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Oxidative Stability of Blend Oil During Deep-Fat Frying of Potato Chips

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Abstract: A study was conducted to find out the best ratio of 3 types of oil [sunflower oil, corn oil and refined, bleached and deodorized palm olein (RBD palm olein)] that is more stable during frying. In this study 6 different ratios, including 1) 100% RBD palm olein, 2) 100% sunflower oil, 3) 100% corn oil, 4) combination of sunflower oil and RBD palm olein (50:50), 5) combination of corn and RBD palm olein (50:50), 6) combination of sunflower and corn oil (50:50) were used to evaluate the oils performance under deep frying conditions. The chemical characteristics of these oils were evaluated by free fatty acids, iodine value and peroxide value. Changes in the above values of the oils were also examined after their use for deep-frying of potato chips at 180°C. Results showed that the iodine value decreased significantly ($p<0.05$) with increased replication time of frying, whereas Peroxide value and free fatty acid increased up.

Key words: Oxidative stability, sunflower oil, corn oil, RBD palm olein

INTRODUCTION

Deep-fat frying may be defined as the process of cooking foods by immersing them in an edible oil or fat maintained at a temperature of about 150-200°C (Rossi *et al.*, 2007). It is used extensively both at home and on a commercial scale to enhance the organoleptic quality of foods (Jaswir *et al.*, 2000). During frying, vegetable oils will undergo a series of chemical reactions, such as hydrolysis, oxidation and polymerization, resulting in quality deterioration with respect to their nutritive value (Anwar *et al.*, 2007). Oil quality and stability are principally affected by lipid oxidation, a general term for a complex process that results in generation of off-flavor and reduction in nutritional value (Giuffrida *et al.*, 2007). Soybean, rapeseed, sunflower, corn or peanut oils, with high contents of polyunsaturated fatty acid, are major edible oils used for cooking purposes. Olive, canola, or almond oils, that are low-linoleic, high-oleic vegetable oils could be used for deep frying because they are quite stable at high frying temperature. However, their high restricts their usage on a huge scale. So the use of more stable frying oils of comparatively low price would be desirable. Blending with oils of high oleic contents is one way to improve the stability of these oils. Previous reports on oil blends have concentrated on fatty acid composition in relation to stability (Warner and Mounts, 1993) and storage stability of oil blends (Khatoon and Gopala Krishna, 1999). Anwar *et al.* (2007) reported the blending of *Moringa oleifera* Oil (MOO) with Sunflower Oil (SFO) and Soybean Oil (SBO) were changed the Fatty Acid (FA) composition, oxidative and thermal stability of sunflower oil and soybean oil. In this study was used 6 ternary mixtures of sunflower oil, corn oil and Refined, Bleached and Deodorized (RBD) palm olein using a constrained mixture design. The multiple ratio of blending was done with the help of Mixture Design, Design Expert version 6.0.

Sunflower oil is rich in polyunsaturated fatty acid (diunsaturated fatty acid) and does not have high oxidative stability. Moreover corn oil that presents a relatively high concentration of Polyunsaturated Fatty Acids (PUFA). In this study Refined, Bleached and Deodorized (RBD) palm olein was used because of its major commercial role during deep-fat frying (Che Man and Tan, 1999). Refined, Bleached and Deodorized (RBD) palm olein contains a mixture of polyunsaturated, monounsaturated and saturated fatty acids. It contains an equal proportion of saturated and unsaturated fatty acids. Sunflower oil and corn oil contains high amount of linoleic acid and Refined, Bleached and Deodorized (RBD) palm olein contains high amount of oleic acid. Proper mixing of high-oleic and high-linoleic oils may result in oil blends with improved stability characteristics. Oxidative alteration in the frying medium is caused by the release of moisture from the food, atmospheric oxygen entering the oil, whereas thermal alteration is caused by the higher frying temperature. The rate of formation of decomposed products depends on the type of food being fried, design of the fryer and the operating conditions (Manral *et al.*, 2008). The necessity of using good frying oil and maintaining it in that state as long as possible become clear when one considers that all fried food absorbs a certain amount of fat (Rani and Chauhan, 1995). Moreover, due to high temperature (150-200°C) and the presence of oxygen and steam released from food, the oil undergoes a series of

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chemical reactions that decomposes it to form a variety of volatile compounds (Rossi *et al*., 2009).

The objectives of this study was to determine the time when oil reaches its maximum safe use during potato chips frying. Also to develop the best mixture of RBD palm olein, corn oil and sunflower oil with higher stability of oil during frying.

MATERIALS AND METHODS

Material: Three types of oil (Refined, Bleached and Deodorized (RBD) palm olein, sunflower oil, corn oil) used in this study was obtained from the super market or company, in Selangor, Malaysia. The oils were blended to form 6 combinations. The multiple ratio of blending was done with the help of Mixture Design, Design Expert version 6.0. with the ratios of 1) 100% RBD palm olein, 2) 100% sunflower oil; 3) 100% corn oil, 4) 50% sunflower oil + 50% RBD; 5) 50% RBD palm olein + 50% corn oil and 6) 50% corn oil + 50% sunflower oil that were created using Mixture Design, Design Expert version 6.0. Fresh potato and salt (sodium chloride) were obtained from a local supermarket. Mini deep fryer (Berjaya, Malaysia) was used for carrying out the frying operations. All the chemicals used were of analytical grade.

Frying experiment: Fresh potatoes were peeled and sliced manually at 1.5 mm thickness. The sliced potatoes were then soaked in a 2.5% NaCl salt solution for 5 min and dried before frying. The flow-chart for the potato chip frying experiments conducted in this study is given in Fig. 1. The oil was heated up to 180±5°C in 10 min and 50 grams of fresh sliced potato were fried for 2.5 min. The oil temperature was allowed to return to 180°C after frying within 30 min. At the end of each frying, 60 g of oil as sample collected, flushed with nitrogen gas and kept in a cold room at 5°C until the day of analysis.

Oil analysis: Free Fatty Acid (FFA), Peroxide Value (PV) and Iodine Value (IV) using Cyclohexane method were determined according to the AOCS (1997).

Potato analysis: AOAC (1995) official method was used to determine the moisture content by oven method). where samples were dried for 16 h or overnight at 105°C.

Data analysis: Statistical analysis of the data for comparison, correlation and regression was carried out using MS-Excel (Error bar), The values were expressed as the mean ± standard deviation. Statistical analysis was performed using the Statistical Analysis System "SAS" (version 9.2) for Windows. The Duncan test was performed to evaluate the significance differences between mean values.

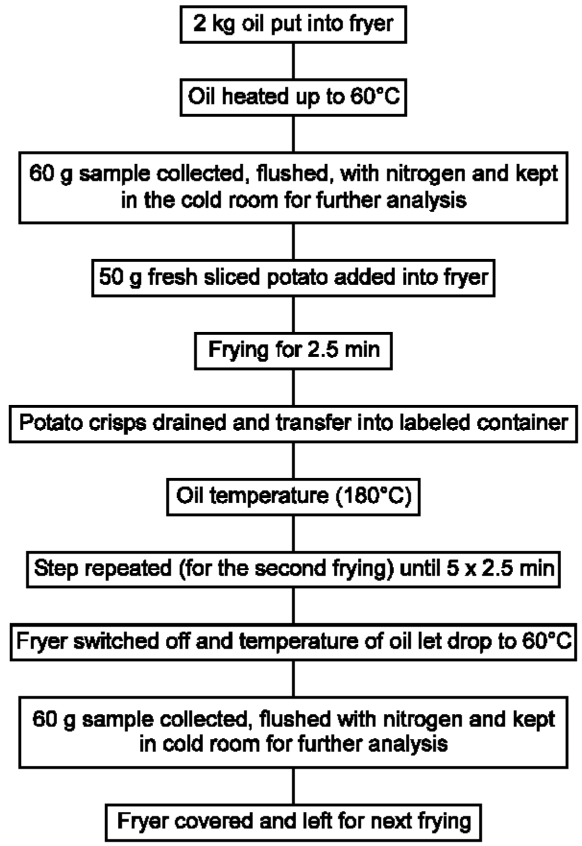

Fig. 1: Flow-chart for the frying process of potato chips

RESULTS AND DISCUSSION

Table 1 shows the PV changes in different ratio of corn oil, RBD palm olein and sunflower oil during deep frying. There was a trend of increased PV contents during five times replication of frying. During frying, the lowest PV was observed in the RBD palm olein sample, followed by the combination of RBD palm olein and corn oil (50:50), while that of sunflower oil was found the highest. Results from Table 1 also showed that the PVs increased for all the oils during repeated deep frying, with the PVs of RBD palm olein and combination of RBD palm olein and corn oil (50:50) increasing slower compared to other oils. Peroxide value of Sunflower oil was increased faster compared to other oils because sunflower oil is rich in polyunsaturated fatty acid (diunsaturated fatty acid) and does not have high oxidative stability. Allam (2001) investigated the oxidative stability of sunflower oil blended with nine oils distinguished by their high oleic acid contents. Monika *et al*. (2002) mentioned that the oxidative stability of 1:1 (v/v) rapeseed/palm olein blend was improved up to 60% in comparison with rapeseed oil, while Shiota *et al*. (1999) reported an improved oxidative stability of fish oil blended with butter. Anwar *et al*. (2007) reported that the blending of *Moringa oleifera* Oil (MOO) has significantly

Table 1: Peroxide value (meq oxygen/kg) of 6 different ratios of sunflower oil, corn oil and RBD palm olein during deep-fat frying

	Frying times						
Sample	0	1	2	3	4	5	Mean
RBD	0.87±0.02[Ff]	6.51±0.06[De]	7.75±0.05[Fd]	8.01±0.07[Fc]	8.42±0.07[Fb]	11.66±0.07[Fa]	7.20
SFO	9.10±0.08[Af]	10.01±0.06[Ae]	14.31±0.09[Ad]	18.45±0.12[Ac]	20.13±0.10[Bb]	24.32±0.13[Aa]	16.05
CO	4.03±0.04[Df]	6.11±0.07[Ee]	8.21±0.08[Dd]	10.64±0.07[Dc]	13.51±0.05[Db]	16.01±0.09[Da]	9.75
SFO:RBD(50:50)	4.98±0.05[Cf]	8.50±0.06[Be]	11.11±0.09[Cd]	13.14±0.10[Cc]	14.31±0.15[Aa]	18.03±0.09[Cb]	11.68
RBD:CO(50:50)	2.51±0.02[Ef]	6.41±0.07[De]	7.90±0.09[Ed]	9.53±0.07[Ec]	10.85±0.09[Eb]	14.02±0.09[Ea]	8.54
CO:SFO(50:50)	6.61±0.03[Bf]	7.97±0.08[Ce]	11.47±0.09[Bd]	15.03±0.11[Bc]	17.11±0.12[Cb]	19.88±0.11[Ba]	13.01

SFO: Sunflower oil; RBD: Refined, bleached and deodorized palm olein; CO: Corn oil.

[a-f]Means within a column with different letters are significantly ($p<0.05$).

[A-D]Means within a row for each parameter with different letter are significantly different ($p<0.05$)

Table 2: Iodine value (g I_2/100 g oil) of 6 different ratios of sunflower oil, corn oil and RBD palm olein during deep-fat frying

	Frying times						
Sample	0	1	2	3	4	5	Mean
RBD	55.70±0.14[Fa]	53.02±0.11[Fb]	48.92±0.10[Fc]	46.20±0.12[Fd]	44.33±0.11[Fe]	41.76±0.10[Ff]	48.32
SFO	142.27±0.10[Aa]	139.22±0.11[Ab]	138.11±0.11[Ac]	137.02±0.13[Ad]	134.02±0.11[Ae]	130.09±0.10[Af]	136.79
CO	132.51±0.12[Ca]	128.19±0.14[Cb]	123.19±0.12[Cc]	120.01±0.10[Cd]	118.11±0.11[Ce]	114.56±0.14[Cf]	122.76
SFO:RBD(50:50)	98.01±0.15[Ea]	95.97±0.12[Db]	93.62±0.13[Dc]	91.01±0.12[Dd]	88.87±0.11[De]	84.41±0.11[Df]	91.98
RBD:CO(50:50)	98.60±0.10[Da]	90.31±0.11[Eb]	84.97±0.15[Ec]	82.62±0.12[Ed]	80.12±0.13[Ee]	79.93±0.11[Ef]	86.09
CO:SFO(50:50)	137.69±0.15[Ba]	132.47±0.15[Bb]	131.22±0.10[Bc]	129.13±0.13[Bd]	125.87±0.10[Be]	123.01±0.15[Bf]	129.90

SFO: Sunflower oil; RBD: Refined, bleached and deodorized palm olein; CO: Corn oil.

[a-f]Means within a column with different letters are significantly ($p<0.05$).

[A-F]Means within a row for each parameter with different letter are significantly different ($p<0.05$)

increased the oxidative stability of both the Sunflower Oil (SFO) and Soybean Oil (SBO). The improvement in the oxidative stability of the investigated oils might be related to the blending of *Moringa oleifera* Oil (MOO). *Moringa oleifera* Oil (MOO) is a naturally high-oleic oil and such high-oleic oils are now gaining much significant for their increased stability medicinal and nutritional attributes (Solfrizzi *et al*., 1999). The reduction in PV, as exhibited by blended formulations, was especially because of the reduction of unsaturated C18:2 at the expense of C18:1 (Reynhout, 1991).

Significant ($p<0.05$) differences were observed in peroxide values at different replication time of deep frying. The values significantly ($p<0.05$) increased from cycle 0 until cycle 5 of frying for all types of samples. Peroxide value is a measure of oxidation degree and measure of the formation of peroxide and hydroperoxide groups that are the initial products of the lipid oxidation in a oil sample (Neil Widlak, 1999). Peroxide value for the combination of RBD palm olein and corn oil (50:50), for example, increased from 2.51 meq/kg in fresh oil to 14.02 meq/kg after fifth frying. The Peroxide value of combination of sunflower oil and corn oil (50:50) increased from 6.61 meq/kg in fresh oil to 19.88 meq/kg after fifth frying. During frying, oils are hydrolysed to form FFA and mono- and diglycerides and these compounds accumulate in the frying oil with repeated use. In addition, oils also oxidize to form hydroperoxide, conjugated dienoic acids, epoxides, hydroxides, aldehydes and ketones. These compounds may undergo fission into smaller fragments or mayremain in the triglyceride molecule and cross-link with each other, leading to dimeric and higher polymeric triglycerides. An increase in these volatile compounds could be attributed to an increase in FFA content and Peroxide Value (PV) in the oil samples (Innawong *et al*., 2004).

PV is an index to quantify the amount of hydroperoxide in fat and oil. Several studies have reported that secondary oxidized oil products are generally toxic. Also, weakly oxidized fat and oil at levels of only 100 mequiv/kg of PV are neurotoxic. Therefore, the formation of hydroperoxide, the primary oxidized product of fat and oil, must be suppressed to protect against the oxidation of fat and oil and the formation of secondary oxidized products from both food quality and food safety perspectives (Gotoh and Wada, 2006).

Table 2 presents the iodine value of all oils during frying. There was a trend of decreased Iodine value content during five times replication of frying. The decrease in iodine value with time of frying could be attributed to the changes in fatty acids taking place with duration of frying (Manral *et al*., 2008). It was observed that Iodine value of refined, bleached and deodorized palm olein RBD palm olein and combination of RBD palm olein and corn oil (50:50) were lower during 5 cycles of frying while that of corn oil were significantly ($p<0.05$) higher. The initial iodine value of RBD palm olein and corn oil (50:50) was 98.60 and decreased significantly ($p<0.05$) to 79.93 after fifth frying. The reduction in IV, as exhibited by blended formulations, was mainly because of the reduction of unsaturated C18:2 at the expense of C18:1. Padmavathy *et al*. (2001) mentioned, the highest decrease in IV in

Table 3: Free fatty acid (%) of 6 different ratios of sunflower oil, corn oil and RBD palm olein during deep-fat frying

	Frying times						
Sample	0	1	2	3	4	5	Mean
RBD	0.10 ± 0.00^{CBf}	0.17 ± 0.01^{Ae}	0.22 ± 0.01^{Ad}	0.29 ± 0.01^{Ac}	0.45 ± 0.00^{Bd}	0.55 ± 0.01^{Ba}	0.296
SFO	0.08 ± 0.00^{De}	0.101 ± 0.00^{Cd}	0.103 ± 0.00^{Cc}	0.106 ± 0.00^{Cd}	0.108 ± 0.00^{Ea}	0.109 ± 0.00^{Da}	0.101
CO	0.12 ± 0.00^{Af}	0.18 ± 0.01^{Ae}	0.23 ± 0.00^{Ad}	0.30 ± 0.01^{Ac}	0.47 ± 0.01^{Ab}	0.58 ± 0.01^{Aa}	0.313
SFO:RBD(50:50)	0.09 ± 0.00^{CDf}	0.14 ± 0.01^{Be}	0.17 ± 0.01^{Bd}	0.19 ± 0.00^{Bc}	0.25 ± 0.01^{Db}	0.35 ± 0.00^{Ca}	0.198
RBD:CO(50:50)	0.11 ± 0.00^{ABf}	0.18 ± 0.01^{Ae}	0.23 ± 0.01^{Ad}	0.29 ± 0.01^{Ac}	0.46 ± 0.01^{ABb}	0.56 ± 0.00^{Ba}	0.305
CO:SFO(50:50)	0.09 ± 0.00^{CDf}	0.14 ± 0.01^{Be}	0.16 ± 0.01^{Bd}	0.20 ± 0.01^{Bc}	0.29 ± 0.01^{Cb}	0.34 ± 0.01^{Ca}	0.203

SFO: Sunflower oil; RBD: Refined, bleached and deodorized palm olein; CO: Corn oil.

$^{a-f}$Means within a column with different letters are significantly ($p<0.05$).

$^{A-D}$Means within a row for each parameter with different letter are significantly different ($p<0.05$)

sunflower oil, lowest decrease in IV in crude palm oil and the decrease for the blend of crude palm oil with sunflower oil was between these.

Sunflower oil is rich in polyunsaturated fatty acid (diunsaturated fatty acid) and corn oil that presents a relatively high concentration of Polyunsaturated Fatty Acids (PUFA). Due to the high levels of unsaturation, these lipids are highly susceptible to free radical oxidative reactions (Valls *et al*., 2003). Also after fourth and fifth frying sunflower oil and combination of sunflower oil and corn oil were highest in iodine value and RBD palm olein and combination of RBD palm olein and corn oil (50:50) were lowest.

FFA content changes of all types of oil combination during deep fat frying are given in Table 3. It is seen that the FFA contents increased for all the oils during repeated deep frying with corn oil increased faster compared to other oils. Free fatty acid of sunflower oil increased slower compared to other oils. Combination of sunflower oil and corn oil (50:50) generally showed lower increases in FFA than did pure corn oil. An increase in free fatty acids has been known to result from hydrolysis of triglycerides, triggered by infusion of moisture from the food into the oil and its oxidation. However, determination of free fatty acids by titration is a quantitative method so it is difficult to make out the extent to which the increase in free fatty acids is due to oxidation or hydrolysis.

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