J Therm Anal Calorim (2017) 130:1281–1292
DOI 10.1007/s10973-017-6423-0

Comparison of the effect of *Pleurotus citrinopileatus* extract and vitamin E on the stabilization properties of camellia oil

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Received: 25 February 2017 / Accepted: 24 April 2017 / Published online: 29 April 2017

Abstract We selected *Camellia tenuifolia* (Hayata) seed oil to compare the effects of mushroom extract and vitamin E on its stabilization properties. *Camellia tenuifolia* was selected for its higher oil content, but its proportions of unsaturated fatty acids and natural antioxidants as well as its oxidation stability are lower than those of *Camellia oleifera* oil. Our aim was to improve the oxidation stability, thermal stability, and photodegradation of *C. tenuifolia* seed oil and then compare the advantages of mixing traditional antioxidant (vitamin E) and mushroom natural antioxidant components (mushroom extract) in the oil. The focus was on the analysis of the effects of *Pleurotus citrinopileatus* (Singer) extract and vitamin E on the stabilization properties of *C. tenuifolia* seed oil, which involved some degradation research, such as evaluating the thermal, oxidation, and antioxidant effects as well as the irradiative (pulsed light) stability of the original oil and oil mixed with additives for comparing the differences by differential scanning calorimetry tests and isothermal microcalorimeter (TAM Air) analyses. We determined the effects of stabilization additives vitamin E and various PC extract doses by using pulsed light irradiation (0, 30, and 60 pulses) and found that the 3 mass% PC extract had the best antiphotodegradation characteristics, and the 0.1 mass% vitamin E indicated the outstanding oxidation stability for among all of the additives in this study. Overall, we obtained the following suitable conditions to stabilize camellia oil: addition of vitamin E, addition of 3 mass% PC extract, and a nitrogen atmosphere.

Keywords *Camellia tenuifolia* (Hayata) seed oil · Mushroom extract · Photodegradation · Vitamin E · Antioxidant effect · Pulsed light

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Introduction

The seeds of *Camellia tenuifolia* (Hayata)/*oleifera* can be pressed to obtain high-quality oils (camellia seed oils) that are used extensively for cooking in Taiwan [1]. The fatty acid compositions of edible oils have been closely associated with changes in health. *Camellia* oil contains abundant unsaturated fatty acids consisting of oleic acid and linoleic acid. The unsaturated fatty acid content in the oil is more than 90 mass%, which is the highest amount reported thus far in edible oils [2]. Moreover, its monounsaturated fatty acid content is greater than that of olive oil, while its unsaturated fatty acid content complies with the international nutritional standards of meals high in omega-3 fatty acids. It is also rich in vitamin E, containing twice as much as olive oil, and it contains squalene and flavonoids [3].

Camellia oil is applied in a medicine for stomach aches and burns [4], and it is antimicrobial, antiviral [5], has skin healing properties [6], protects the liver against CCl_4-induced oxidative damage [7], suppresses the cholesterol content in the body, and promotes resistance to oxidative stress [8]. We selected *Camellia tenuifolia* to compare the effects of *Pleurotus citrinopileatus* (Singer) (Pleurotaceae,

Agaricomycetes) extract and vitamin E (vit E) on the stabilization properties. The main advantage of *Camellia tenuifolia* is its higher oil content, but its proportions of unsaturated fatty acids and natural antioxidants as well as its oxidation stability are lower than those of *Camellia oleifera*. Thus, our aim was to improve the oxidation stability, thermal stability, and photodegradation properties of *Camellia tenuifolia* seed oils and then compare mixing traditional antioxidant (vitamin E) and mushroom natural antioxidant components (mushroom extract) in the oil.

The mushroom extract was from the culinary-medicinal golden oyster mushroom *Pleurotus citrinopileatus* (PC), which is a popular species in many countries, especially in Asia [9, 10]. Many scientific studies indicate that this mushroom possesses biological and pharmacological activity, such as antitumor activity, antigenotoxicity, and antihyperglycemic effect [11–13]. Chen et al. [14] also examined the ergothioneine (EGT) content of the mushroom extracts from the fruiting bodies and mycelia of 20 edible and medicinal mushroom species and found that species of the genus *Pleurotus* contained substantial amounts of ergothioneine (2-mercaptohistidine trimethylbetaine), which is also one of the main reasons for using the mushroom extract as a natural antiaging additive [15–17]. Ergothioneine is an effective intrinsic antihydroxyl radical, antiperoxyl radical, and antiperoxynitrite radical antioxidant compared with classic molecules with antioxidant capacities, such as reduced glutathione, uric acid, and Trolox [18]. The mushroom extract also contains other antioxidants, such as flavonoids and phenols, which are also beneficial to human health.

Pulsed light is a high-energy short pulse current through an inert gas (xenon) of the bulb that stimulates a high-intensity white light; the broadband wave number of white light is from 190 to 700 nm, and it contains ultraviolet, visible, and infrared light [19]. It also has a short irradiation time with no radiation, no chemical residues, low energy pollution, and high efficiency [20]. Pulsed light irradiation causes the inactivation photochemical effect on microorganisms. When microorganisms absorb pulsed light, it changes the structure of DNA, the genetic information, causing damage, preventing cell replication and division, and finally causing microbial death [21]. This achieves sterilization but has insignificant effects on the nutritional value and quality of food [22]. Thus, it is gradually replacing the traditional disadvantages of sterilization under high-temperature and high-pressure conditions.

The focus of the study was on the effects of *Pleurotus citrinopileatus* extract and vitamin E on the stabilization properties of *Camellia tenuifolia* seed oil. We came up with a novel idea for adding natural, healthy, and physiologically active natural antioxidants, which will involve some degradation research, such as evaluating the thermal, oxidation, antioxidant effect, and irradiation (pulsed light) stabilities of the original oil as well as with the addition of additives for comparing the differences by differential scanning calorimetry (DSC) tests and isothermal microcalorimeter (TAM Air) analyses. We are also developing a novel approach to elucidate the degradation conditions, including the thermal, strong light exposure, and antioxidation properties, of the original camellia oil for proper storage and antidegrading conditions, such as the onset temperature (DSC)/time (TAM Air), the peak maximum temperature (DSC)/time (TAM Air), and the exothermic reaction by thermal analyses. The parameters and properties can be applied to design food processing, heat treatment, and storage conditions.

Materials and methods

Materials

Camellia tenuiflora seeds were obtained from a local market in the city of Taichung, Taiwan. Camellia oil was obtained by pressing dehusked camellia seeds at 65 °C with pre-roasting. The oil thus obtained was subjected to filtration using a filter cloth to remove physical impurities, and it was transferred to transparent glass bottles stored in the dark at 4 °C. The original fatty acid profile of camellia oil was studied by gas chromatography (GC) (Agilent 6890N, Wilmington, DE, USA) equipped with a flame ionization detector (GC-FID) and a Restek Rt-2340 NB Cap. column (105 m × 0.25 mm × 0.20 μm) analysis [23]. The camellia oil fatty acid profile was determined to be as follows: oleic acid (82.05 mass%), palmitic acid (7.70 mass%), linoleic acid (8.06 mass%), and stearic acid (2.19 mass%) (see Table 1).

Mushroom extract

Fruit bodies of *Pleurotus citrinopileatus* mushrooms were purchased from Xie-Yi Agricultural Products Company (Taichung, Taiwan) and then freeze-dried. Afterward, a

Table 1 Fatty acid composition of camellia oil

Fatty acid	Fatty acid/mass%
Palmitic acid	7.70
Stearic acid	2.19
Oleic acid	82.05
Linoleic acid	8.06
Total saturated fatty acids	9.89
Total unsaturated fatty acids	90.11

coarse powder (60 mesh) was obtained using a mill (Retsch ultracentrifugal mill and sieving machine, Haan, Germany). The mushroom extract was prepared following the procedure of Lin et al. [24] with slight modifications. A subsample (10 g) was extracted by stirring with 200 mL of 75 °C water at 125 rpm for 60 min and filtering through Whatman No. 1 filter paper. The precipitate obtained was stirred again in 200 mL of 75 °C water and centrifuged. The combined supernatant was evaporated at 40 °C in vacuo. The obtained residue was dissolved in 10 mL of distilled water and stored at 4 °C for further use. Consequently, the concentration of mushroom extract was 0.365 g dry material mL^{-1} (see Table 2).

Mixture preparation

Pleurotus citrinopileatus extract (1, 3, and 5 mass% PC extract) and synthetic antioxidants (0.1 mass% vitamin E, T3634, Sigma-Aldrich, St. Louis, MO, USA) were added directly to camellia oil. A control sample was prepared using camellia oil without any antioxidant. All of the samples were kept at 4 °C. Figure 1 presents a flow diagram showing the effects of the PC extracts and vitamin E on the prevention of oxidation in the camellia oil.

Table 2 Extraction yield and antioxidant components (ergothioneine, flavonoids, and total phenols) of *Pleurotus citrinopileatus* mushroom extract

Pleurotus citrinopileatus	Extract
Extraction yield	36.5 mass%
Antioxidative component	
Ergothioneine	0.59 mg mL^{-1}
Flavonoids	0.35 mg mL^{-1}
Total phenols	0.22 mg mL^{-1}

Determination of antioxidant components

Ergothioneine, flavonoids, and total phenols were determined according to the methods described by Liang et al. [25], Zhishen et al. [26], and Taga et al. [27], respectively. The amounts of the components were calculated on the basis of the calibration curves of the corresponding authentic compounds; gallic acid and quercetin were used for the total phenols and flavonoids, respectively. The antioxidant properties were calculated as follows: chelating ability and scavenging activity (%) = [(ΔAbs of control − ΔAbs of sample)/ΔAbs of control] × 100. A value of 100% indicates the strongest chelating ability or scavenging activity. A higher absorbance indicates a higher reducing power.

Determination of the antioxidant properties

The reducing power was determined according to the method of Oyaizu [28]. The reducing power assayed is the ability of the extracts to form a colored complex with ferricyanide, which is an electron acceptor. The scavenging ability of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals was determined on the basis of Shimada et al. [29]. The scavenging ability assayed is the ability of the extracts to react with DPPH radicals and reduce most DPPH radical molecules. The chelating ability was determined according to the method of Dinis et al. [30]. Ferrous ions play an important role as catalysts in the oxidative process, leading to the formation of hydroxyl radicals and hydroperoxide decomposition by the Fenton reaction. The chelating ability assayed is the ability of the extracts to inhibit the formation of complexes of ferrozine and ferrous ions.

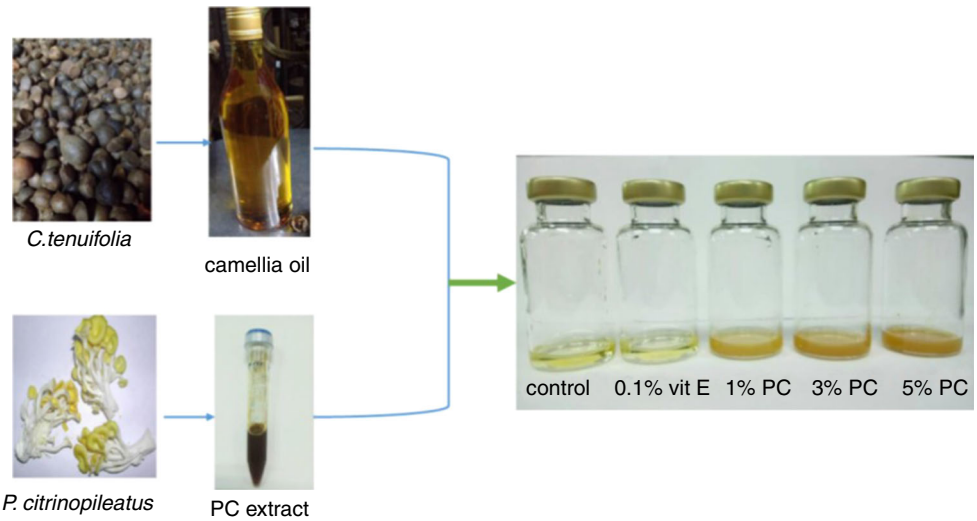

Fig. 1 Flow diagram showing the influence of vitamin E and *Pleurotus citrinopileatus* extract on the prevention of oxidation in camellia oil

Pulsed light irradiation

Samples were subjected to irradiation using a Xenon RC-801 pulsed light system (Xenon Corp.) employing a LH-840 lamp housing and B-type 16″ linear lamp (280–700 nm). The apparatus generated three pulses per second at 169 J pulse^{-1}. An average dose was 11.50 kJ m^{-2} pulse^{-1} [31]. A 10 g sample mixture was placed in the Petri dish and irradiated with 0, 30, or 60 pulses.

Differential scanning calorimetry (DSC) tests

Calorimetric measurements were taken with a DSC (TA Q20) (TA Instruments, Newcastle, DE, USA). DSC analysis was performed on samples sealed in 20-μL aluminum pans; the test cell was sealed manually by a special tool equipped for TA's DSC. In all DSC studies, nitrogen was the purge gas with a flow rate of 50 mL min^{-1}. ASTM E698 was used to obtain thermal curves for analyzing the parameters. Samples of 1.4–1.8 mg were used for acquiring the experimental data [32–36]. Non-isothermal tests of the scanning rate selected for the programmed temperature ramp were 2, 4, 6, and 8 °C min^{-1}, and after the oil underwent pulsed light irradiation treatment, the scanning rate selected for the programmed temperature ramp was 4 °C min^{-1} for the range of temperatures chosen from 30 to 450 °C for each experiment.

Measurement of the oxidation stability

The oxidation stability analysis experiments were performed using a TAM Air isothermal microcalorimeter (TA Instruments, Newcastle, DE, USA), which was equipped with eight twin calorimetric channels. One side of the microcalorimeter was used for the sample, and the other was used for a static reference. The generated signal was recorded in situ by a computer. Isothermal microcalorimeter measurements were taken using the ampoule method, and the instrument was brought to equilibrium temperature overnight in advance. The operating temperature range of the TAM Air thermostat was from 5 to 90 °C, with a stability of ±0.02 °C. The baseline was held at ~20 μW. We used the TAM Air software to control the thermostat [37, 38]. All 20-mL ampoules were cleaned prior to use. Next, approximately 1 mL of sample was placed in each ampoule and used for acquiring the experimental data. A TAM Air isothermal microcalorimeter was used to investigate the oxidation stability at 60.5 °C. The TAM Air isothermal microcalorimeter results for all samples were evaluated using PC extract and vitamin E with camellia oil under an isothermal temperature of 60.5 °C. We prepared approximately 1 g of each for each degradation process, blew away air using oxygen and nitrogen for 30 min under oxidizing and non-oxidizing conditions, respectively, never did any blowing under normal conditions, and then sealed all samples in glass ampoules. The original camellia oil (non-refined) was used as a control.

Table 3 Antioxidant properties of vitamin E and *Pleurotus citrinopileatus* mushroom extract

Antioxidant	Chelating ability/%	Reducing power	Scavenging activity/%
0.1 mass% vitamin E	98.42	1.198	93.47
1 mass% PC extract	34.32	0.371	26.03
3 mass% PC extract	72.04	0.813	50.60
5 mass% PC extract	85.32	1.102	69.87

Results and discussion

The results of the materials analyses

Table 1 shows the fatty acid composition of camellia oil from GC analysis, which verified the fatty acid composition of the camellia oil and confirmed that the amount of oleic acid and linoleic acid was more than 90 mass% of the total unsaturated fatty acids. From Table 2, we obtained a *Pleurotus citrinopileatus* mushroom extraction yield of 36.5 mass%, and the antioxidant component of *Pleurotus citrinopileatus* mushroom extract, ergothioneine (0.59 mg mL^{-1}), has the highest proportion in the extract. Moreover, comparing the data in Table 3 of the antioxidant properties with the chelating ability, reducing power, and scavenging activity, respectively, it is clear that vitamin E has outstanding antioxidant properties among all of the additives, and increasing PC extract doses increased the antioxidant properties.

DSC analysis

In Fig. 2, the DSC curves clearly show that the original camellia oil (non-refined) with various scanning rates of 2, 4, 6, and 8 °C min^{-1} undergoes a distinct exothermic reaction. The onset temperature, peak maximum temperature, and enthalpy of the exothermic reaction associated with the DSC transition were found in determining the thermal characteristics of the camellia oil. The detailed results of DSC analysis are listed in Table 4. From Table 4, it can be observed that the onset temperature was ca. 140 °C, which was previously reported for the exothermic reaction of camellia oil. The main exothermic reaction was thermal decomposition behavior by heat, which could be obtained from the original camellia oil's (non-refined) peak maximum temperature of ca. 170 °C. Generally, edible oil used in food cooking will not exceed 300 °C, thus more

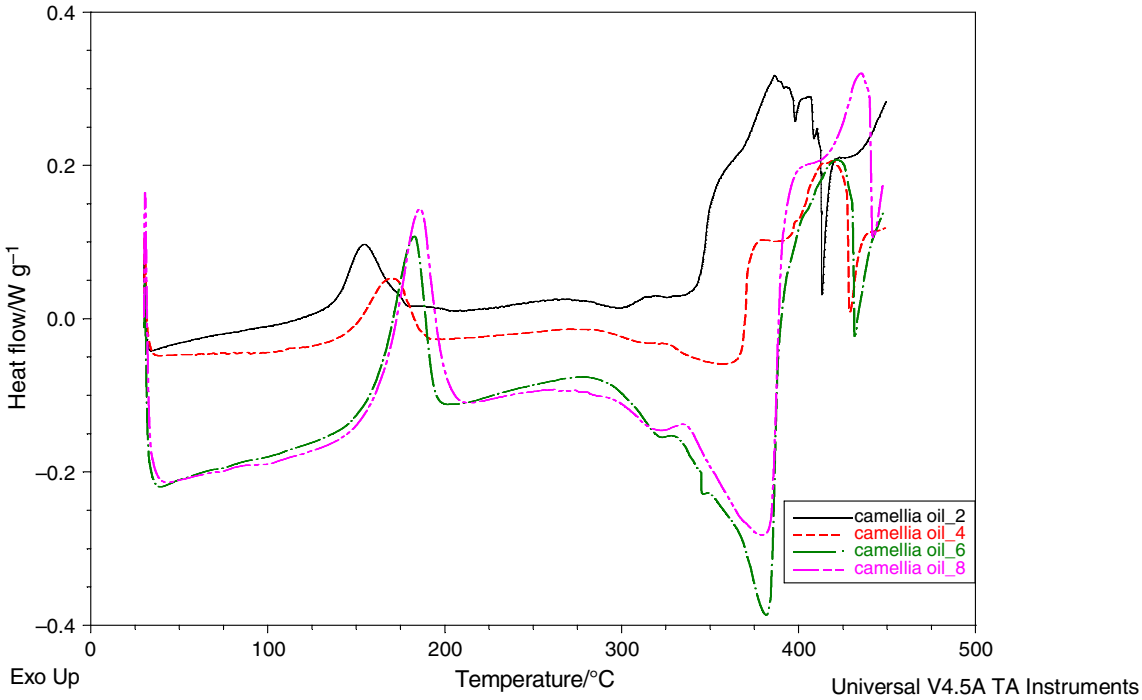

Fig. 2 DSC thermal curves of heat flow versus temperature for the camellia oil with scanning rates of 2, 4, 6, and 8 °C min^{-1}

Table 4 Results of DSC tests of camellia oil with scanning rates of 2, 4, 6, and 8 °C min^{-1} in the range of temperatures from 30 to 450 °C

Sample	Mass[a]	Condition[b]	$ExoT_o^c$	$ExoT_p^d$	$Exo\Delta H^e$
Original camellia oil	1.48	2	136.34	154.04	72.30
	1.67	4	143.80	169.29	37.66
	1.50	6	158.38	182.45	55.76
	1.45	8	163.01	185.53	52.87

[a] Mass: sample mass in mg

[b] Heating conditions: non-isothermal in °C min^{-1} for the DSC test

[c] Onset temperature of the exothermic reaction of the DSC non-isothermal test in °C

[d] Peak temperature of the exothermic reaction of the DSC non-isothermal test in °C

[e] Enthalpy of the exothermic reaction determined by the DSC test in kJ kg^{-1}

than 300 °C of the endothermic reaction, so we did not do further research in this study.

Figure 2 shows that the original camellia oil (non-refined) did not have good thermal properties. In addition, DSC was used with four scanning rates (2, 4, 6, and 8 °C min^{-1}) to analyze the original camellia oil and compare the exothermic reaction characteristics. The peak temperature is also influenced by the scanning rate. The DSC thermal curves of the original camellia oil show a delay in the peak temperature. The greater scanning rates (6 and 8 °C min^{-1}) may lead to a wide DSC thermal curve, neglecting the slight exothermic reaction differences. Therefore, when analyzing the original camellia oil for thermal and irradiation (pulsed light) stability, we added additives to compare the differences in the DSC tests and found better conditions at the lower scanning rate. Thus, we selected a scanning rate of 4 °C min^{-1} as a follow-up to pulsed light irradiation to determine its effects on camellia oil-related research.

The effect of additive mixed in camellia oil with pulsed light irradiation

Camellia oil was either not irradiated (control) or irradiated with pulsed light with doses of 0, 30, and 60 pulses at ambient temperature. Table 5 and Figs. 3–7 show original camellia oil and that with additive (0.1 mass% vitamin E, 1 mass% PC extract, 3 mass% PC extract, and 5 mass% PC extract) for comparing the differences with various doses of pulsed light irradiation (0, 30, and 60 pulses) by DSC tests. Moreover, comparing Tables 1 and 2, we confirmed that after pulsed light irradiation, the quality of the oil was indeed affected, and as the irradiation dose increased, the onset temperature was pushed to a lower temperature.

Table 5 shows the results of mixing 0.1 mass% vitamin E additive in camellia oil with various doses of pulsed light irradiation (0, 30, and 60 pulses), and the results indicate that for 0.1 mass% vitamin E compared with the original oil, the onset temperature was promoted from 143 to

Table 5 Results of DSC tests on camellia oil and different antioxidant additives after pulsed light irradiation

Sample	Pulsed light/ pulses	Mass[a]	$ExoT_o^b$	$ExoT_p^c$	$Exo\Delta H^d$
Original camellia oil	0	1.67	143.80	169.29	37.66
	30	1.67	140.09	169.50	42.18
	60	1.63	140.75	170.30	42.13
Camellia oil + 0.1% vit E	0	1.71	153.70	174.46	33.82
	30	1.67	161.10	181.43	37.58
	60	1.63	163.61	179.10	33.50
Camellia oil + 1.0% PC extract	0	1.70	146.56	172.77	49.29
	30	1.66	141.36	168.81	43.54
	60	1.30	137.87	161.86	53.06
Camellia oil + 3.0% PC extract	0	1.86	N/A	N/A	N/A
	30	1.60	N/A	N/A	N/A
	60	1.50	140.91	162.84	43.36
Camellia oil + 5.0% PC extract	0	1.53	135.01	162.73	52.15
	30	1.67	133.58	177.55	22.76
	60	1.49	142.85	170.30	60.43

[a] Mass: sample mass in mg

[b] Onset temperature of the exothermic reaction of the DSC non-isothermal test in °C

[c] Peak temperature of the exothermic reaction of the DSC non-isothermal test in °C

[d] Enthalpy of the exothermic reaction as determined by the DSC test in kJ kg^{-1}

153 °C, indicating good antiphotodegradation characteristics. Table 5 and Fig. 6 show the 3 mass% PC extract additive mixed in oil under lower doses of pulsed light irradiation, such as 0 and 30 pulses, and this mixture exhibited excellent antiphotodegradation characteristics, which were better than those of 0.1 mass% vitamin E. In addition, Table 5 and Fig. 6 show that for 3 mass% PC extract additive mixed in oil under a lower dose of pulsed light irradiation, in the DSC tests for the range of temperatures from 30 to 300 °C, we did not see any exothermic reaction. This is probably because the PC extract contains ergothioneine, which has good UV resistance and is often added to cosmetics as a sunscreen agent or antioxidant [39].

Oxidation stability measurement results

TAM Air isothermal analysis was set up at 60.5 °C, the temperature at which the liquid chemicals of gasoline, diesel, and volatile organic solvents emit sufficient flammable vapor to bring the concentration of the flammable vapor in the head space above the liquid to the lower flammable limit. Thus, this temperature is usually adopted to classify liquid chemicals, such as gasoline, diesel, and volatile organic solvents, for the purpose of assessing their fire and explosion hazards, and a liquid chemical with a flash point below 60.5 °C is defined as a flammable liquid

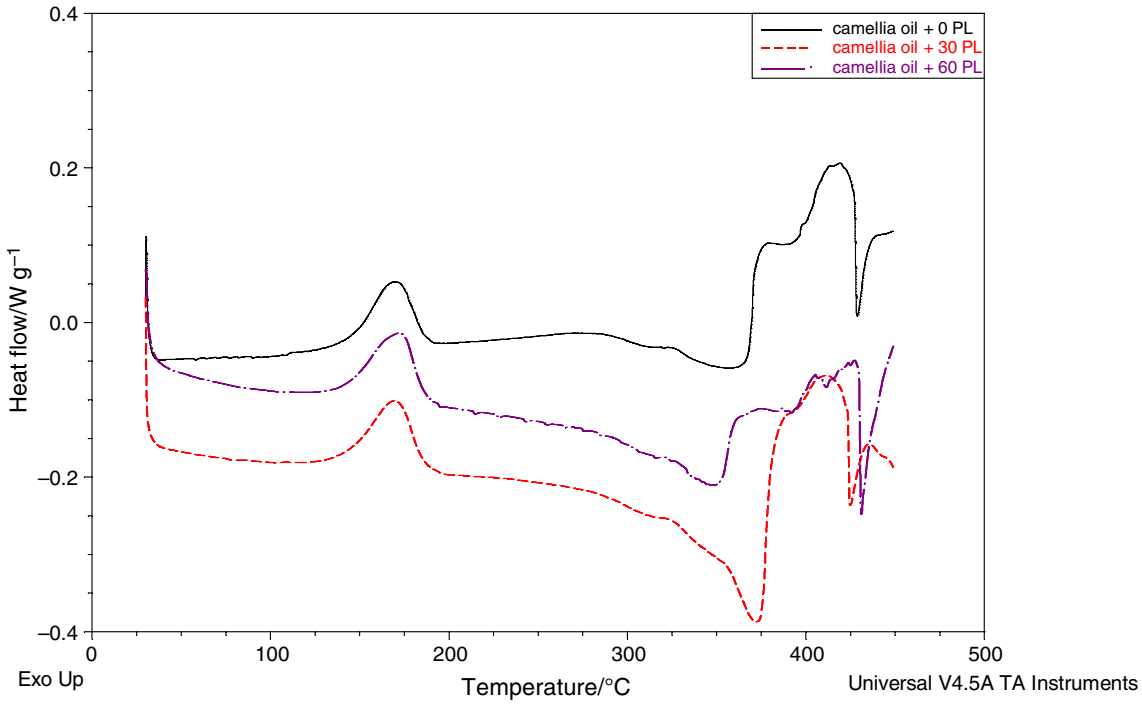

Fig. 3 DSC thermal curves of heat flow versus temperature for the camellia oil after pulsed light irradiation

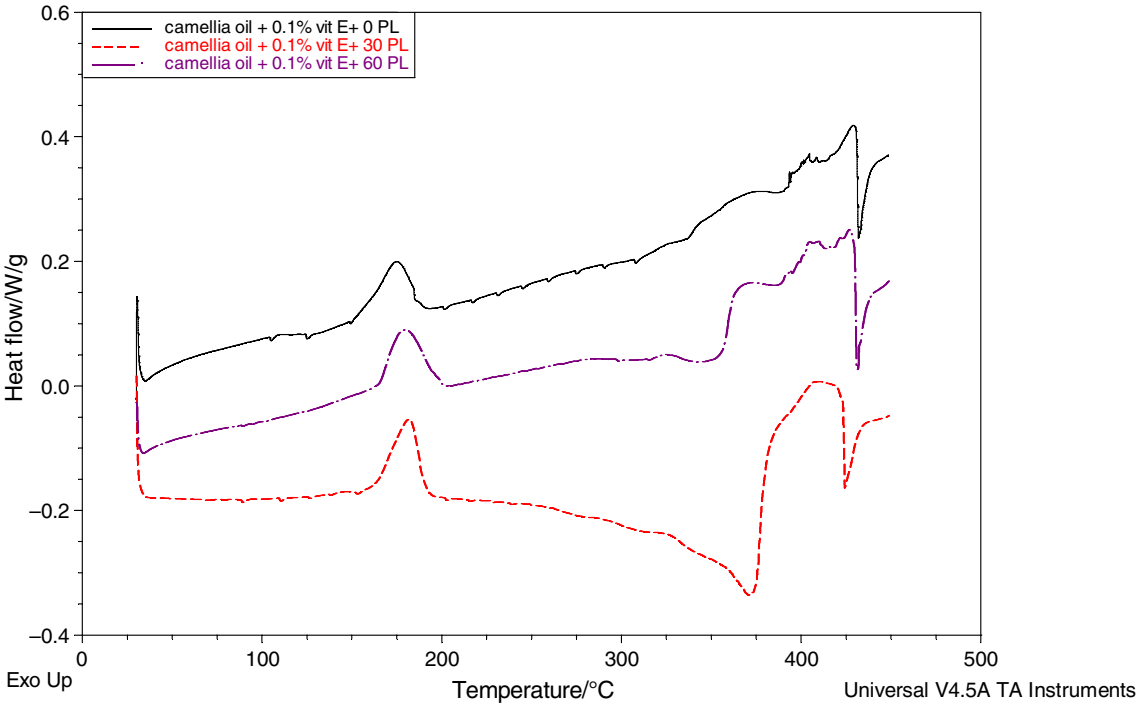

Fig. 4 DSC thermal curves of heat flow versus temperature for the 0.1 mass% vitamin E mixed with camellia oil after pulsed light irradiation

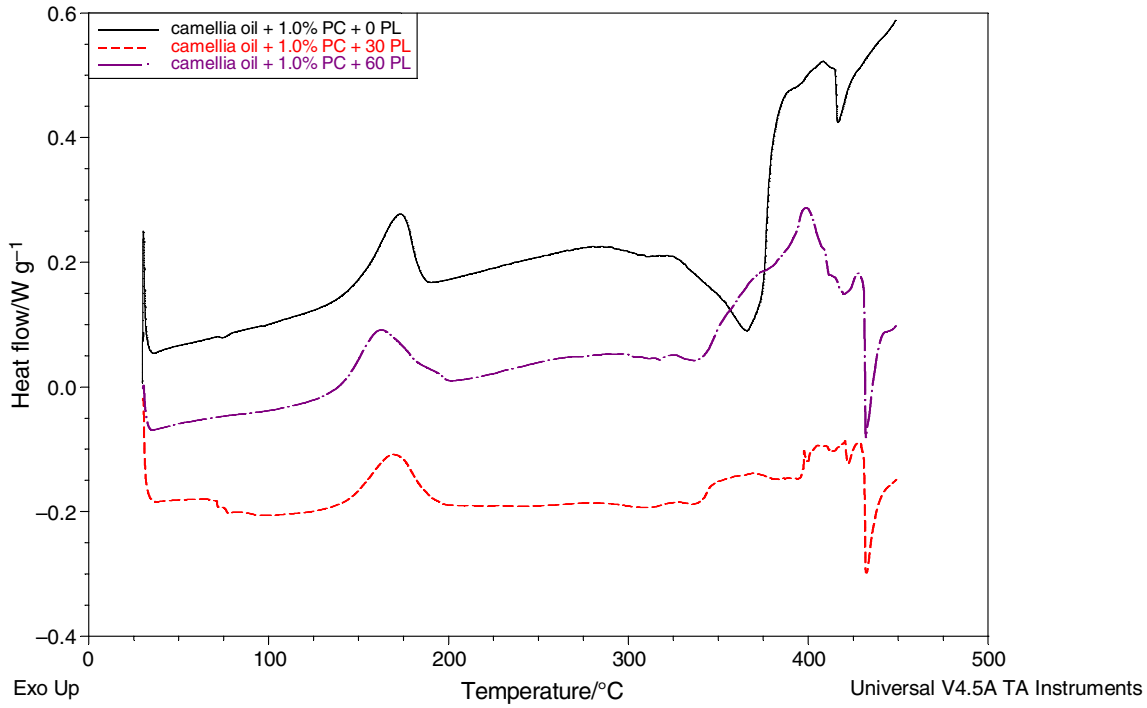

Fig. 5 DSC thermal curves of heat flow versus temperature for the 1 mass% PC extract mixed with camellia oil after pulsed light irradiation

by the US Department of Transportation (DOT 49 CFR 173.120), requiring special protective procedures to be implemented while storing or transporting it [40].

The results for the TAM Air measurement under a high isothermal temperature of 60.5 °C in different atmospheres of air, nitrogen, and oxygen for various additives mixed in

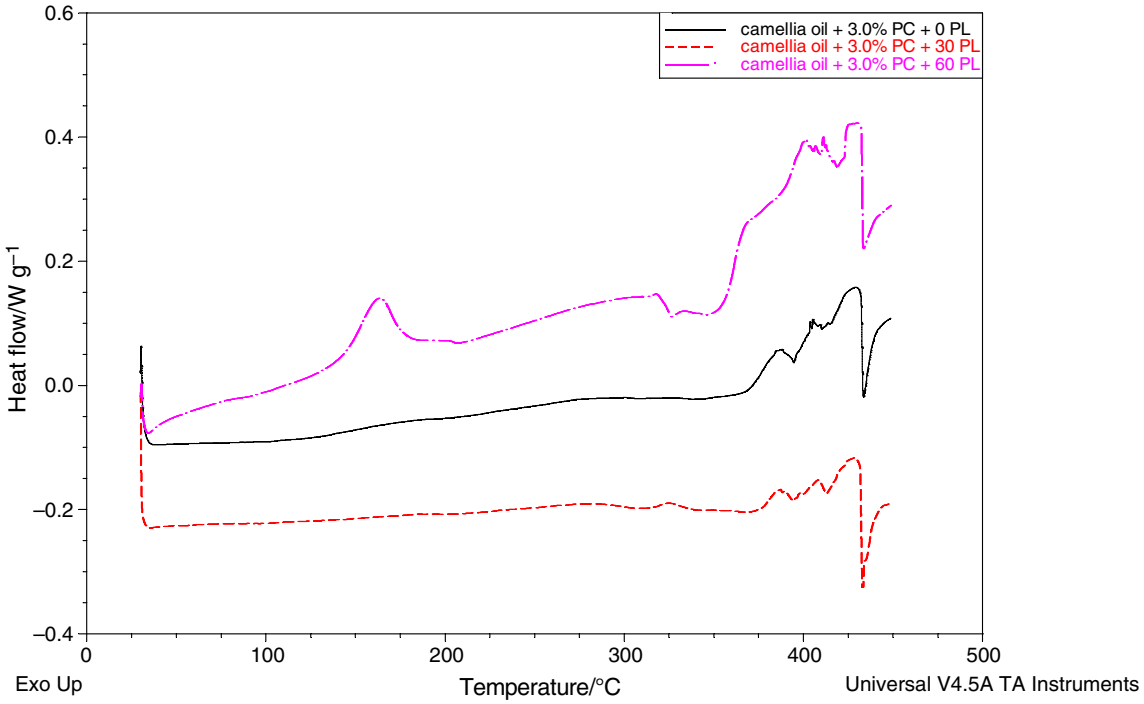

Fig. 6 DSC thermal curves of heat flow versus temperature for the 3 mass% PC extract mixed with camellia oil after pulsed light irradiation

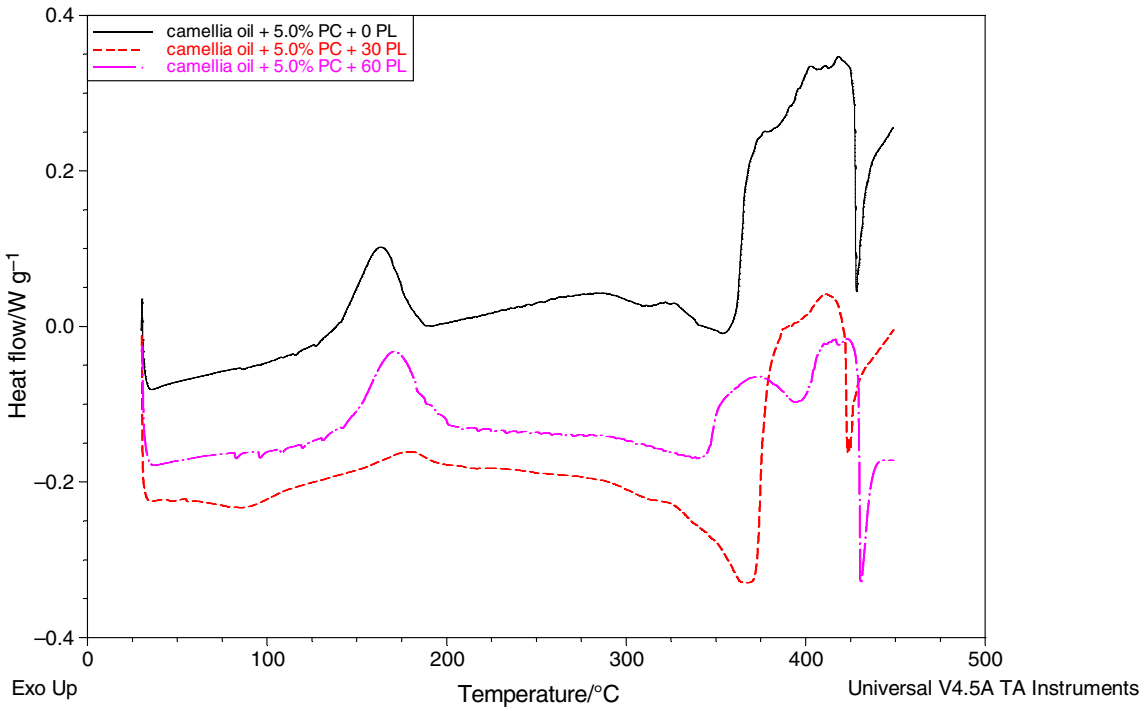

Fig. 7 DSC thermal curves of heat flow versus temperature for the 5 mass% PC extract mixed with camellia oil after pulsed light irradiation

original camellia oil were obtained, and then, we determined the oxidation stability of the oil. Figures 8–10 show that all of the samples under a nitrogen atmosphere have good stability, but under air and oxygen atmospheric conditions, a significant exothermic peak appears. Comparing the original camellia oil under air, nitrogen, and oxygen atmospheric conditions in Table 6, we found that under an oxygen atmosphere, the oil stability was destroyed more than in air or nitrogen, which showed that when the oil was exposed to air and oxygen, the oxygen oxidized the oil.

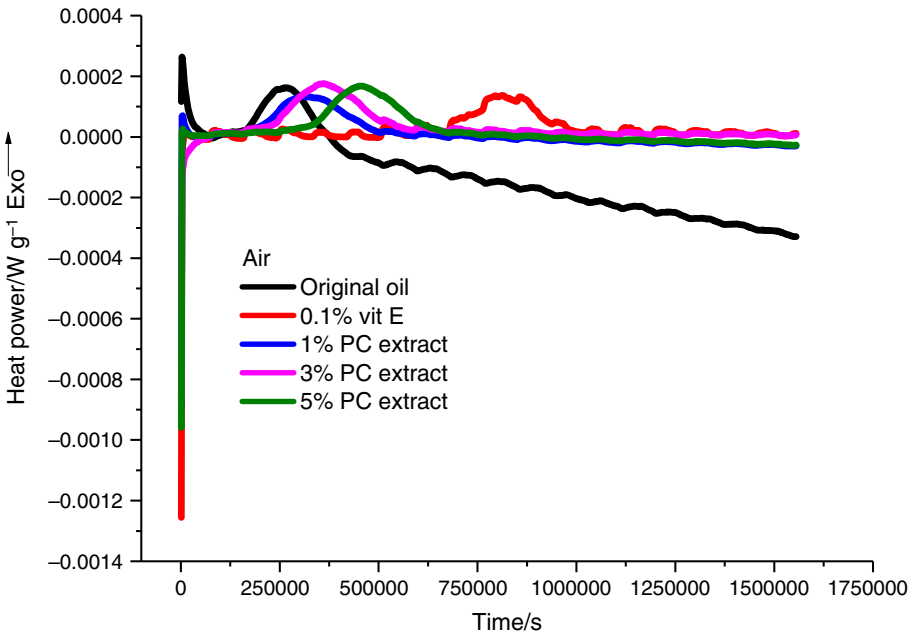

Fig. 8 Results of the TAM Air calorimeter tests for all samples under an air atmosphere

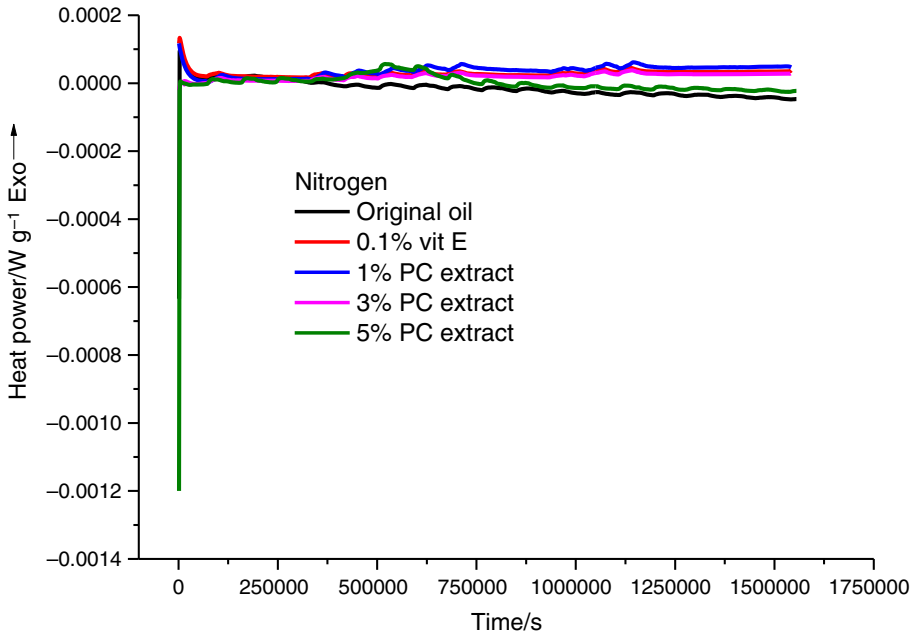

Fig. 9 Results of the TAM Air calorimeter tests for all samples under a nitrogen atmosphere

In addition, the oxidation stability measurement results in Table 6 and Figs. 8 and 10 show that the original camellia oil and that with additive (0.1 mass% vitamin E, 1 mass% PC extract, 3 mass% PC extract, and 5 mass% PC extract) indicate the differences in TAM analyses under air and oxygen atmospheres. This table and these figures also indicate that increasing PC extract doses increases the thermal and oxidation stabilities (the stabilities for 1, 3, and 5 mass% PC extract were 1725, 2375, and 2450 min and 2500, 2450, and 2500 min under air and oxygen atmospheres, respectively). Moreover, comparing Figs. 8 and 10, we confirmed that for 0.1 mass% vitamin E compared with the original oil, the onset time was raised from 1275 to 8325 min and from 1100 to 9625 min under air and oxygen atmospheres, respectively, which showed the outstanding antioxidation characteristics under a high isothermal temperature. In addition, Table 6 and Figs. 8 and 10 show that when the PC extract was added into the

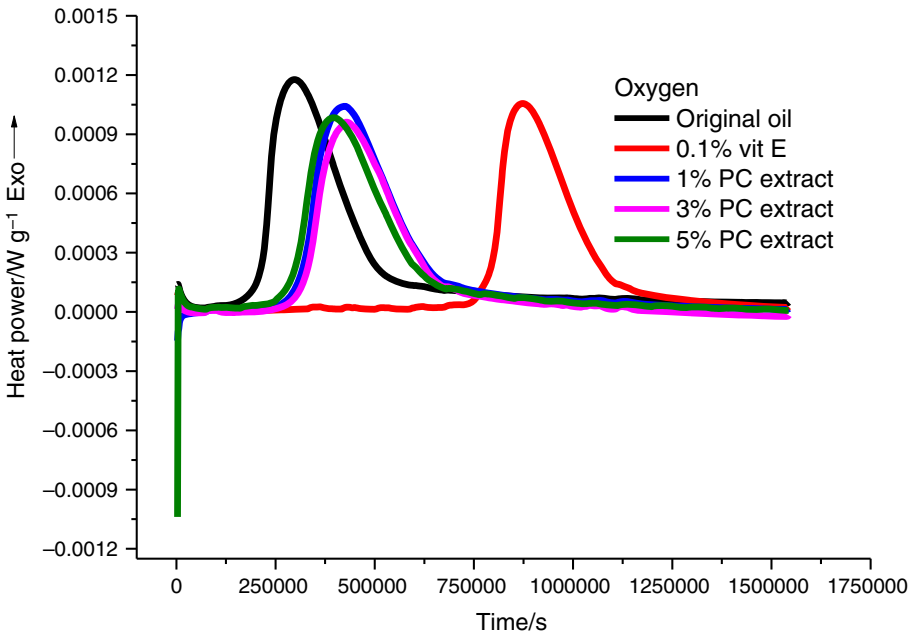

Fig. 10 Results of the TAM Air calorimeter tests for all samples under an oxygen atmosphere

Table 6 Results of the TAM Air calorimeter tests for all samples under different atmospheric conditions

Sample	Atmosphere	Additive	Mass[a]	T_0^b	T_p^d	ΔH^d
Camellia oil	Air	Original	1.05	1275	10,000	35.80
		0.1% vit E	1.07	8325	21,300	31.82
		1.0% PC	1.25	1725	14,250	31.66
		3.0% PC	1.06	2375	16,925	37.16
		5.0% PC	1.02	2450	21,325	39.05
	Nitrogen	Original	1.04	N/A	N/A	N/A
		0.1% vit E	1.00	N/A	N/A	N/A
		1.0% PC	1.04	N/A	N/A	N/A
		3.0% PC	1.02	N/A	N/A	N/A
		5.0% PC	1.06	N/A	N/A	N/A
	Oxygen	Original	1.00	1100	21,275	255.44
		0.1% vit E	1.00	9625	25,650	218.43
		1.0% PC	1.03	2500	23,850	257.55
		3.0% PC	1.06	2450	24,975	243.37
		5.0% PC	1.03	2500	24,675	235.81

[a] Mass: sample mass in ampoule in g

[b] Time to onset temperature of the exothermic reaction as determined by the TAM Air isothermal test in min

[c] Time to the peak maximum heat flow of the exothermic reaction as determined by the TAM Air isothermal test in min

[d] Enthalpy of the exothermic reaction as determined by the TAM Air test in kJ kg^{-1}

oil, it presented an antioxidant effect, but this effect was not as good as the effect of vitamin E. Then, by using the DSC and TAM Air calorimeters, we compared the thermal, oxidation, and antioxidant effects as well as irradiation (pulsed light) stabilities of the original oil and that with additives, which could establish the suitable conditions to stabilize camellia oil as follows: addition of vitamin E, addition of 3 mass% PC extract, and nitrogen atmosphere.

Conclusions

To evaluate the effects of *Pleurotus citrinopileatus* extract and vitamin E on the stabilization properties of *Camellia tenuifolia* seed oil, we developed a novel approach for adding natural, healthy, and physiologically active natural antioxidants to elucidate the degradation, including evaluating the thermal stability, stability after strong light

exposure, and antioxidation properties of the original camellia oil to determine proper storage and stabilization conditions. We compared the effects of stabilization additives vitamin E and various PC extract doses by using pulsed light irradiation (0 and 30 pulses) and found that the 3 mass% PC extract had the best antiphotodegradation characteristics among all of the additives used in this study. In addition, the significant results of the oxidation stability measurements indicated that for the 0.1 mass% vitamin E additive compared with the original oil, the onset time of degradation was raised from 1275 to 8325 min and from 1100 to 9625 min under air and oxygen atmospheres, respectively, which showed the superior antioxidation characteristics of all of the additives under high isothermal temperatures. Overall, by conducting tests with the DSC and TAM Air calorimeters, we obtained the following suitable conditions to stabilize camellia oil: addition of vitamin E, addition of 3 mass% PC extract, and a nitrogen atmosphere. This study is a forward-looking and innovative research project on the effects of functional ingredients of *Pleurotus citrinopileatus* on improving food oil processing and storage conditions. In the future, our goal is to improve the processing technology for healthy foods and improve the use of functional ingredients in the food safety and food processing areas.

Acknowledgements We are indebted to Asia University and China Medical University in Taiwan under contract number ASIA-105-CMUH-08 for financial support. In addition, the authors are indebted to SD Biotech Inc. in Taiwan for technical support on the pulsed light experiments.

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