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Effects of Roasting *Camellia tenuifolia* Seeds with/without Shells on the Quality of Seed Oil

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Abstract

Hsieh, C. M., J. C. Yang, D. S. Chen, Y. C. Chuang, E. I. C. Wang, and Y. L. Lee. 2014. Effects of Roasting *Camellia tenuifolia* Seeds with/without Shells on the Quality of Seed Oil. J. Taiwan Agric. Res. 63(1):17–29.

Camellia tenuifolia is an indigenous camellia oil tree species native to Taiwan. Its fruit is smaller in size than the big-fruit species *C. oleifera*. With a lower annual oil yield and healthful ingredients to human body, the *C. tenuifolia* seeds oil has been considered a valuable oil to Taiwanese folklore. Generally the seeds of camellia species have a hard shell, while the shell of *C. oleifera* seeds is easy to make crack because of the bigger gaps between shell and seed kernel. Their seeds are also more uniform in size and the shells are easier to be removed. When processing for oil, *C. oleifera* seeds are usually shelled before pressing. On the other hand, seeds of *C. tenuifolia* have a variety of seed sizes and tough shell, with smaller gaps between shell and seed kernel. Thus, its seeds are more difficult to remove shell and hence, frequently *C. tenuifolia* seeds are directly pressed for oil without shelling. In this study, seeds of *C. tenuifolia* with or without shell were treated under different roasting conditions, from 110 to 130℃ for 5 to 10 min, and then were pressed for seed oil. Physico-chemical characteristics of the seed oils, including oil yield and stability index, acid value, peroxide value, smoke point, phenol content and reducing power, were analyzed. Results indicated that shelled seeds produced 13% more oil than that with shell on. All tested oils had acid value less than 1.0, peroxide value less than 10.0, and smoke point greater than 200℃. Results suggest that with or without the shell, the pressed oils all reached the food standard of general pressed oils. Regardless of with or without the shell, along with the increasing intensity of roasting, the phenol content and reducing power also increased. At suitable roasting treatment conditions, the oil quality will be better and oil be more stable during storage.

Key words: *Camellia tenuifolia* seed oil, Shell, Roasting, Oil quality, Oil oxidative stability.

INTRODUCTION

Consumption of oleic acid has been proven to reduce the risks of cardiovascular diseases (Kris-Etherton 1999; Sales-Campos *et al*. 2013). Tea oil camellia seed oil (also known as camellia oil) has high content (up to or even > 80%) of oleic acid (Zhong *et al*. 2007) and thus is also called "the oriental olive oil". In Chinese families, camellia oil is a culinary oil with a history over two thousand years. In sixteen century Shizhen Li (1518–1593 AD) touted the oil's functions and wrote in his re-

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nowned ancient book “Compendium of Materia Medica”. It has deeply influenced in the Chinese culture since then, and many therapeutic remedies involve the camellia oil.

Modern scientific research has also proved the oil’s functions, including the reduction of oxidation, inflammation, hyperlipidemia and the occurrence of neoplasm, the protection of heart and liver, and the improvement in immune system (Li *et al*. 2011). Moreover, camellia oil is frequently incorporated in varied folk medicinal prescriptions. In response to the functions of camellia oil carried down from ancestors, some researchers have focused on its ingredients to identify or explain these functional mechanisms. They found tea polyphenols and tea saponins are unique to camellia oil (Li *et al*. 2011). Additionally, two lignans (one is sesamin) found in the *Camellia oleifera* oil were identified to possess good anti-oxidation activities (Lee & Yen 2006). These studies are mere beginnings. Many remediation formulae have been validated through food incorporated with camellia oil to provide said functions and health benefits. Thus, this is still a domain urgently awaits further investigation. These functions include mitigation of gastroesophageal reflux, stomach ulcer, asthma, blood sugar, cough, skin health, anemia, constipation, blood circulation, and tonic for postnatal delivery.

There are many varieties of camellia oil trees in mainland China, and most of them belong to species *C. oleifera*, which bear bigger fruits compared to an indigenous species *C. tenuifolia* of Taiwan, mainly distributed in broadleaf forests of the north, with a comparatively lower annual yield. The oil value from *C. tenuifolia* is sold at a substantially higher price than those from *C. oleifera*. One reason is the low yield of seeds from *C. tenuifolia* and the other is its higher bioactivity being claimed. For maintaining the claimed functions, pressed oil without refinement is the main products on Taiwan’s market. In Taiwan, most camellia oil trees are cultivated in organic management with no pesticides and chemical fertilizers, only few cases using a small amount of natural fertilizers, in order to meet the regulation of organic farming and to obtain high quality oil products.

The commonly seen camellia oils in Taiwan marketplace are pressed from *C. oleifera* seeds. Fruit of the species has a diameter of ca. 3–5 cm, holding 2 to 8 seeds inside, and the seeds are 1–1.5 cm in diameter. The indigenous *C. tenuifolia* has smaller fruit sizes of ca. 1–3 cm in diameter, with thinner pericarp, and each fruit holds 1 to 3 seeds. The diameter of the seeds is ca. 0.5–2 cm. The seeds of oil camellia have a hard outer shell, which accounts for ca. 20% of dry seed weight. After oil camellia fruit are collected and dried (either by sun or under shade), seeds separate from the fruit shell; when the moisture content reduced down to about 5%, the seed kernels will separate from the seed pericarp. For *C. oleifera*, the interstices among kernel and shell are about 1–3 mm; whereas, those for *C. tenuiflora* are 0.5–2 mm with a tougher shell texture. In Taiwan, the commonly deployed shelling devices for oil seed camellia contain two rollers with adjustable gaps. By adjusting the gap distance to slightly smaller than the seed sizes and the rollers are activated after the seeds are poured in, the rolling action causes the shell to crack and separate from the kernel. Due to the more uniform seed size and larger gap between kernel and the shell, seeds of *C. oleifera* can be cracked easier and achieved 80% shelling rates after 2 passes in the usual shelling operations by commercial operators. However, seeds of *C. tenuifolia* often vary in sizes, having tight gap between kernel and the shell. Therefore, it will cause damages to the surface of larger kernels or even crack them due to the smaller roller gaps. In contrast, a larger roller gaps would shell the smaller seeds ineffectively. As a result, producers of *C. tenuifolia* oil in Taiwan may either remove the seed shells before processing or retain them when pressing for oil.

In this study, seeds of *C. tenuifolia* have been sorted according to sizes and proceeded

to shell to ensure be 100% shelled by inspection. Two streams of seeds with or without shell were roasted under 110 to 130℃ for 5 to 15 min. The treated seeds were cold-pressed to produce oil, and the quality and characteristics of the collected samples were then analyzed and compared.

MATERIALS AND METHODS

Camellia seeds and oil pressing process

The seeds of *C. tenuifolia* were harvested from trees growing in northern Taiwan, dried at room temperature in a shade, and then removed capsule's pericarps. A coffee bean roaster (ET-2, Xiong-Bang Ltd., Taoyuan, Taiwan) was used to roast the kernels at temperatures of 110, 120 and 130℃ for 5, 10 or 15 min as in our previous study (Hsieh *et al*. 2013). The roasted kernels were practiced as a general manufacturing process commonly used in Taiwan. The yield was calculated by the weights of kernels with cake cloth subtracting the weights of oil cakes (with the cloth) after pressing and divided by the kernels' weight (%).

Acid value, peroxide value, and smoke point

Acid value (AV) was determined as that reported in the previous study (Hsieh *et al*. 2013) by an auto-titrator 785 DMP Trino (Metrohm, Switzerland) following the instructions of the instrument. The oil peroxide value (POV) was determined according to the AOCS Official Method 965.33, with an oil weight 2.50 g (a half of the standard method) as previously described (Hsieh *et al*. 2013). The oils were preserved at 4℃ for the analysis of AV and POV. In order to simulate a household oil storage condition, the oil bottles were opened and closed occasionally during the storage period. Smoke point was monitored by using 2–5 mL of oil on a hotplate (IKA C-MAG HS7 IKAMAG®, Staufen, Germany) when smoke rose from the oil surface during continuing heating.

Oil stability index

Oil stability index (OSI) assay is a method of evaluating oil stability. It is the time (hour) of an oil sample that achieves a maximum change in conductivity caused by oxidation at 110 or 130℃ (Lampert 1999). The increasing conductivity is resulted from the production of volatile organic compounds, such as ketones and aldehydes derived from oxidized fatty acids. The analytical method followed the method of the previous study (Hsieh *et al*. 2013). A Rancimat apparatus (873 Biodiesel Rancimat, Metrohm AG, Switzerland) was used: the OSI of each oil sample (3.00 g) was monitored at temperatures of 110, 120 or 130℃, under continuous aeration at 10 L h^{-1} air flow.

Total phenol content

The method of Singleton & Rossi (1965) was modified for the oil's total phenol analysis (Hsieh *et al*. 2013). Gallic acid (GA) (Sigma Co., USA) was used as a standard, dissolving in distilled water at concentrations of 0, 0.1, 0.2, 0.3, 0.4, and 0.5 mg mL^{-1}.

Reducing power

The analytical method developed by Oyaizu (1986) and modified by Hsieh *et al*. (2013) was used to analyze the pressed oil samples. Standard trolox prepared in methanol (0.08, 0.2, 0.4, 0.6, and 0.8 mM) was used to build a standard curve for quantification.

RESULTS

Production of cold pressed oils

Production of Camellia oil from roasting shelled and shell-on *C. tenuifolia* seeds at 110 to 130℃ for 5 to 15 min was listed in Table 1. The production of oil for kernels without the shell was 30.5 g ± 1.5 g oil per 100 g, which was about twice the production of shell-on seeds (14.0 g ± 2.1 g oil per 100 g). Because shell weights were about 20% of seeds, after deducting the weights of the shells, the net pro-

duction of shell-on seeds increased to 17.6 g ± 2.6 g oil per 100 g (deduced by calculation, shown in the parentheses in Table 1). Apparently, oil production of the shell-on seeds was about one-half of that of kernels without the shells. Comparing the effects of different roasting conditions on oil production, the production tended to slightly decrease with increasing roasting intensities [The black bars show the results for shell-on seeds; white bars for shelled seeds; and gray bars represent for the deduced quantity (Fig. 1)]. When comparing seeds of the most intensive roasting treatment (at 130℃ for 15 min) with the non-treated seeds, the shell-on seeds showed a difference in oil production by 7.8% based on the net kernel weights. For the shelled seeds, the production difference was 3.7%. Again, it indicated that there was a two-fold difference in whether shells remained or shelled.

Acid value of oils

Acid value (AV) is the amount of free fatty acid per 1 g of oil that can be neutralized by KOH (in mg). The higher the values, the greater the degree of triacylglycerols become hydrolyzed. Thus, the acid value represents an inverse indication of the oil quality. AV-1 represents the acid values of the freshly-pressed oils and AV-2 represents the acid values of oils stored at 4℃ for 1.5 year (Fig. 2). The AV-1 of shell-on roasted treatments had acid values

Table 1. Comparison of oil production and quality of *Camellia tenuifolia* seeds pressed with and without shells.

AVG ± SD[z]	Shell	No Shell
Production	14.00 ± 2.10 (17.60 ± 2.60)[y]	30.50 ± 1.50
AV-1	0.81 ± 0.12	0.64 ± 0.11
POV-1	4.99 ± 2.49	3.34 ± 1.36
POV-2	5.73 ± 3.01	3.22 ± 1.13
SP	216.8 ± 7.40	211.40 ± 5.40

[z] Average ± standard deviation. Data calculated from all oil samples, including non-roasted and roasted. Units: Production, g oil per 100 g kernels; AV-1, acid value, mg KOH g^{-1} oil; POV, peroxide value, meq peroxide kg^{-1} oil; -1 and -2 representing a two-month-gap determinations between them stored at 4℃; and SP, smoke point, ℃.
[y] Data in the parentheses is the net production of shell-on seeds, deducting 20% shell weights from the raw material weights.

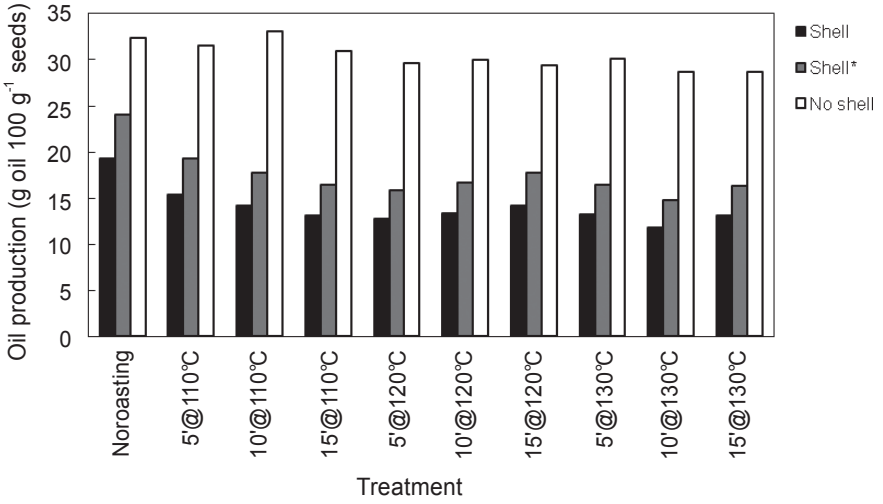

Fig. 1. Oil production of *Camellia tenuifolia* seeds pressed with and without shells treated by different roasting conditions. Shell*, values are deduced from the sample's weight after deducting 20% shell weights.

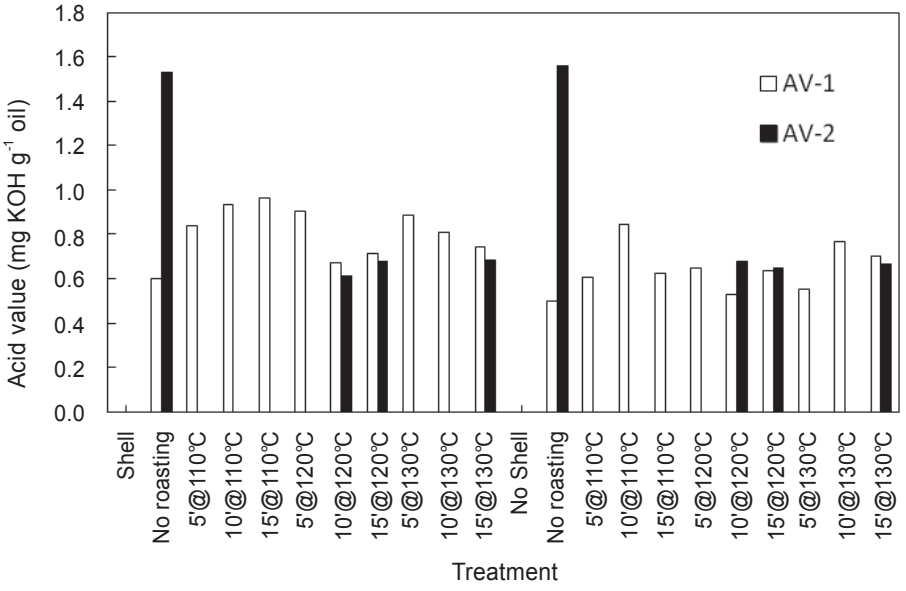

Fig. 2. Acid values (AVs) of pressed camellia oils with and without shells treated by different roasting conditions. AV-2 data were analyzed after 1.5 year cold storage at 4℃; AV-1 data were determined at time of oil pressing.

between 0.60–0.96; those without shells had acid values between 0.50–0.85. The lowest acid value was found in the oil from unroasted seeds with respective acid values of 0.50 and 0.60 for shelled and shell-on seeds. The average acid values of these 2 groups were 0.64 ± 0.11 and 0.81 ± 0.12, respectively (Table 1). Thus, the results indicated that shelled seeds produced oils of better quality than those pressed with shell-on.

Comparing the different roasting conditions, all oils had acid values < 1.0, indicating good quality; with increasing intensity of roasting, values of AV changed in an M-shaped curve. For both with- and without-shell seeds, the optimal roasting condition was at 120℃ for 10 min, where the respective AV values were 0.67 and 0.53. The oils of better AV-1 seeds including those roasted at 120℃ for 10 and 15 min and those roasted at 130℃ for 15 min were stored at 4℃ for 1.5 year and their AV values were also determined (AV-2, Fig. 2). Results indicated that oil AV values were increased greatly in the unroasted seeds (> 2 times the fresh oils), while values for the with- and without-shell oils were similar as the fresh oils.

Analysis of peroxide value of oils

The peroxide value (POV) of oil is the amount of peroxide substances expressed as milli-equivalent (meq peroxide) in 1 kg of oil. The higher the oil POVs, the greater the degrees of oxidation and the oil quality get worse. In this study, the average POV-1 values for seed oils of *C. tenuifolia* from with- and without-shell seeds were 4.99 ± 2.49 and 3.34 ± 1.36, respectively. After storing at 4℃ for 2 mo., the POV-2 values became 5.73 ± 3.01 and 3.22 ± 1.13, respectively (Table 1). Results indicated that seeds without the shell produced oils of better quality than that of shell-on oils. After 2 mo. of cold storage, the POV values of the shelled did not change, whereas the shell-on pressed oils had an average increase of 0.74. The effects of roasting conditions on the oil POVs were graphed in Fig. 3. Oils from seeds without the shell generally had POVs decreased with increasing intensity of roasting. The value of POV-1 decreased from 5.6 to 2.1 and the value of POV-2 maintained similar extent after 2 mo. of storage. The oils from

shell-on seeds with lower roasting intensity, however, tended to have higher POVs than the unroasted seeds (4.0). For those roasted at the conditions between 110℃ (5–15 min) and 120℃ for 5 min, the POVs reached 7.0–8.0, while those shell-on seeds treated with higher roasting intensity (120℃ for 15 min and treatments at 130℃) produced oils of POVs < 3.0, less than the unroasted shell-on samples. The highest roasting intensity of 130℃ for 15 min produced oil with POV for only 1.9. It is worth noting that seeds roasted at 120℃ for 10 min up to 130℃ for 15 min showed no apparent changes in POVs during 2 mo. of cold storage. For all oil samples cold-stored for 1 year, their POV-3 values increased to tow-fold of the original ones (Fig. 3), indicating that peroxide gradually accumulates in all samples. The oils from more-intense roasting treatments appeared to accrue peroxide species at slower paces than those unroasted or low-intensity roasting and thus had lower overall POVs. After 1 year of cold storage, the seeds treated at 130℃ for 15 min had POVs of 4.11 and 4.96 for seeds with and without the shell, respectively.

Smoke point of oils

At high temperatures, oil or fat will produce bluish hazy smoke because breakups of triglycerides. The specific temperature at which smokes first appear is called smoke point. Generally, the more stable the oil, the higher the smoke point. For unroasted seeds both with- or without-shell, the smoke point was identical, at 207℃ . After roasting at different conditions, the with- and without-shell oils had average smoke points of 216.8℃ ± 7.4℃ and 211.4℃ ± 5.4℃ , respectively (Table 1); all smoke points were greater than 200℃ (Fig. 4). The with-shell seeds along with increasing intensity of roasting would produce oils with increased smoke points up to 228.0℃ (at roasting condition of 130℃ for 10 min). However, at the treatment of 130℃ for 15 min, smoke point decreased to 206.1℃ . For the without-shell seeds along with the increasing roasting intensity, the smoke points of oils first increased and then decreased. The highest smoke point of 219.3℃ was observed for seeds roasted at 120℃ for 5 min.

Indices of oxidative stability of oils

Analysis of oil oxidative stability provides important reference to keeping or storing

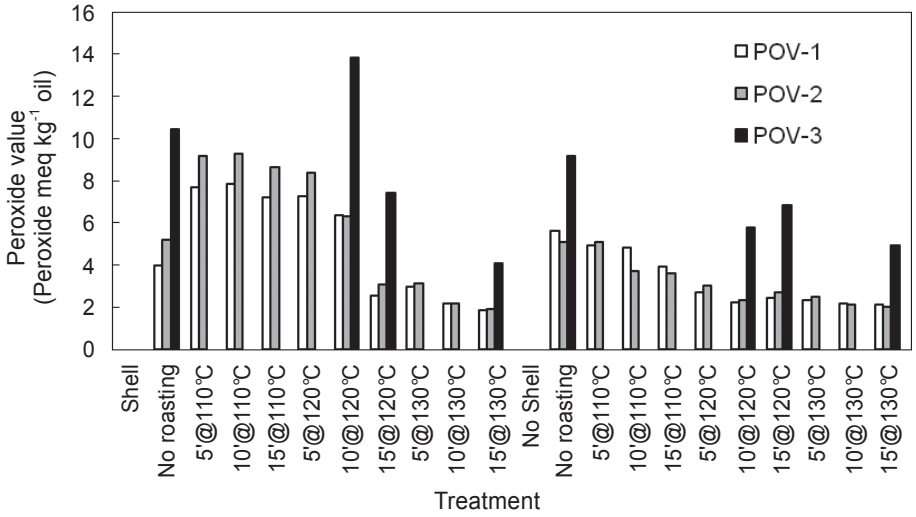

Fig. 3. Peroxide values (POVs) of pressed camellia oils with and without shells treated by different roasting conditions. POV-2 and POV-3 were determined with the oil samples stored at 4℃ for 2 mo. and 1 year, respectively, after the analysis of POV-1.

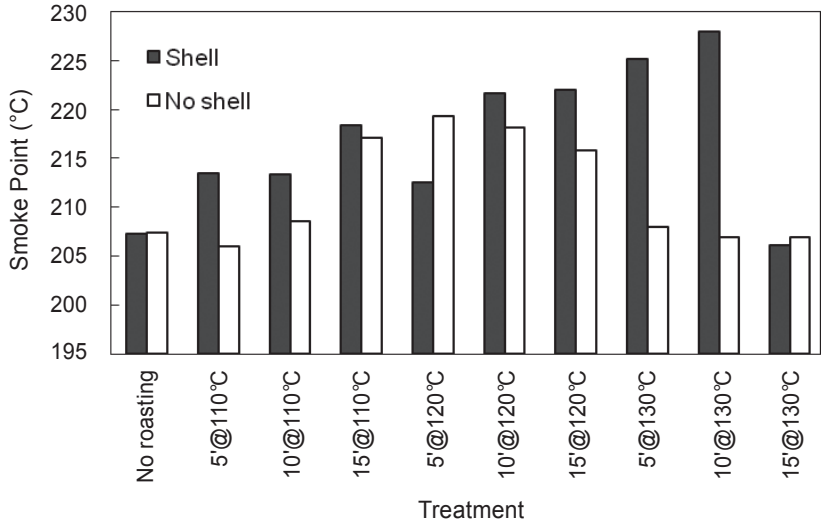

Fig. 4. Smoke points (SPs) of pressed camellia oils with and without shells treated by different roasting conditions, at 110, 120 or 130℃ for different times.

quality oil. By the Rancimat method for analysis, in which 10 L h^{-1} of air is fed to oil sample maintained at 110, 120, or 130℃ to facilitate oil oxidation, and the oil stability index (OSI) is then measured. The index points were determined at the time of rapid oxidative degradation of oils and hence, the oxidative stabilities of different samples were compared in parallel. As shown in Fig. 5, the values of OSI in seeds of *C. tenuifolia* with- or without-shell varied to the intensity of roasting. The OSI of the pressed oils indicated that for each 10℃ temperature increment, values of OSI changed about halved. The OSI of oils from with-shell seeds had lower values than those from without-shell seeds. The OSI of the unroasted and those roasted at 130℃ appeared

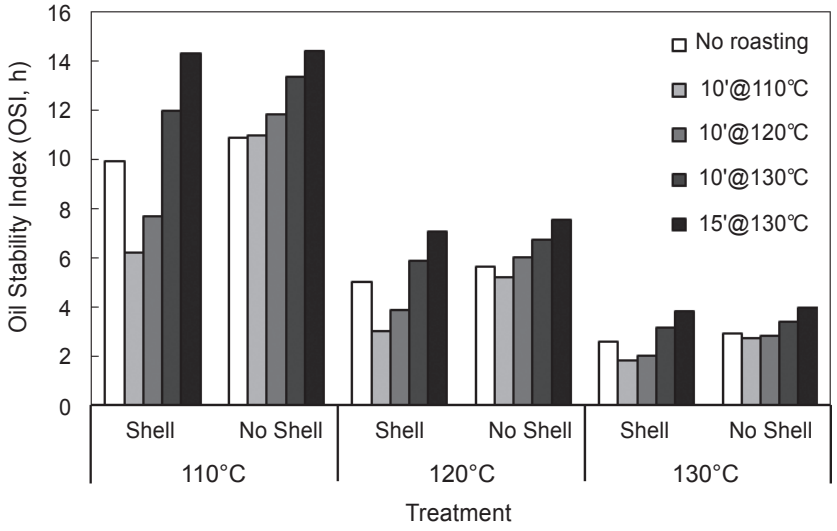

Fig. 5. Oil stability indices were determined with the pressed camellia oils, with and without the shell, treated by different roasting conditions, at 110, 120 or 130℃ for different times.

to be similar. The OSI values of the unroasted seeds at 110, 120, and 130℃ for the without-shell seed oils were higher than those of the with-shell seed oils with the differences of 0.96, 0.60 and 0.33 h, respectively. Comparisons of the results from different roasting conditions suggest that a positive correlation of OSI value exists in the without-shell oils with the roasting intensity, i.e., the higher the roasting temperature and longer the time and the higher the OSI value. Conversely, for the with-shell seeds roasted at lower intensities (110 or 120℃ for less than 10 min), the OSI values were significantly lower than the unroasted ones; whereas, when roasted at 130℃ for 10 or 15 min, the OSI values of the oils were higher than the unroasted ones. Regardless of with- or without-shell, the oils with the highest OSI values were roasted at the highest intensity (130℃ for 15 min). For the with-shell seed oils, OSI values were at 14.28, 7.04, and 3.80 h when tested respectively at 110, 120, and 130℃. To the without-shell seed oils, OSI values were at 14.41, 7.55, and 3.94 h for the same temperature series. The differences in OSI between the with- and without-shell seeds were 0.13, 0.51 and 0.14 h at 110, 120, and 130℃, respectively.

Phenol content and reducing power of oils

The phenol content of seed oils were shown in Fig. 6A. The content tended to increase with increasing roasting intensity, and there appeared to be no distinctive trend in difference of phenol content between the with- and without-shell seed oils. The highest phenol content was found in the most intense roasting conditions (130℃ for 15 min); the with- and without-shell seeds produced oils with 0.089 eq ± 0.004 eq and 0.078 eq ± 0.003 eq GA mg mL^{-1} oil, respectively. The oil reducing power analysis results are shown in Fig. 6B. Both the with- and without-shell seeds had reducing power increased with increasing roasting temperature. As shown, in addition to the similar results as unroasted treatments, the without-shell seeds had higher reducing power than the with-shell seeds. The highest values of oil reducing power were found from the highest roasting intensity treatments (130℃ for 15 min). The respective values for the with- and without-shell oils were 0.318 mM ± 0.010 mM and 0.353 mM ± 0.004 mM Trolox, respectively. Comparing the results shown in Fig. 6A and Fig. 6B, it is apparent that there was a positive correlation between oil phenol content and its reducing power.

DISCUSSION

This study mainly investigated the effects of roasting *C. tenuifolia* seeds with- or without-shell at different conditions on the resulting oil quality and properties. The primary components of the pericarp shell are lignin, pentosans, saponin and tannin, largely hydrophilic substances. It contains practically no oil (Yang 2009; Guo *et al*. 2010) and is of high water solubility. The fragments of shells would absorb oil resulting in a lower oil yield of shell-on seeds than that of shelled seeds. The main purpose of roasting treatment is to reduce moisture content in the kernels as well as to coalesce oil droplets at elevated temperature so that oil production improved. However, the procedure adopted in this study employs the roasting and then cooling down to room temperature before pressing step. Instead of increasing oil production, seed oil was slightly decreased by the process, the results similar to our earlier report (Hsieh *et al*. 2013). The plausible reason is that at room temperature, small quantities of more saturated fatty acids might coalesce with the substrate tissue or residues to decrease oil production. On the other hand, it is significant that the without-shell seeds produce 13–15% more oil, than those with-shell ones. In a report by Yang (2009), shelling treatment resulted in a gain of 30% oil than the shell-on seeds when solvent extraction was the method of oil production. Thus, seeds with- or without-shells will significantly affect oil production. Though pressing the shell-on seeds reduces the costs of labor and machinery, in

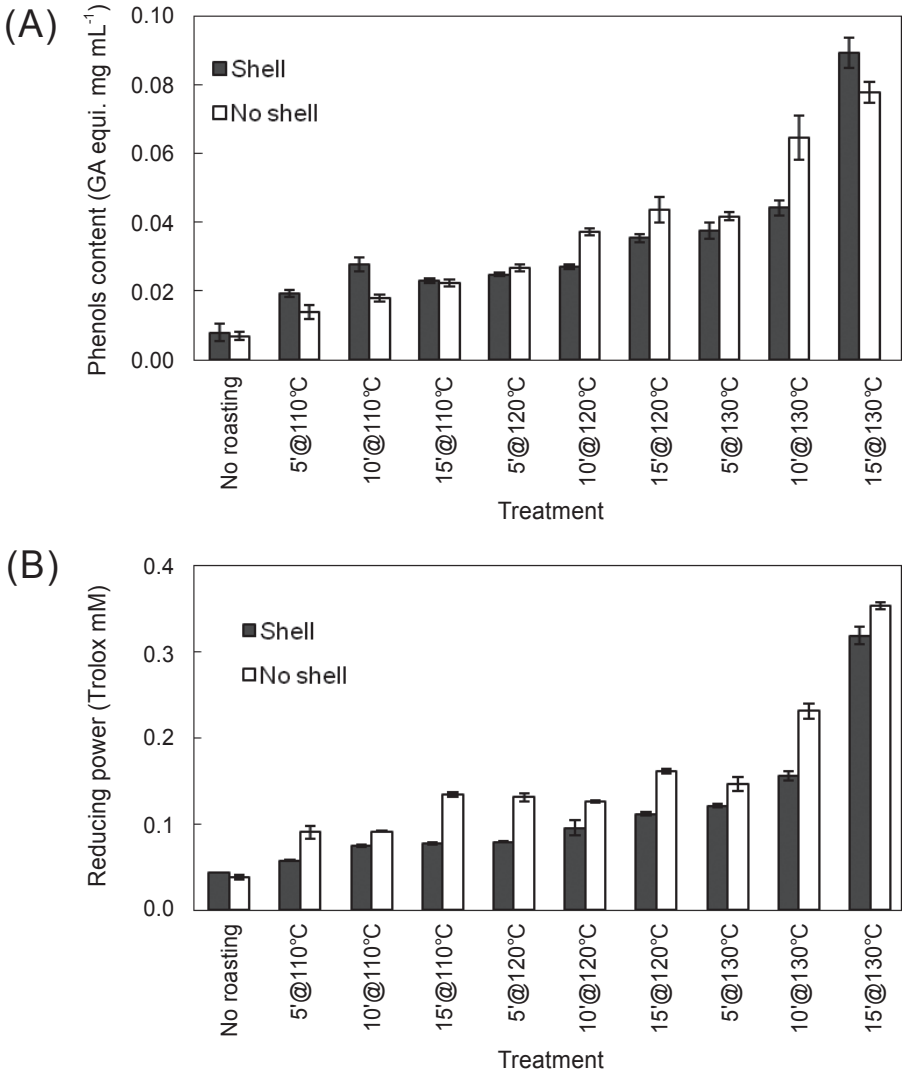

Fig. 6. Phenol content (A) and reducing powers (B) of pressed camellia oils with and without shells, respectively, treated by different roasting conditions, at 110,120 or 130℃ for different times.

any case, the principal consideration in using shell-on or shelled seed is oil quality, which is also the main purpose of this study. We investigated the effect of with- or without-shell on the characteristics of AV, POV, SP, and OSI of the resulting oils. In addition, the pressed seed oil from *C. tenuifolia* oil is well-known for its healthy nutrition facts and therapeutic effects (as some claim). Scientists are eager to analyze its active ingredients and quick functionalities. Shen *et al*. (2012) found that camellia oil contained certain lipophilic phenolic compounds which had antioxidant activities that might be related to the desired functionalities. Therefore, detecting phenol content in the oil becomes imperative, particularly by using Folin-Ciocalteu's reagent to analyze total phenols (Singleton *et al*. 1999). As a consequence, the reducing power with antioxidant capacity of seed oil was also analyzed using the reductive capability of ferricyanide ions to ferrocyanide ions (Oyaizu 1986). The results could serve as

a complement to the understanding of the anti-oxidative activity of camellia oil.

The AV and POV values of oils are the most important quality criteria of food oils. The AVs of all oil samples (freshly pressed) were less than 1.0. As the national standard for pressed camellia seed oils is wanting, and at present, the pressed peanut oils should have AV less than 2.0 and pressed sesame oils should be lower than 4.0. Comparatively, the quality of camellia seed oils obtained in this study was superior. Regardless of with- or without-shell seeds, the lowest AV value from freshly pressed oils (AV-1, Fig. 2) was from unroasted seeds (0.50–0.60); and for the roasted seeds, those treated at 120℃ for 10 to 15 min had better AVs (0.53–0.71). After cold storage at 4℃ for 1.5 year, AV values of the roasted oils did not increase; whereas, AVs of the unroasted oils increased significantly. The possible reasons will be discussed later in the text. As for POVs of the oils (Fig. 3), all samples had values less than 10. Again, there was no national standard for pressed camellia oils. In general, POV of pressed oils must be lower than 20. Therefore, the experimentally produced camellia oils were all had a good quality. Regardless whether the seeds were pressed with- or without-shell, all oil samples still maintained in a POV value less than 20 after 1 year of cold-storage at 4℃ . Moreover, the oils from highest-intensity roasted seeds had the lowest POV values. From the results of AV and POV measurements, suitable roasting treatment for both with- and without-shell camellia seeds tended to decrease the oil POV values and inhibit the increase of AV value during storage. Consequently, roasting treatment is beneficial to the shelf life of camellia oil keeping food safe for ingestion by consumers.

From the oil stability index (OSI, Fig. 5), it is expected that roasting treatment would obtain a similar effect as that of POV. Generally, roasting treatment reduces POV and increases OSI, implying that camellia seeds so treated contained more antioxidant substances. This is in turn proven by the oil phenol content (Fig. 6A) and reducing power (Fig. 6B). Particularly, for the shelled camellia seeds, the increasing roasting intensity caused POVs to decrease and OSI to increase; suggesting that seed kernels released more antioxidant substances because of the roasting. Conversely, the shell-on camellia seed oils at lower roasting intensities (110–120℃ for 10 min) produced both POV and OSI inferior to that of unroasted seed oils. Therefore, higher intensities (130℃ for 10 or 15 min) were required to allow the resulting oils having better oxidative stability than that of unroasted one, and reach similar POV and OSI values as those without-shell seed oils. Based on the results, we speculate that at lower roasting intensities, the with-shell camellia seeds would have oxidative substances eluded from the shells causing the POV and OSI values of the oils to be inferior to the unroasted one. When roasting temperature and duration were increased, the release of kernel antioxidant substances instead overcame the shell-derived oxidants leading to reduced POV and increased OSI values for the oils. Analysis of the phenol content in oils (Fig. 6A) indicated that presence or absence of shell did not affect the contents. The reducing power analysis (Fig. 6B), however, consistently indicated that roasting treatment rendered without-shell seed oils to have better reducing power than those with-shells. These results have proven that presence of shells tended to reduce the antioxidant capacity of the resulting oil. Regardless of the shell conditions, the most stable oils were from seeds roasted at the highest intensity of 130℃ and 15 min. Xu *et al*. (2007) also found that heat treatment increased phenol content in the orange peel extract and increased its antioxidant capacity. The results were in congruency with our earlier study results (Hsieh *et al*. 2013), indicating that suitable roasting treatment increased phenol content in the pressed oil and its anti-oxidative capacity. The increased phenol content and reducing power of the roasted seeds may be resulted from non-enzymatic browning reaction, such as Maillard

reaction, caramelization and chemical oxidation of phenols (Manzocco *et al*. 2000). As seen, color of oils pressed from roasted seeds gradually darkened following the roasting intensity.

The presence or absence of shells exerted significant effects on the SP of the oils (Fig. 4). The value of SP of the with-shell seed oils tended on average to be 5℃ , higher than those from without shell seeds (Table 1). The SP of the without-shell seed oils varied with the roasting intensity in an inverse V-shaped pattern, SP increase initially and then decrease, which tied in well with the changes in oil AV values. In roasting treatments, the AV changed with roasting intensity in an M-shaped pattern, indicating that the AVs of mid-intensities (for both with- and without-shell seeds) were less than those of low- and high-intensity roasting conditions. For which, the mid-intensity roasting led to lower free fatty acid contents in the oils. These results are in agreement with the SPs that higher values indicated less free fatty acid contents. Therefore, roasting camellia seeds at mid-intensity facilitates oil production with lower AVs. In the storage experiment, there were no significant AV changes for roasted seed oils stored at 4℃ for 1.5 year. Whereas, those from unroasted seeds showed significant AV increases after storing at the same conditions for 1.5 year. A most probable cause is the enzymatic activities persisting in the cold-pressed and cold-stored oils. Megahed (2011) found that by treating wheat at 70℃ for 30 min, lipase activity was inhibited and decreased AV of the subsequently produced oil. Therefore, high-temperature roasting treatment can effectively denature the lipase in the seeds which in turn inhibits hydrolysis reaction producing free fatty acids and causes AV to remain stable.

This study has proven that after suitable roasting, *C. tenuifolia* seeds could produce oils of enhanced quality, including better POVs, SPs, OSI, phenolic compounds, reducing powers, etc. In addition, roasting treatment significantly inhibited AV increase during storage. Overall, disregarding the slight decreases or changes of oil SP and AV, for *C. tenuifolia* seed oils, the best roasting conditions was the highest intensity at 130℃ for 15 min, in which the produced oils had the best oxidative and storage stability, the highest phenols and the strongest reducing power. Additionally shelling of seeds is advised that would increase oil production and provide the best oil quality.

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苦茶籽帶殼與否及炒培處理之榨出油品質比較

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摘要

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台灣特有苦茶品種 *Camellia tenuifolia* 果實較一般大果品種 *C. oleifera* 小，並且產量少，其壓榨油具有特殊的人體保健功效，所以成為台灣民間珍貴的食用油。苦茶籽有一層硬質種仁殼，大果種因為殼質較脆，殼與仁之間的間隙大，並且種子大小相近，所以脫殼容易，一般加工製程會經過脫殼再榨油。然而小果種的茶籽殼質韌、殼與仁之間的間隙小，並且種子大小不一，所以脫殼相對不容易，故有一部分小果種苦茶籽沒有經過脫殼就直接榨油。本研究分析小果種苦茶籽帶殼或脫殼後，再處理不同的炒培條件 (介於 110–130℃, 5–15 min)，分析其產油率、油脂酸價、過氧化價、煙點、油脂安定指數、酚類化合物含量及還原力。結果顯示，無殼者產率高於帶殼者 13%。所有試驗的油脂酸價均 < 1.0，過氧化價 < 10.0，煙點 > 200℃，顯示均達一般壓榨油脂的食用標準。不論是否帶殼，隨著炒培條件的增強，酚類化合物含量及還原力隨之增加，並且在合宜的炒培處理條件下，油脂品質較好、儲藏安定性較佳。

關鍵詞：小果種苦茶籽油、種仁殼、炒培、油脂品質、油脂氧化安定性。

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