the lipid oxidation of fried products during storage in the dark. The inhibitory effect of selected oils on CD and CT formation was time-dependent.

CD contents of all oils increased slowly in the beginning of storage and the increase became faster thereafter. Moreover, the rate of formation of conjugated dienes and polymers reach an equilibrium, leading non-significant change in K232 (Nystrom et al., 2005). So, there was no significantly different between SBO and oil blends before 4th day; while, K232 values in SBO increased significantly. The K232 increased gradually with the increase in time (0-24 days) with a greater rate for the SBO (percentage increase of 366). The SBO stabilized with the oils showed lower levels of the K232 after 24 days. The formation of CT as well as unsaturated ketones and aldehydes result in increase of K268, showed a pattern similar to K232. SBO had the highest content of

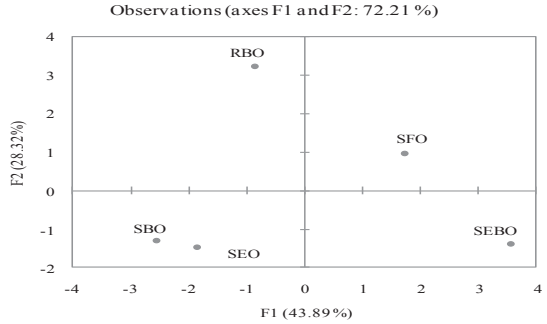

Figure 1. Plots of the x-loadings for Fatty Acids

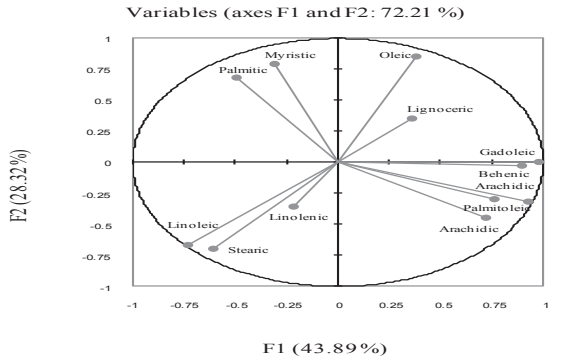

Figure 2. Plots of the Scores for Fatty Acids

Table 2. Discriminate Variables Factors of Principal Components Analysis

	F1	F2
Eigen value	5.27	3.4
Variability (%)	43.89	28.32
Cumulative (%)	43.89	72.21
Myristic acid (C14:0)	-	-18.62
Palmitic acid (C16:0)	-	-13.61
Palmitoleic acid(C16:1)	-10.97	-
Stearic acid (C18:0)	-	14.33
Oleic acid (C18:1)	-	-21.36
Linoleic acid (C18:2)	-	-13.2
Linolenic acid (C18:3)	-	-3.75
Arachidic acid (C20:0)	16.32	-
Gadoleic acid (C20:1)	18.04	-
Arachidic acid (C20:2)	10.01	-
Behenic acid (C22:0)	15.19	-
Lignoceric acid (C24:0)	-	3.68

Table 3. Changes in Peroxide Values of SBO and Oil Blends during Oven Test

Time (days)	SBO CONTROL	SBO:CAO (80:20 V/V)	SBO:SEO (80:20 V/V)	SBO:RBO (80:20 V/V)	SBO:PNO (80:20 V/V)	SBO:SEBO (80:20 V/V)
0	2.34±0.04Aa	2.15±0.04Aa	2.51±0.17Aa	2.33±0.07Aa	3.79±0.17Ab	2.42±0.27Aa
4	7.93±0.01Bc	6.51±0.14Bb	4.32±0.24Ba	5.21±0.05Ba	16.08±0.62Bd	5.55±0.07Ba
8	13.7±0.30Cc	8.51±0.19Cb	6.22±0.09Ca	8.81±0.03Cb	21.33±0.19Cd	9.21±0.08Cb
12	17.45±0.18Dc	13.21±0.08Db	8.32±0.05Da	8.7±0.21Ca	23.37±0.23Dd	11.51±0.21Da
16	20.1±0.07Ed	17.27v0.10Ec	12.49±0.07Ea	15.34±0.09Db	25.17±0.03Ee	12.54±0.07Ed
20	25.35±0.06Fd	20.62±0.23Fb	16.36±0.10Fa	22.14±0.08Ec	27.38±0.01Fd	16.65±0.24Fa
24	28.33±0.12Gd	22.74±0.24Gd	18.87±0.04Ga	20.63±0.05Fc	37.58±0.16Ge	19.59±0.14Gb

Table 4. Changes in p-anisidine Values of SBO and Oil Blends during Oven Test

Time (days)	SBO CONTROL	SBO:CAO (80:20 V/V)	SBO:SEO (80:20 V/V)	SBO:RBO (80:20 V/V)	SBO:PNO (80:20 V/V)	SBO:SEBO (80:20 V/V)
0	4.75±0.43Ac	4.27 ±0.08Aa	4.74 ±0.05Ac	4.32 ±0.05Aa	4.45 ±0.03Ab	4.41 ±0.04Ab
4	7.71±0.13Bc	5.89 ±0.11Bab	6.16 ±0.40Bb	7.90 ±0.04Bcd	5.09 ±0.53Ba	8.68 ±0.18Bd
8	10.84±0.36Cc	12.23 ±0.50Cd	13.64 ±0.46Cab	9.78 ±0.04Cb	6.36 ±0.16Ca	12.04±0.04Cd
12	14.90 ±0.23Db	21.93 ±2.28Dd	13.23 ±0.16Cab	14.58 ±0.06Db	10.48 ±0.02Da	18.31 ±0.06Dc
16	27.07 ±0.69Ed	20.71 ±0.82Db	22.76 ±0.11Dc	18.04 ±0.04Ea	18.98 ±0.05Ea	18.89 ±0.03Ea
20	39.14 ±0.27Ff	28.68 ±0.20Ed	25.54 ±0.03Ec	18.38 ±0.02Ea	21.85 ±0.21Fb	30.12 ±0.18Fe
24	44.07 ±1.38Ge	34.25 ±0.23Gb	27.13 ±0.06Fa	26.23 ±0.42Fa	40.59 ±0.51Fd	36.69 ±0.09Gc

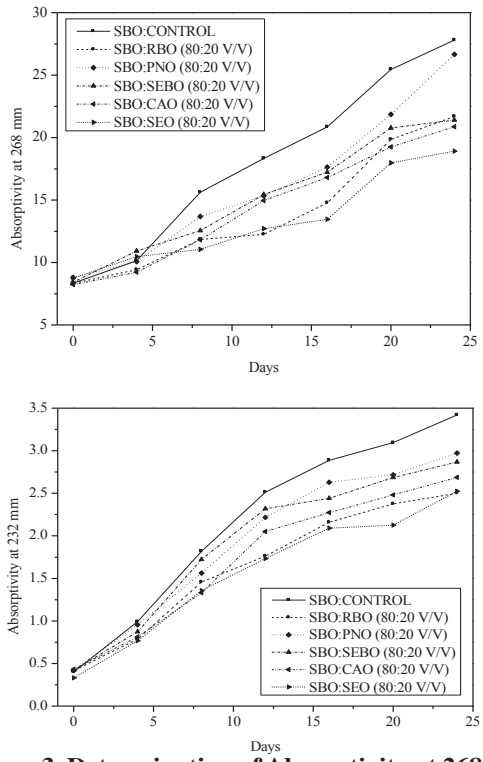

Figure 3. Determination of Absorptivity at 268 nm (a) and 232 nm (b)

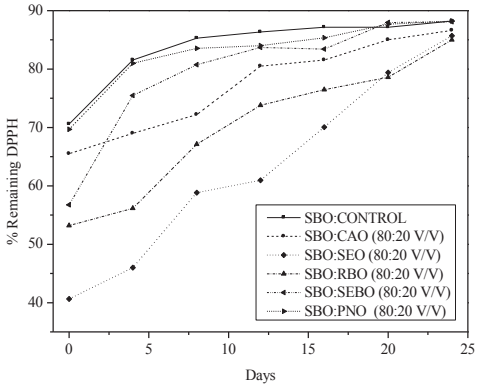

Figure 4. Antioxidant Capacity (DPPH Assay)

conjugated oxidative products, owing to its high linoleic acid content.

Radical scavenging activity (DPPH) assay

Blending selected oil with SBO increased antiradical action of SBO (Figure 4). The impact of SEO as additives on SBO oxidation was the strongest followed by RBO, CAO, SEBO and PNO. Rice bran oil has higher oxidative stability because it comprises not only tocopherol but also gamma-oryzanol. Therefore, the presence of gamma-oryzanol is possible to inhibiting the lipid peroxidation in several oil modes. Lignans and tocopherols are well known naturally occurring antioxidant components present in SEO, with sesamin and sesamolin being the predominant sesame lignans (Podloucka et al., 2013). It is also well known that c-oryzanol together with tocopherols are responsible for the high antioxidative strength of the RBO (Debnath et al., 2012). Seabuckthorn seed oil is a rich source of tocopherols and carotenoids, which are known to have significant antioxidant activities (Ting et al., 2011).

In summary, several of oil blends proved to be highly active and raise the nutritional values. While sesame oil was capable of high inhibition in the formation of oxidation compounds followed by rice bran oil, camellia oil, seathornbulk oil and peanut oil. Nevertheless, the quality, composition, bioactive properties and oxidative stability of all the studied oils were greatly affected by the storage time. Thus, a long-term storage of these oils should be avoided.

Acknowledgements

The authors would like thank the National High-tech R & D Program of China (863 Program) (Number: 2013AA102104), the Special Fund for the Establishment of Modern Agricultural R & D Systems (Number: nycytx-004), and the National Research Center of Soybean Engineering and Technology for the support of this project.

References

Abdulkarim SM, Myat MW, Ghazali HM, et al (2010). Sensory and physicochemical qualities of palm olein and sesame seed oil blends during frying of banana chips. *J Agric Sci*, **2**, 18-29.

Abou-Gharbia HA, Shehata AA, Shahidi F (2000). Effect of processing on oxidative stability and lipid classes of sesame oil. *Food Res Inter*, **33**, 331-40.

Aladedunye F, Przybylski R (2013). Frying stability of high oleic sunflower oils as affected by composition of tocopherol isomers and linoleic acid content. *Food Chem*, **141**, 2373-80.

Anwar F, Hussain AI, Iqbal S, et al (2007). Enhancement of the oxidative stability of some vegetable oils by blending with Moringa oleiferaoil. *Food Chem*, **103**, 1181-91.

AOCS p-Anisidine value method Cd 18-90 D (1998). Firestone (Ed.), Official methods and recommended practices of the American oil chemists' society, AOCS Press, Champaign III, USA.

Bansal G, Zhou W, Barlow PJ, et al (2010). Review of rapid tests available for measuring the quality changes in frying oils and comparison with standard methods. *Crit Rev Food Sci Nutr*, **50**, 503-14.

Cabiscol E, Tamarit J, Ros J (2010). Oxidative stress in bacteria and protein damage by reactive oxygen species. *Inter Microbiol*, **3**, 3-8.

Choe E, Min DB (2007). Chemistry of deep fat frying oils. *J Food Sci*, **72**, R77-R86.

Choe E, Oh S (2013). Effects of water activity on the lipid oxidation and antioxidants of dried laver (Porphyra) during storage in the dark. *J Food Sci*, **78**, 1144-51.

Chotimarkorn C, Silalai N (2008). Addition of rice bran oil to soybean oil during frying increases the oxidative stability of the fried dough from rice flour during storage. *Food Res Inter*, **41**, 308-17.

Chung J, Lee Y, Choe E (2006). Effects of sesame oil addition to soybean oil during frying on the lipid oxidative stability and antioxidants contents of the fried products during storage in the dark. *J Food Sci*, **71**, 222-6.

Debnath S, Rastogi NK, Gopala KA et al (2012). Effect of frying cycles on physical, chemical and heat transfer quality of rice bran oil during deep-fat frying of poori: An Indian traditional fried food. *Food Bio Proc*, **90**, 249-56.

Dhyani D, Maikhuri RK, Rao KS, et al (2007). Basic nutritional attributes of *Hippophae rhamnoides* (Seabuckthorn) populations from Uttarakhand Himalaya, India. *Current*

Sci, **92**, 1148-52.
Gulla S, Waghray K, Rcddy U (2010). Blending of oils-does it improve the quality and storage stability, an experimental approach on soyabean and palmolein rased blends. *Am J Food Technol*, **5**, 182-94.
Gupta RK, Singh N (2013). *Morinda citrifolia* (Noni) alters oxidative stress marker and antioxidant activity in cervical cancer cell lines. *Asian Pac J Cancer Prev*, **14**, 4603-6.
Haiyan Z, Bedgood DR, Bishop AG, et al (2007). Endogenous biophenol, fatty acid and volatile profiles of selected oils. *Food Chem*, **100**, 1544-51.
Iqbal S, Bhanger MI, Anwar F (2005). Antioxidant properties and components of some commercially available varieties of rice bran in Pakistan. *Food Chem*, **93**, 265-72.
IUPAC (1979). Standard methods for the analysis of oils and fats and derivatives: Pergamon Press. Toronto, Canada.
Kang HB, Zhang YF, Yang JD, Lu KL. (2012). Study on soy isoflavone consumption and risk of breast cancer and survival. *Asian Pac J Cancer Prev*, **13**, 995-8.
Latif S, Anwar F (2011). Aqueous enzymatic sesame oil and protein extraction. *Food Chem*, **125**, 679-84.
Lee CP, Yen GC (2006). Antioxidant activity and bioactive compounds of tea seed (*Camellia oleifera* Abel.) oil. *J Agric Food Chem*, **54**, 779-84.
Li Y, Zhang Y, Sui X, et al (2013). Ultrasound-assisted aqueous enzymatic extraction of oil from perilla (*Perilla frutescens* L.) seeds. *CyTA-J Food*, **12**, 1-6.
Li Y, Zhang Y, Wang M, et al (2012). Simplex-centroid mixture design applied to the aqueous enzymatic extraction of fatty acid-balanced oil from mixed seeds. *J Am Oil Chem Soc*, **90**, 349-57.
Mariod A, Matthaus B, Eichner K (2004). Fatty acid, tocopherol and sterol composition as well as oxidative stability of three unusual Sudanese oils. *J Food Lipids*, **11**, 179-89.
Marmesat S, Morales A, Velasco J, et al (2012). Influence of fatty acid composition on chemical changes in blends of sunflower oils during thermoxidation and frying. *Food Chem*, **135**, 2333-9.
Mohdaly AA, Sarhan MA, Smetanska I, et al (2010). Antioxidant properties of various solvent extracts of potato peel, sugar beet pulp and sesame cake. *J Sci Food Agric*, **90**, 218-26.
Moura JM, Maurer D, Yao L, et al (2013). Characteristics of oil and skim in enzyme-sssisted aqueous extraction of soybeans. *J Am Oil Chem Soc*, 1-10.
Naghshineh M, Ariffin AA, Ghazali HM, et al (2010). Effect of saturated/unsaturated fatty acid ratio on physicochemical properties of palm olein-olive oil blend. *J Am Oil Chem Soc*, **87**, 255-62.
Navarro M, Castro W, Biot C (2012). Bioorganometallic compounds with antimalarial targets: Inhibiting hemozoin formation. *Organometallics*, **31**, 5715-27.
Nystrom L, Makinen M, Lampi AM, et al (2005). Antioxidant activity of steryl ferulate extracts from rye and wheat bran. *J Agric Food Chem*, **53**, 2503-10.
Padmavathy A, Siddhu A, Sundararaj P (2001). Effect of blending edible grade crude palm oil with refined groundnut or sunflower oils on storage stability and sensory attributes. *J Oil Technol Assoc India*, **33**, 93-103.
Pegg RB (2001). Measurement of primary lipid peroxidation products (D2. 1.1-D2. 1.15). Current protocols in food analytical chemistry, John Wiley & Son Inc, New York.
Podloucka P, Berka K, Fabre G, et al (2013). Lipid bilayer membrane affinity rationalizes inhibition of lipid peroxidation by a natural lignan antioxidant. *J Phy Chem*, **117**, 5043-9.
Ramadan MF, Kinni SG, Seshagiri M, et al (2010). Fat-soluble bioactives, fatty acid profile and radical scavenging activity of Ssemecarpus anacardium seed oil. *J Am Oil Chem Soc*, **87**, 885-94.
Ramadan MF, Wahdan KM (2012). Blending of corn oil with black cumin (*Nigella sativa*) and coriander (*Coriandrum sativum*) seed oils: Impact on functionality, stability and radical scavenging activity. *Food Chem*, **132**, 873-9.
Reena MB, Lokesh BR (2007). Hypolipidemic effect of oils with balanced amounts of fatty acids obtained by blending and interesterification of coconut oil with rice bran oil or sesame oil. *J Agric Food Chem*, **55**, 10461-9.
Shah AH, Ahmed DI, Sabir M, et al (2007). Biochemical and nutritional evaluations of sea buckthorn (hyppophae rhamnoides L. Spp. Turkestanica) from different locations of Pakistan. *Pak J Bot*, **39**, 2059-65.
Sharif A, Farhoosh R, Khodaparast, MH et al (2009). Antioxidant activity of bene hull oil compared with sesame and rice bran oils during the frying process of sunflower oil. *J Food Lipids*, **16**, 394-6.
Stephens AM, Dean LL, Davis JP, et al (2010). Peanuts, peanut oil, and fat free peanut flour reduced cardiovascular disease risk factors and the development of atherosclerosis in Syrian golden hamsters. *J Food Sci*, **75**, 116-22.
Sugiyama Y, Masumori N, Fukuta F, et al (2013). Influence of isoflavone intake and equol-producing intestinal flora on prostate cancer risk. *Asian Pac J Cancer Prev*, **14**, 1-4.
Ting HC, Hsu YW, Tsai CF, et al (2011). The in-vitro and in-vivo antioxidant properties of seabuckthorn (Hippophae rhamnoides L.) seed oil. *Food Chem*, **125**, 652-9.
Valko M, Izakovic M, Mazur M, Rhodes C J, Telser J (2004). Role of oxygen radicals in DNA damage and cancer incidence. *Mol Cell Biochem*, **266**, 37-56.
Warner K, Gupta M (2005). Potato chip quality and frying oil stability of high oleic acid soybean oil. *J Food Sci*, **70**, 395-400.
Zhang YF, Kang HB, Li BL, Zhang RM (2012). Positive effects of soy isoflavone food on survival of breast cancer patients in China. *Asian Pac J Cancer Prev*, **13**, 489-82.
Zhu H, Li X, Shoemaker CF, et al (2013). Ultra-high performance liquid chromatography analysis of volatile carbonyl compounds in virgin olive oils. *J Agric Food Chem*, **61**, 12253-9.
Zhu YY, Zhou L, Jiao SC, Xu LZ (2011). Relationship between soy food intake and breast cancer in China. *Asian Pac J Cancer Prev*, **12**, 2837-40.