Relationship between antioxidant components and oxidative stability of peanut oils as affected by roasting temperatures

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October 28, 2020

Abstract

The study sought to investigate the effect of roasting temperatures on antioxidant components and oxidative stability of peanut oils. The total phenolic content, total flavonoid content, α–tocopherol content, and phytosterol content in peanut oils was influenced by roasting at temperatures of 120, 140, and 160, while those roasting temperatures had no effect on the fatty acid profile and γ–tocopherol content of peanut oils. Roasting promotes the quality of peanut oil aroma via the Maillard reaction, particularly those derived from N–heterocyclic compounds (such as pyrazine and pyrrole). The oxidative stability of peanut oils was investigated using the Rancimat method, and the results show that there is a linear relationship between roasting and natural logarithm of induction period (R2: 0.959˜0.998). This was determined based on the Arrhenius equation, which indicated the activation energy (Ea) were 82.08˜108.61 KJ/mol. In PCA analysis, the antioxidant stability of the increase levels of phenols released in the peanut oils was found to be rise with increment of roasting temperatures. The data obtained in this study should be confirmed to the nutritional benefits of peanut oils that will be most appealing to consumers.

Introduction

Oil–bearing crops include those whose fruits (or mesocarps), seeds, and nuts are worth for the edible or industrial oils to extracted. The Food and Agriculture Organization of the United Nations (FAO) listed 21 oil crops, which collectively yield an annual production of world oilseed for about 100 million tons (Athar and Nasir, 2005). Vegetable oils have progressively supplanted animal oils as a major source of dietary fat, leading to oil crop production becoming one of the prevailing forms of world agriculture. Oil crops contain diverse array that strengthen nutritional value of human diet, with the oils generated by such crops being especially good sources of tocopherol and thus promoting the balanced intake of vitamin E (Athar and Nasir, 2005; Kornsteiner et al., 2006). Peanuts, most fundamental food crop in the world, where China, India, and the United States are top three peanuts worldwide producers (Arya et al., 2016). The peanuts pods ripen approximately 150 days after the seeds planted. With mechanized reaping, the whole peanut plant, including the seed pods, are removed from the soil before being dried (sun or hot–air) and then seed shelling (Arya et al., 2016; Nawade et al., 2018). Peanuts easily lipid oxidize and decompose during storage and transportation due to their high–fat level (>50%), and this influence their nutritional, agricultural and edible safety importance (Chukwumah et al., 2007; Liu et al., 2018; Hu et al., 2019; Xie et al., 2019).

The cooking methods used with edible oils differ in terms of the temperature, duration, and the amount of oil used. Vegetable oils are important constituents of the daily diet of most people, although the actual intake of such oils differs considerably depending on the cooking methods used. The World Health Organization

(WHO) has identified three important factors for determining the nutritional value of oils: I) the presence of antioxidants; II) the ratio of saturated fatty acids (SFA), mono–unsaturated fatty acids (MUFA), and poly–unsaturated fatty acids (PUFA); and III) the essential fatty acid ratio (Hashempour–Baltork et al., 2016). Relatedly, the WHO has recommended a ratio of 1:1.5:1 for SFA:MUFA: PUFA and a ratio of 1:5˜10 for α– linolenic acid (omega–3): linoleic acid (omega–6) in people's dietary intake. Vegetable oils are high in MUFA and, as part of a low–cholesterol diet, have been found to lead to reduced cardiovascular disease (CVD) risk, in addition to potentially improving serum lipid profiles, decreasing LDL oxidation, and exerting a cardioprotective effect (Hashempour–Baltork et al., 2016; Chen et al., 2008). The antioxidant components in vegetable oils is composed of hydrocarbons, carotenes, tocopherol, phytosterols, and triterpenes, the minor constituents of various vegetable oils are associated with medicinal qualities and thus can be useful in preventing or delaying the onset of chronic diseases and promoting health (Chen et al., 2008; Alasalvar and Bolling, 2015; Ghosh et al., 2017).

Organic solvent extraction (mostly using petroleum ether, petroleum benzene, and hexane) and mechanical pressing are two conventionally used commercial methods in producing vegetable oils. However, the residual solvent remains of the former process can cause environmental safety issues and neurological damage, while mechanical pressing provides only a low yield of oils (Mingyai et al., 2018; Yang et al., 2018). To increase the extractability of oil, several destructive pretreatments need to be performed. Cold-pressed oils are generated with no refining process and have good flavor, stable quality, and are high in bioactive components, qualities which have led them to be regarded as excellent food oils by consumers (Yang et al., 2018). Roasting, grinding, and pressing have been the key steps in peanut oil processing. Recent research findings, however, have given mind to the enhancement of substitute processing techniques for oil production and flavor. Roasting constitutes a critical processing stage that affect the color, composition, conversion to bioactive compounds, and or ganoleptic qualities of the extracted oils, as well as their oxidative stability (Chang et al., 2016; Taş and Gökmen, 2017; Różańska et al., 2019). Research has shown, for example, that roasting increases the oxidative stability of sesame oil, with no oxidation being observed for 50 days after roasting (Rostami et al.,2014).

Insufficient information regarding edible oils has made it increasingly difficult for consumers to choose oils for purchase. Traditional peanut oil preparation focuses on the relationship between roasting temperature and aroma but ignores thermal-oxidative degradation and active substance. In this study, peanuts were roasted at different temperatures (120, 140, and 160) to determine how those roasting temperatures affect the chemical properties related to the quality of the oils generated. We investigated various quality indices and the oxidative stability of the generated peanut oils, as these factors have received increasing attention as edible oils have been increasingly recognized as a necessary source of antioxidant components in a healthy balanced diet. Relatedly, the obtained data should be useful for deepening the understanding of the chemical profile, in addition to providing scientific evidence for enhancing the human diet qualities. Moreover, this present work may serve as a worth reference for future complementary studies aimed at evaluating the beneficial effects of vegetable oils on human health.

Materials and Methods

Materials

6–hydroxy–2,5,7,8–tetramethylchroman–2–carboxylic acid (Trolox), 1,1–diphenyl–2–picrylhydrazyl (DPPH), 2,4,6–Tripyridyl–S–Triazine (TPTZ), α–tocopherol, γ–tocopherol, gallic acid, quercetin, Folin–Ciocalteu reagent, Fatty acid methyl ester standard mixture, and other chemicals and solvents were supplied by Merck (Darmstadt, Germany), Sigma–Aldrich (St. Louis, MO, USA), and CHEMICAL CO., LTD (Miaoli, Taiwan).

Production of peanut oils

Samples of peanut were supplied in February 2019 by a marketing cooperative (Chiayi, Taiwan). The peanuts are separated into batches, each batch were being weighted separately to 5kg, and roasted in a roasting machine at 120°C, 140°C, or 160°C for 10 min individually. Then, each sample of the roasted peanut

was pressed for its oil using a mechanical pressing machine, and after filtered, the oil is finally collected.

Fatty acid and quality indices analysis

Fatty acids composition of each sample was analyzed through GC/FID. Following the AOCS official method Ce 2–6616, triacylglycerol was first converted to methyl ester, and then by using a DB–23 column (30 m×0.25 mm×0.25 μm) with helium at flow rate of 1.0 ml/min, methyl esters were being separated. The condition of oven temperature is as follow: I) held at 200°C for 8 min in the beginning, II) increased to 220°C (speed of 10°C/min), then held for 40 min. The FID and the injector (split mode 1:40, 4 mm liner) was maintained at 270°C and 250°C, respectively. The quantification using the normalization method for each oil sample, the determination of quality indices, including the acidity value (AV), peroxide value (POV), anisidine value (p–AV), and color, was performed using various instruments. The AV (mg KOH/g) was measured by titration using 0.1N KOH/alcoholic solution. The POV (meq/Kg) was measured using a titration with 0.01N sodium thiosulfate solution. The p–AV was measured using 0.25% anisidine/glacical acetic acid by UV absorbance at 350 nm. The Totox value was then calculated using the formula AV + 2POV to defined the given oil sample's overall oxidation state. The color analysis was using UV–light absorption and the browning index (BI) according to previous research (Yang et al., 2018).

Antioxidant components and antioxidant capacity analysis

Tocopherol analysis was performed by HPLC as described previously using Hitachi instruments equipped (Hitachi, Japan) with a C18–Varian column (25 cm×4 mm; Kanto Chemical Co., Inc., Japan), and detection was applied using a UV detector at 298 nm (Yang et al., 2017). The calibration curves of each standard were initiated by plotting peak area versus the corresponding concentration, respectively. Phytosterol analysis was performed by GC/MS as described previously using Agilent instruments equipped with a DB–1 column (60 m×0.25 mm i.d.; Agilent, Palo Alto, CA, USA). The 5α–cholesterol was taken as an internal standard, and the ratio of the peak area of the analyte and internal standard was used as an analytical signal (Jun–Hua et al., 2008).

The total phenolic and total flavonoid contents were analyzed using the method mentioned in previous literature (Yang et al., 2018). Each oil sample (5g) was mixed with acetone/methanol (2:8) to 50 ml. The total phenolic content and total flavonoid content of oil samples were evaluated by methods described inprevious literature (Yang et al., 2018). The antioxidant activity of each peanut oil sample was evaluated using, the biochemical methods of DPPH and Ferric ion reducing antioxidant power (FRAP) assays. The DPPH radical–clearing capacity was measured following to previous research (Lin et al., 2019). Each oil sample was diluted with acetone/methanol (2:8) to concentrations of 1 mg/mL, and then mixed together with DPPH radicals (0.2mM) of methanol solution. After vigorously shake, the mixture was incubated at room temperature for 30 min, and then measured absorbance at 517 nm. The FRAP was measured following to the method used in previous research (Fernández–Arroyo et al., 2011). Each oil sample was diluted with acetone/methanol (2:8) to concentrations of 2 mg/mL, and then mixed with FRAP reagent (acetate buffer, $FeCl_3$ solution, and TPTZ; 10:1:1). After vigorously shake, the mixture incubated at room temperature for 10 min, and next, measured absorbance at 595 nm. Trolox was used as the positive control.

Volatile compound analysis

The volatile compounds extracted using SPME with DVB/CAR/PDMS (Supelco, Inc.) fiber following to previously described (Yang et al., 2017). Individual oil samples (5g) were chosen and placed into a sealed bottle and water bath at 50°C immediately. The aroma compounds were extracted using SPME method for 30 min. The fiber was then removed and transferred into the GC/MS injector For the GC–MS measurements, GC HP 6890 (Calif, USA) attached to an HP5973MSD detector with a DB–1 column (60 m×0.25 mm×0.25 μm, Agilent, Palo Alto, CA, USA) was used. Helium was operated at flow rate of 1 mL/min. The ionization potential used was 70 eV, and the temperature of the ion source was at 230 °C. The condition of the oven temperature was as follow: I) 40 °C as initial temperature, then increased to 120 °C (speed of 3°C/min) and II) then set to a rate of increase to 200 °C (speed of 5°C/min), the temperature which then was held for 10 min. The linear retention indices (RIs) were calculated from the retention times of n–alkanes (C_5–C_{25}),

and the volatiles Identification by matching the RI with data found other literature (Yeh et al., 2014). The quantities of volatile compounds were indicated using the peak area.

Kinetic parameters of Rancimat test

Using a Rancimat 743 apparatus, oil samples (5g) were being tested for oxidative stability at 5 different temperatures (100, 105, 110, 115, and 120°C). The induction period(IP, hours) which is used as a measurement of oxidative stability, were automatically recorded at an air flow rate of 10L/h, and the intersected point of two extrapolated parts of the curves were taken as the IPs of each samples.

The samples' kinetic parameters were established by following to previous described method (Farhoosh et al., 2008). Kinetic rate constant, temperature coefficients (T Coeff, K^{-1}), activation energies (E a, kJ/mol) and pre–exponential or frequency factors (A, h^{-1}) were defined by method described inprevious literature (Yang et al., 2018).

Statistical analysis

The data reported was obtained from triplicate measurements of samples. The results were analyzed by one–way analysis of variance (ANOVA) using SAS 9.0 (SAS Inst., Cary, NC, USA), and $p < 0.05$ was considered statistically significant. In addition, the data were analyzed using Principal Component Analysis (PCA) combined with VARIMAX rotation. XLSTAT software (version 2010.2.01, Addinsoft Deutschland, Andernach, Germany) was used for PCA analysis.

RESULTS AND DISCUSSION

Quality indices

The high temperature used in roasting can promote lipid oxidation, which in turn influences the quality of a peanut oil (Al Juhaimiet al., 2018). The results show that the BIs of the peanut oils generated by different roasting temperatures in this study ranged from 37.94˜195.71(Table 1). Simultaneously, the color of peanut oil changes from a dark yellow to red brown as roasting temperature increased. Furthermore, the AVs of the peanut oils generated by different roasting temperatures ranged from 1.12˜1.94mg KOH/g, while the POVs of the peanut oils generated by different roasting temperatures ranged from 5.48˜8.67 meq peroxide/kg. These values meet the Chinese National Standard criteria for peanut oil. AV and POV determinations are often used as general indications of the condition and edibility of oils. When an oil has a POV>10 meq peroxide/kg, it is less stable and to have a short shelf life (Madhujith and Sivakanthan, 2018). Relatedly, oxidation products can cause undesirable health problems. The result show that the p–AVs of the peanut oils were generated by different roasting temperatures in this study ranged from 5.47˜10.42 meq/kg. We further found that the TOTOX values of the peanut oils generated by roasting at 120, 140, and 160 were 16.43, 26.70, and 27.76, respectively. The quality standards of the European Pharmacopoeia require specific levels of TOTOX [?]30(Xu et al., 2015).

Various fatty acids influence the nature of an oil's physicochemical and nutritional performance. Regarding the fatty acid compositions of the peanut oils generated after roasting in this study, we found out 8 kinds fatty acids. The obtained data further showed that no significant differences in fatty acid composition for the oils generated by different roasting temperatures (Table 2, $p<0.05$). Oleic acid (36.67˜38.44%) is an important nutritional component of peanut oil. Compared with PUFA, oleic acid is more resistant to thermal oxidation, both at ambient storage temperatures and the high temperatures that prevail during cooking and frying of food (Penget al., 2017). Relatedly, vegetable oils with higher U/S ratios are more precious in terms of nutritional quality, as they may contribute to a greater extent to lowering the LDL cholesterol and total cholesterol of people, while not affecting their levels of beneficial HDL cholesterol (Hashempour–Baltork et al., 2016; Cicero et al., 2018). We found that the UFA/SFA values of the peanut oils generated by roasting in this study ranged from 3.58˜3.68. Other studies have indicated that the U/S values of camellia seed oils ranged from 3.23˜3.31(Yang et al., 2018).

Antioxidant components change

Lipid oxidation results in undesirable taste and flavor, and oils with high levels of lipid oxidation may lost nutritional value and generate toxic compounds (Peng et al., 2017; Yang et al., 2017). Antioxidant components in oils are thus important with respect to their dietary effects when consumed by humans. The past literature has reported that the natural antioxidant activity of refined oil may be lower than that of crude oil (Cicero et al., 2018). The result show that the α–tocopherol levels of the peanut oils generated by roasting at 120, 140, and 160 in this study were 72.33, 60.39, and 55.72 μg/g, respectively; their γ–tocopherol contents were 67.31, 72.91, and 70.51μg/g, respectively; their total phenolic contents were 18.31, 29.63, and 36.61 GAE μg/g, respectively; and their total flavonoid contents were 4.27, 3.96, and 4.44 QE μg/g, respectively (Table 3). In analyzing the phytosterol derivatives of the peanut oils, we identified squalene, campesterol, stigmasterol, stigmast–5–en–3–ol, and stigmasta–5,24(28)–dien–3–ol. The results further showed that as the roasting temperatures of the peanut oils increased, the levels of squalene, campesterol, stigmasterol, and stigmast–5–en–3–ol contained in the oils also increased.

The antioxidants in oils improve their oxidative stability and prevent their oxidative degradations, either by delaying the oxidation reaction by reacting with free radicals or by inhibiting the propagation step by reacting with alkoxy and alkyl peroxy radicals (Redondo–Cuevas et al., 2018). The results of this study further showed the DPPH clearing capacity of 2.5% peanut oil was 42.02˜52.34%, while the FRAP was 151.22˜328.64 Trolox μg/g (Table 3.). The oil generated by roasting at 160 had the best antioxidant capacity among the three varieties. Roasting could increase the release of phenols by bound phenolic compounds of peanuts brown skin, and the formation of Maillard reaction products like melanoidins (Taş and Gökmen, 2017; Różańska et al., 2019). These substances protect tocopherols from heat degradation during roasting. However, while phytosterols are important, the interactions between the antioxidants have synergistic effects (Chenet al., 2016).

The olfactory sensations of edible oils are very important, and these sensations combine the effects of an oil's constituents on the taste and olfactory organs. The processing techniques used in producing oils would affect significantly the major volatile components concentrations, and hence determine their flavor quality. In this study, we detected 20 volatile compounds in the peanut oils generated by different roasting temperatures, including 7 N–heterocyclic compounds, 5 alkane compounds, 4 O–heterocyclic compounds, and 2 aldehyde compounds, as well as alcohol and sulfide (Table 4). Roasting affects the production of volatile compounds, particularly those derived from N–heterocyclic compounds (such as pyrazine and pyrrole), with the formation of alkylated pyrazines occurring via automatic condensation or condensation with other aminoketones of α–aminoketones in the Strecker degradation (Siegmund and Murkovic, 2004; Dun et al., 2019; Yang and Chian, 2019). Peanuts contain abundant amounts of essential precursors for the Maillard reaction, and the carbon skeleton of the pyrazines is derived in the Maillard reaction from carbohydrate degradation, while the pyrazinic nitrogen originates directly from amino acids (Siegmund and Murkovic, 2004; Dun et al., 2019). We found that some volatile compounds were formed during lipid oxidation, with dioxygen leading to the formation of hexanal, 2–hepten–1–ol, and nonanal. Hexanal emerged from linoleic acid, whereas nonanal is an oleic acid derivative that mainly imparts a fresh and fatty flavor (Haiyanet al., 2007). The results showed that high roasting temperatures induce the formation of volatile compounds through the Maillard reaction and lipid oxidation. In particular, high roasting temperatures result in the removal 2,3,4–trithiapentane, helping to prevent foul odors.

Oxidation stability

Oxidation process accelerate Rancimat test by disclose oil samples to high temperature and high oxygen solubility, and that in turn determine the induction period for the formation of volatile acids (Robertson et al., 2000; Yeh et al., 2014). In this study, we investigated the oxidative stability of the peanut oils generated using the Rancimat test at temperatures of 100˜120°C (Fig. 1). For use of the Rancimat test at temperature of 100, 105, 110, 115, and 120, the induction times were 13.58, 12.01, 8.56, 4.89, and 3.94 h, respectively, for the oils roasted at 120; 20.85, 14.15, 8.75, 5.67, and 3.68 h, respectively, for the oils roasted at 140; and 21.55, 15.12, 10.87, 5.88, and 3.71 h, respectively, for the oils roasted at 160. Simultaneously, semi–logarithmic relationship for all the oil samples by Equation I, including a linear dependency with

good correlation of determination, R^2 0.959˜0.998 for the different roasting temperatures (Fig. 1). The kinetic parameters of the Rancimat test are valuable for the goal of distinguishing between various oils, for characterizing the differences or similarities in oils, and for predicting the oxidative stability of oils under various storage conditions (Kochhar and Henry, 2009). The E a values for all the oil samples were determined using Equation II, the bond scission that take place forming primary oxidation products is shown through the delay of the initial oxidation reaction (Farhoosh and Hoseini–Yazdi, 2014). Table 5 shows that the E a values of the assayed oils were 82.08 kJ/mol for the oil roasted at 120, 105.2 kJ/mol for the oil roasted at 140, and 108.61 kJ/mol for the oil roasted at 160. Other studies have indicated that the E a values for vegetable oils ranged from 86.86˜82.42 kJ/mol. The E a value of oil is influenced by level of unsaturated fatty acids and antioxidants present in the oil (Yang et al., 2018).

This study investigated the compound changes and olfactory sensations for peanut oils roasted at different temperatures, which characterized in terms of oxidative stability by PCA (Fig. 2). The key results include the finding: 1) The E a values of the oils indicated that their oxidative stability was highly correlated with their levels of total phenol (R:0.963), DPPH (R:0.963), FRAP (R:0.944), and r–tocopherol (R:0.739). The occurrence of total phenol and γ–tocopherol led to a high Ea value in the products, causing great DPPH and FRAP performance simultaneously. 2) The N–heterocyclic compounds in the oils provided an overall indication of their olfactory sensations. In the process of roasting, the oxide (O–heterocyclic (R:–0.986), aldehyde (R:–0.950), and alcohol (R:–0.890)) compounds generated were transformed into N–heterocyclic compounds as the temperature increased due to the Maillard reaction.

Conclusions

The results obtained in this study provide consumers with important information regarding the qualities of roasted peanut oils. The major findings were as follows: I) The tested peanut oils were rich antioxidant components (include tocopherol, phytosterol, phenolic, and flavonoid) and these compounds are very important for improved product functionality and shelf life; II) The olfactory sensations of the tested oils were positively correlated with the temperatures at which they were roasted; III) Great oxidative stability prevents oxidation and deterioration. Theobtained data should be useful for deepening the understanding of the chemical composition of peanut oils, in addition to providing scientific evidence for improving the quality of human diets.

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Table 1. Quality indices in peanut oils were influenced by roasting temperatures.

BI**						
POV						
AV						
p–AV						
TOTOX						

Results from three separate experiments are expressed as mean ± SD. A-C: Data with identical letters in the same row are

Table 2. Fatty acid compositions (%) in peanut oils was influenced by roasting temperatures.

	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	P o r a
	120	120	120	120	140	140	140	140	160	160	160	1
C16:0	14.36	±	0.06^{c*}		13.68	±	0.04^{c}		14.18	±	0.06^{b}	
C18:0	3.01	±	0.01^{d}		3.07	±	0.02^{d}		3.63	±	0.02^{c}	
C18:1	37.23	±	0.15^{b}		36.67	±	0.20 ^{b}		38.44	±	0.11^{a}	
C18:2	40.65	±	0.24^{a}		40.80	±	0.19^{a}		39.00	±	0.21^{a}	
C20:0	1.25	±	0.01^{d}		1.53	±	0.02^{d}		1.29	±	0.01^{d}	
C20:1	0.75	±	0.01^{e}		0.83	±	0.01^{e}		0.73	±	0.01^{e}	
C22:0	2.00	±	0.03^{d}		2.48	±	0.01^{d}		2.10	±	0.01^{c}	
C24:0	0.75	±	0.01^{e}		0.94	±	0.01^{e}		0.64	±	0.01^{e}	
U/S**	3.68	±	0.01		3.61	±	0.02		3.58	±	0.02	

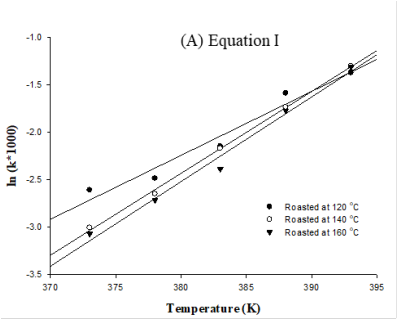
	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	Peanut oil roasted at	[illegible]
* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	* Results from three separate experiments are expressed as mean ± SD. a-e: Data with identical letters in the same column are not significantly different ($p < 0.05$). **U/S: unsaturated fatty acid/saturated fatty acid	[illegible]

Table 3 Antioxidant components and antioxidant capacity in peanut oils was influenced by roasting temperatures.

antioxidant components	
α–tocopherol [1*]	
γ–tocopherol [1]	
squalene1[1]	
campesterol [1]	
stigmasterol [1]	
stigmast–5–en–3–ol [1]	
stigmasta–5,24(28)–dien–3–ol [1]	
total phenol [2]	
total flavonoid [3]	
Antioxidant capacity	
DPPH [4]	
FRAP [5]	
Results from three separate experiments are expressed as mean ± SD. A-C: Data with identical letters in the same row are	

Table 4 Volatile compounds (%) in peanut oils were influenced by roasting temperatures.

Compound	RI
hexanal	778
2–methylpyrazine	794
fruanmethanol	844
methylbutyloxirane	878
3,5–dimethylcyclohexene	882
2,5–dimethylpyrazine	884
benzaldehyde	925
2,3,4–trithiapentane	942
2–hepten–1–ol	948
2–ethyl–6–methylpyrazine	964
2,5–dimethylheotane	981
benzeneacetaldhyde	1008
acthylpyrrole	1032
2–ethyl–3,5–dimethylpyrazine	1056
nonanal	1100
benzeneethanol	1108
2–acetyl–3–methylpyrzaine	1120
undecane	1132
3,5–diethyl–2–,ethylpyrazine	1184
tetradecane	1744
Data present are in mean ± SD form (n=3). N.D: not detected.	Data present are in mean ± SD form (n=3). N.D: not de



(B) Equation II

	Peanut oil roasted at		
	120 ◦ C	140 ◦ C	160 ◦ C
	ln(k)=a(1/T)+b		
a	-9.8725	-12.653	-13.064
b	23.74	30.87	31.87
R2	0.956	0.997	0.983
*E*a(kj/mol)	82.08	105.2	108.61

Fig. 1 Rancimat test for peanuts oil-(A) Semi-logarithmic relationship and (B) Regression parameters for Arrhenius relationships.

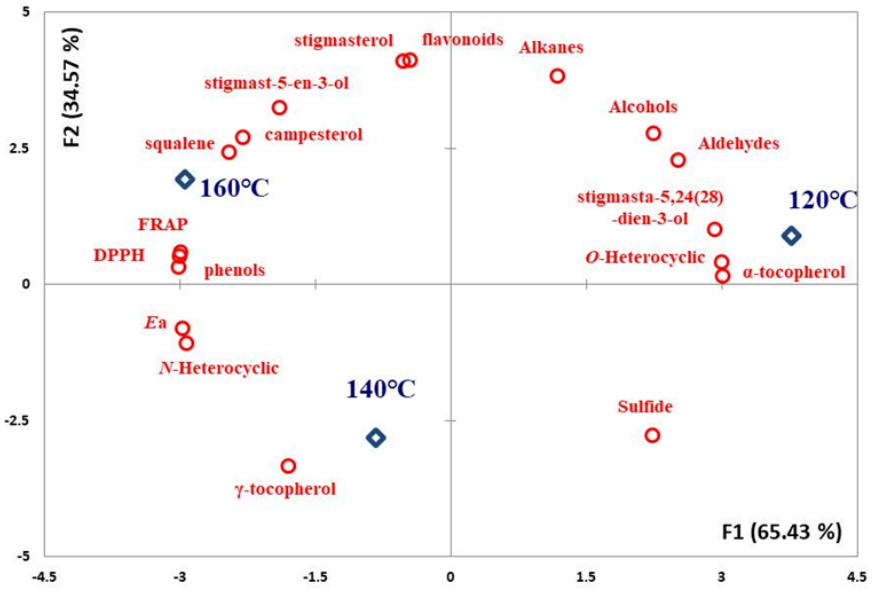


Fig. 2. PCA plots of composition change and oxidation stability for peanut oils generated by different roasting temperatures