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A study on vegetable oil blends

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The oil stability index (OSI) and peroxide value (PV) were used to determine the quality of oil blends. The quality of soybean oil (SBO) blended with other refined, bleached and deodorized (RBD) oils was between the quality of SBO and the RBD oils selected for blending. However, crude peanut oil blended with SBO diminished the quality of SBO while crude sesame oil with unique antioxidants improved the quality of SBO blends. To study the effect of fatty acid composition (FAC) on the oxidative stability of oil blends, 21 oil blends were prepared by using 7 commercial RBD oils which were re-deodorized and followed by tocopherol adjustment. A mathematical model describing the relationship between OSI and FAC of 21 oil blends was obtained as follows: $\text{OSI (h)} = 7.5123 + \%\text{C16:0} \times (0.2733) + \%\text{C18:0} \times (0.0797) + \%\text{C18:1} \times (0.0159) + \%\text{C18:2} \times (-0.1141) + \%\text{C18:3} \times (-0.3962)$, $r^2 = 0.911$. The difference between the values of each predicted and measured OSI were within 10%, which indicated that the oxidative stability of oil blends of any ratio from the 7 RBD oils under study could be predicted by using this model. © 1998 Elsevier Science Ltd. All rights reserved

INTRODUCTION

Soybean oil (SBO) is one of the major cooking oils in Taiwan. However, the high linolenic acid content of SBO causes oil instability when the oil is used at high temperatures, e.g. cooking, stir-frying and deep-frying. Partial hydrogenation, addition of antioxidants and metal chelators (Warner *et al.*, 1985; Frankel *et al.*, 1985; Snyder *et al.*, 1986), mutation breeding to reduce the linolenic acid content (Anonymous, 1990; Haumann, 1990; Scowcroft, 1990), and interesterification of SBO and palm olein (Neff *et al.*, 1992, 1993), have been used to improve SBO resistance to oxidation. Partial hydrogenation of polyunsaturated vegetable oils is less appealing because some evidence shows that trans isomers may have adverse nutritional effects (Mensink and Katan, 1990; Zock and Katan, 1992). SBO with antioxidant addition is more effective in increasing oil shelf life during storage than in resisting oil oxidation at high temperature. New soybean breeding with low linolenic acid content does not appear in the Taiwan market, and interesterification of SBO with other stable vegetable oils increases processing costs which is not acceptable in the Taiwan oil industry. As a consequence, blending of SBO with other vegetable oils was proposed to study the effects of changes in fatty acid compositions (FAC) on the resulting oil oxidative stability. Also, a mathematical model was derived from the correlations between the oil stability index (OSI) and FAC of various oil blends, which could be used to predict the oil stability of oil blends of any ratio.

MATERIALS AND METHODS

Materials

Soybean oil (SBO), high oleic sunflower oil (HOSUN), sunflower oil (SUN), high oleic safflower oil (HOSAF), corn oil, canola oil, olive oil, peanut oil and sesame oil were purchased from a local supermarket. All of these oils were refined, bleached and deodorized (RBD) except for peanut and sesame oils. Chloroform, acetic anhydride, potassium iodide and α-, β-, γ-, and δ-tocopherols were purchased from E. Merck (Darmstadt, Germany). Tertiary butyl-hydroquinone (TBHQ) was obtained from Aldrich (WI, USA).

Methods

Analyses

The peroxide value and oil stability index (OSI) were determined using American Oil Chemists' Society (AOCS) Methods Cd 8-53 and Cd 12b-92, respectively. The copper content was determined using the Atomic Absorption Spectrophotometric Method of AOCS Method Ca 18-79. The tocopherol (TOC) content was determined by HPLC (ABI Analytical Kratos Division,

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Ramsey, NJ) according to the procedure described by Lai *et al.* (1989). Fatty acid compositions were determined by gas liquid chromatography of their methyl esters on a 30 m×0.25 mm (ID) SP2330 fused silica capillary column (Chu, 1991).

Experiments on oil oxidative stability

Various oil blends were prepared by mixing different ratios (w/w) of oil species. Storage tests at room temperature (25°C) and at 60°C were performed, respectively, for each oil blend. Oil sampling and analyses were conducted at different periods of time for oils stored at room temperature for 60 days and for oils stored at 60°C for 100 h, respectively.

TOC removal

TOC removal of each oil was performed by deodorizing the oil at 250 ± 5°C, 5 ± 2 mBar for 1.5 h.

RESULTS AND DISCUSSION

Changes in PV and OSI of six single oils before and after blending

The PV, OSI and copper content of six oils including soybean, olive, high oleic safflower (HOSAF), corn, peanut and sesame oils were analyzed, and the results are shown in Table 1. The initial PV showed the initial oil quality. Generally, a lower initial PV was preferred due to the greater freshness of the oils. However, the results showed that the lower initial PV has no effect on the increase of OSI of the six oils. Corn and olive oils with higher initial PV showed higher OSI as compared with SBO which had lower initial PV and OSI. The presence of antioxidants and the polyunsaturated fatty acid (PUFA; C18:2 + C18:3) content are more important than the initial PV in affecting the oxidative stability of oils. Sesame oil, containing unique antioxidants, e.g. sesamol, sesamol dimer, sesamolin and TOC, showed the highest OSI value of 16.2 h despite its high PUFA content (45.8%), while SBO showed the lowest OSI value of 1.95 h. Aside from the inherent antioxidants in the various oils, the

Table 1. PV, OSI and Cu contents of six commercial single vegetable oils and their oil blends

Oil type[1]	PV (meq kg^{-1})	OSI (h)	Cu (ppm)
Single oil			
SBO	2.10 ± 0.05^{4e}	1.95 ± 0.11^{e}	0.041 ± 0.004^{d}
Corn	7.84 ± 0.10^{a}	2.20 ± 0.03^{d}	0.029 ± 0.005^{e}
HOSAF	6.32 ± 0.12^{d}	$5.08 + 0.15^{b}$	$0.039 + 0.004^{d}$
Olive	7.36 ± 0.06^{c}	5.07 ± 0.12^{b}	0.052 ± 0.005^{c}
Peanut	7.70 ± 0.08^{b}	4.05 ± 0.11^{c}	0.083 ± 0.006^{a}
Sesame	$0.13 + 0.09^{f}$	16.20 ± 0.07^{a}	0.060 ± 0.005^{b}
Oil blends			
Olive/SBO[2]	4.09 ± 0.16^{c}	3.19 ± 0.11^{c}	n.d.
HOSAF/SBO[2]	3.65 ± 0.13^{e}	3.21 ± 0.17^{c}	n.d.
Corn/SBO[2]	4.21 ± 0.05^{b}	2.09 ± 0.13^{e}	n.d.
HOSAF/Olive/SBO[3]	4.98 ± 0.11^{a}	3.86 ± 0.25^{a}	n.d.
Peanut/SBO[2]	3.73 ± 0.09^{d}	2.44 ± 0.21^{d}	n.d.
Sesame/SBO[2]	0.86 ± 0.12^{f}	3.55 ± 0.17^{b}	n.d.

n.d., not determined.

[1] Oil type: SBO: soybean oil, Corn: corn oil, HOSAF: high oleic safflower oil, Olive: olive oil, Peanut: peanut oil, Sesame: sesame oil.

[2] Blending ratio = 4:6.

[3] Blending ratio = 3:3:4.

[4] Mean ± standard deviation; $n = 3$. Means in a column followed by the same letter are not significantly different ($p > 0.05$) (LSD test).

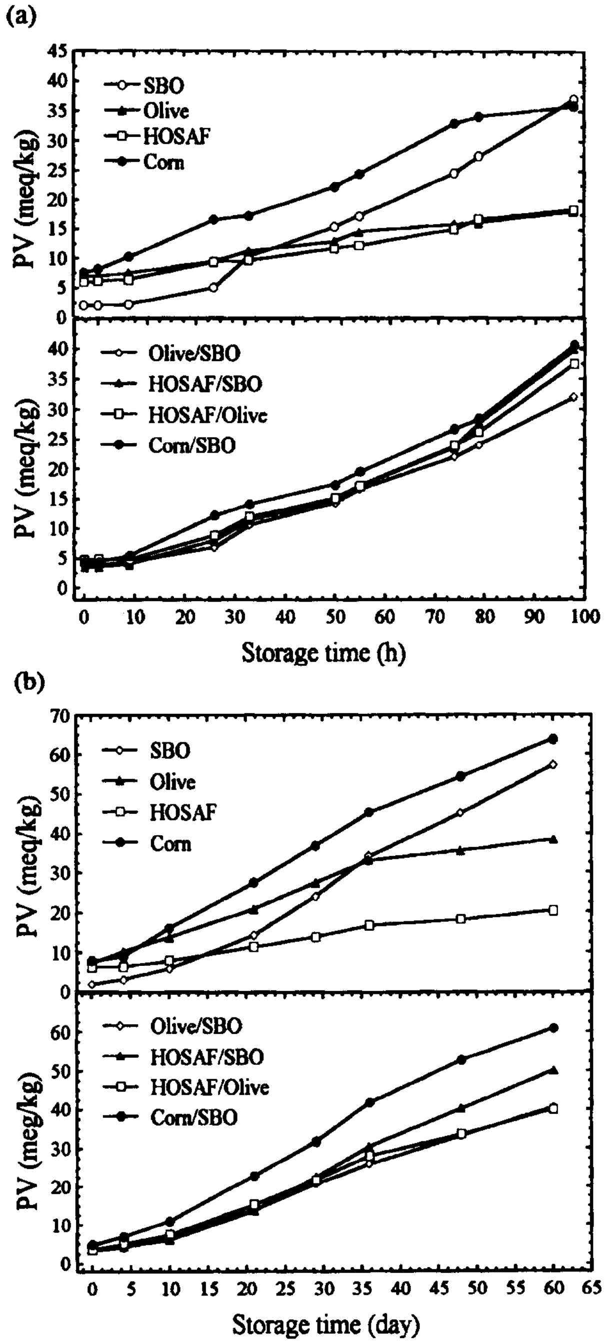

Fig. 1. Changes in the peroxide values of four single vegetable oils and their oil blends during storage experiments: (a) at 60°C; (b) at room temperature (25°C). See Table 1 for oil abbreviations.

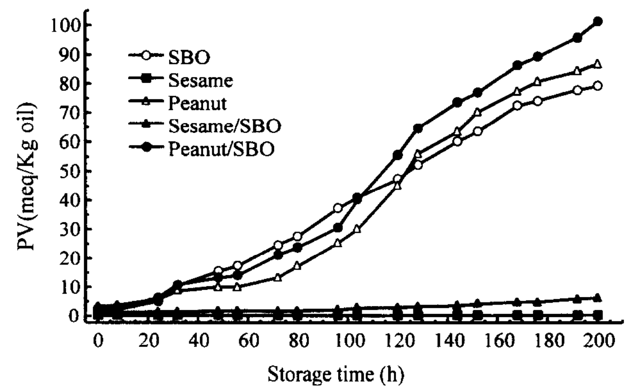

Fig. 2. Changes in the peroxide values of soybean, sesame and peanut oils and their oil blends during storage experiments at 60°C. See Table 1 for oil abbreviations.

polyunsaturated fatty acids content was an important factor influencing oil stability. Comparing the PUFA content, SBO (59.3%) and corn oil (62.4%) with lower OSI, had higher PUFA contents than did the other oils with higher OSI, i.e. peanut (37.7%), HOSAF (14.3%) and olive oils (11.6%), the results of which indicated that OSI was inversely related to PUFA content.

In the oil blending experiment, olive, HOSAF, corn, sesame and peanut oils were blended with SBO due to the substantial production of SBO in Taiwan. The ratios of oil blends were: 4:6 for olive:SBO, HOSAF:SBO, corn:SBO, sesame:SBO, and peanut:SBO, and 3:3:4 for HOSAF:olive:SBO. From the results of measurements of OSI for all single oils and their oil blends, the resultant value of every oil blend was situated between the two values of the constituent single oils (Table 1). Similar results were obtained from measurement of PV for all single oils and their oil blends during storage experiments at both 60°C (Fig. 1a) and room temperature (Fig. 1b). However, for peanut/SBO as shown in Fig. 2, PV increased beyond the value of each constituent oil after 100 h of storage at 60°C. Peanut oil, without refining, contained twice the Cu of SBO. The high Cu content of peanut oil had an adverse effect on the quality of SBO when blended with peanut oil. Furthermore, the low TOC (240 ppm) content of peanut oil might explain the reduced oxidative stability of the SBO blend. However, as shown in Fig. 2, crude sesame oil blended with SBO improved the quality of the oil blend during storage at 60°C as compared with single SBO. The presence of unique antioxidants in sesame oil, as mentioned previously, and their synergistic action might explain the higher stability of sesame/SBO blend compared to the peanut/SBO blend.

Correlation between fatty acid composition and OSI

The oil stability was affected by the fatty acid composition (FAC) and tocopherol (TOC) content of the oils. TOC is an important antioxidant in vegetable oils. As a result of the different levels of TOC content in various oil species, the re-deodorization process was performed to remove the inherent TOC in the oils in order to study the effect of FAC on oil stability. SBO, corn oil, HOSUN, SUN, canola, HOSAF and olive oils were selected for oil blending experiments. All of these oils were RBD oil except for olive oil. Re-deodorization of these oils could not completely remove the inherent TOC of the oils (Table 2). The remaining TOC contents of the oils were within 71.8 ± 8.6% of the original values. In order to attain the same level of TOC contents in these oils, adjustment of TOC content was performed. The highest contents of α- and γ-TOC in the HOSUN and corn oils, respectively, were selected as the standard levels for adjusting the TOC contents of the re-deodorized oils. The total TOC contents of all the oils were adjusted to 1536 ± 30 ppm, among which α- and γ-TOC contents were 800 ± 9 and 700 ± 8 ppm, respectively. Table 3 shows first the OSI values and FAC of these seven single oils after deodorization and TOC adjustment. Moreover, all of the oils with TOC adjustment were used to prepare 21 oil blends having different FAC and OSI values (Table 3). The relationships between OSI and FAC were derived using the SAS statistics software as follows:

Table 2. Tocopherol contents of 7 commercial single vegetable oils before, after deodorization, and after deodorization and tocopherol adjustment

Oil type[1]	Tocopherol content (ppm)														
	Original					Deodorized					Deodorized and tocopherol adjusted[2]				
	α	β	γ	δ	Total	α	β	γ	δ	Total	α	β	γ	δ	Total
SBO	144	27	624	229	1025	77	17	381	119	595	790	18	690	120	1538
Corn	247	31	692	39	1009	152	19	546	21	738	806	20	695	23	1544
HOSUN	787	—	66	—	853	504	—	43	—	546	809	—	709	—	1519
SUN	641	—	65	—	706	504	—	43	—	546	806	—	709	—	1515
Canola	170	134	403	41	748	127	87	261	27	503	791	88	691	28	1599
HOSAF	446	12	58	26	544	290	9	29	18	346	791	9	705	20	1525
Olive	153	—	30	—	183	131	—	26	—	157	809	—	703	—	1513

—, Not detectable.

[1] Oil type: SBO: soybean oil, Corn: corn oil, HOSUN: high oleic acid sunflower seed oil, SUN: sunflower seed oil, Canola: Canola oil, HOSAF: high oleic safflower oil, Olive: olive oil.

Table 3. Fatty acid compositions and OSI values of 7 single oils and 21 oil blends

Oil type[1] and blend	Ratio(w/w/w)	Fatty acid composition (%)					OSI (h)		OSI Difference[2] (%)
		C16:0	C18:0	C18:1	C18:2	C18:3	Experimental	Predicted	
SBO	100	10.4	3.5	21.5	51.5	7.8	2.22	2.01	−9.50
HOSUN	100	4.7	3.6	64.5	24.8	0.3	6.66	7.16	7.51
SUN	100	6.2	3.5	20.7	67.9	0.2	2.17	1.99	−8.23
Corn	100	10.7	1.6	24.5	61.3	1.1	3.24	3.52	8.90
HOSAF	100	4.8	2.0	77.4	13.8	0.5	8.92	8.44	−5.32
Canola	100	4.7	2.0	60.0	21.7	9.1	3.71	3.83	3.22
Olive	100	12.9	2.0	71.2	10.7	0.9	10.97	10.75	−1.95
SBO/HOSUN/SUN	80/10/10	9.4	3.5	25.7	50.5	6.3	2.61	2.52	−3.52
SBO/HOSUN/SUN	10/80/10	5.4	3.6	55.8	31.8	1.0	5.76	6.13	6.32
SBO/HOSUN/SUN	10/10/80	6.5	3.5	25.2	62.0	1.0	2.33	2.51	7.85
HOSUN/SUN/Corn	80/10/10	5.5	3.4	56.1	32.8	0.4	6.74	6.28	−6.78
HOSUN/SUN/Corn	10/80/10	6.5	3.3	25.5	62.9	0.3	2.60	2.66	2.35
HOSUN/SUN/Corn	10/10/80	9.7	2.0	28.1	58.3	0.9	3.57	3.73	4.56
SUN/Corn/HOSAF	80/10/10	6.5	3.2	26.8	61.8	0.3	3.06	2.79	−8.96
SUN/Corn/HOSAF	10/80/10	9.7	1.8	29.4	57.2	1.0	3.70	3.86	7.52
SUN/Corn/HOSAF	10/10/80	5.5	2.1	66.4	24.0	0.5	7.70	7.30	−5.33
Corn/HOSAF/Canola	80/10/10	9.5	1.7	33.3	52.6	1.8	3.90	4.05	−2.10
Corn/HOSAF/Canola	10/80/10	5.4	2.0	70.4	19.3	1.4	7.80	7.49	7.56
Corn/HOSAF/Canola	10/10/80	5.3	2.0	58.2	24.9	7.4	4.20	4.26	−7.56
HOSAF/Canola/Olive	80/10/10	5.6	2.0	75.0	14.3	1.4	8.60	8.21	5.88
HOSAF/Canola/Olive	10/80/10	5.5	2.0	62.9	19.8	7.4	5.00	4.98	7.56
HOSAF/Canola/Olive	10/10/80	11.3	2.0	70.7	12.1	1.7	10.00	9.83	2.33
Canola/Olive/SBO	80/10/10	6.1	2.2	57.3	23.6	8.2	4.30	4.34	−4.33
Canola/Olive/SBO	10/80/10	11.8	2.2	65.1	15.9	2.4	9.40	9.19	−6.81
Canola/Olive/SBO	10/10/80	10.1	3.2	30.3	44.4	7.2	3.20	3.07	−2.31
Olive/SBO/HOSUN	80/10/10	11.8	2.3	65.6	16.2	1.5	9.70	9.52	−6.88
Olive/SBO/HOSUN	10/80/10	10.1	3.4	30.8	44.8	6.4	3.50	3.40	−9.85
Olive/SBO/HOSUN	10/10/80	6.1	3.4	60.9	26.1	1.1	6.60	7.00	8.66

[1] Seven single oils were deodorized, and α- and γ-tocopherol were adjusted to about 800 and 700 ppm, respectively. See Table 2 for oil abbreviations.

[2] OSI difference % = [(Predicted OSI-Experimental OSI)/Experimental OSI)]×100%.

$$\begin{aligned}\mathrm{OSI(h)} &= 7.5123 + \%\mathrm{C16:0} \times (0.2733) + \%\mathrm{C18:0} \\ &\quad \times (0.0797) + \%\mathrm{C18:1} \times (0.0159) + \%\mathrm{C18:2} \\ &\quad \times (-0.1141) + \%\mathrm{C18:3} \times (-0.3962),\ r^2 = 0.911\end{aligned}$$

The effect of each fatty acid on OSI was observed from the coefficients of each fatty acid in the equation. The order of positive influence of fatty acid on OSI was palmitic acid followed by stearic acid and oleic acid. For unsaturated fatty acid, linolenic acid had the most negative influence on OSI, followed by linoleic acid and oleic acid. The predicted OSIs of 21 oil blends were calculated using the equation shown above. Comparing the predicted OSI with the experimental OSI, the difference was found to be within 10%, which indicated that this mathematical model can be used to evaluate the correlation between OSI and FAC. Moreover, people in the industry might use this model to predict oil stability in advance when different oil species are selected for blending purposes. However, the inherent TOC contents of the selected oils must be considered.

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