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Thermal and storage characteristics of tomato seed oil

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ABSTRACT

The objectives of this research were to determine the changes in quality and oxidative stability of tomato seed oil, including color, antioxidant activity, peroxide value, saponification value, iodine value and acid value, during heating for 50 h at a common frying temperature (180 °C) and under different storage conditions of temperature (25 °C and 35 °C), light, and headspace volume (10 mL and 25 mL in 50 mL container) as a function of storage time (up to 210 days at 25 °C and 105 days at 35 °C). Results showed that tomato seed oil had high thermal stability with excellent physicochemical profile after heating. The antioxidants such as tocopherol and polyphenol were likely the most significant contributor to the high thermal stability. High temperature, exposure to light, and large headspace volume significantly accelerated the deterioration of tomato seed oil during storage, among which the temperature had the most pronounced effect followed by light and headspace volume. It is suggested that tomato seed oil is packaged with minimal light exposure and stored at a low temperature. The study provided important information for the quality evaluation and control of tomato seed oil and has a great significance for value-added utilization of the by-product from tomato processing industry.

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1. Introduction

Tomato seeds generated as a processing byproduct of tomato industry contain about 20.0–36.9 g/100 g of oil (on a dry basis). There is a potential of producing more than 0.14 million tons of tomato seed oil each year in the world (Shao et al., 2012). Tomato seed oil consists of up to 80.1 g/100 g of total unsaturated fatty acid with high content of linoleic (53.7 g/100 g) and oleic acids (23.8 g/100 g) (Shao, Atungulu, Pan, Yue, Zhang & Chen, 2013), which were proven to prevent thrombosis, atherosclerosis, high cholesterol and dilate blood vessels (Roche, 1999). Meanwhile, tomato seed oil exhibited higher antioxidant activity than common commercial edible oils, such as olive oil and soybean oil (Shao et al., 2012). These results indicate that tomato seed oil may have an up-and-coming potential to be used as edible oil with high nutritional quality.

Most edible oils used for frying are heated to 150 °C–190 °C for hours in the presence of air, moisture, and food, and a series of reactions such as hydrolysis, oxidation, and polymerization of oils take place and produce volatile or nonvolatile compounds (Choe & Min, 2007). The extent of reactions depends on frying temperature and time, and characteristics of oil and food. Most of volatile compounds may evaporate with steam into the atmosphere and remaining volatile compounds and nonvolatile compounds in oil undergo further chemical reactions and change the physical and chemical properties of oil (Choe & Min, 2007). Therefore, to evaluate the thermal stability of frying oil, it is important to determine the extent of deterioration taking place during frying by analyzing the changes in physicochemical characteristics of oil. In addition to thermal stability, high storage stability is also important for commercial edible oils. Oxidation is the main cause of quality deterioration during oil storage, and the rate of oxidation determines the shelf life of oils. Several factors including the amount of oxygen, storage temperature and exposure to light could influence lipid oxidation during storage (Bendini, Cerretani, Salvador, Fregapane,

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& Lercker, 2010). The impacts of these factors on storage stability of tomato seed oil have not been studied.

Physicochemical characteristics of oil, including specific gravity, refractive index, peroxide value (PV), saponification value (SV), iodine value (IV) and acid value (AV), are normally used as the quality indicators of edible oil (Pristouri, Badeka, & Kontominas, 2010). Antioxidant activity is another important quality parameter of edible oil. The method of measuring the potential of scavenging radical 2, 2-diphenyl-1-picrylhydrazyl (DPPH) was commonly used to evaluate the antioxidant activity of oil (Kalantzakis, Blekas, Pegklidou, & Boskou, 2006), which was also used in this study.

Tomato seed oil has not been investigated for its oxidative stability during frying and for effect of different storage conditions on its quality. Generating comprehensive information on the quality deterioration that occurs during heating and storage of tomato seed oil is important for its further utilization.

Therefore, this study was performed with the following objectives: (1) to determine the changes in physicochemical characteristics of tomato seed oil during heating at a common frying temperature and (2) to study the effects of different storage conditions including storage temperature, light, and headspace volume as a function of storage time on the physicochemical properties of tomato seed oil.

2. Materials and methods

2.1. Extraction of tomato seed oil

Processing-tomatoes bred for saucing and canning purposes were used in this study (Li, Pan, Upadhyaya, Atungulu, & Delwiche, 2011). Tomato pomace generated by a hot-break process was collected from the Pacific Coast Producers (Woodland, CA, USA), and stored at −18 °C until it was used. The seeds were separated from dried pomace by an aspirator system (FC2K testing husker, YAMANMOTO, CO., Higashine, Japan) and before oil extraction, the seeds were ground to powder using a grinder extractor mill (M2 Stein Mill, The Steinlite Corporation, Atchison, KS, USA) and sieved through a Tyler Sieve Shaker (RO-TAP Testing Sieve Shaker, W.S. Tyler Co., Cleveland, OH, USA) with a 0.42 mm screen. Tomato seed oil was then extracted using hexane (≥98.5%, Sigma–Aldrich). It was found that the optimum oil extraction conditions were 8 min of extraction time at temperature of 25 °C, solvent-to-solids ratio of 5/1 (v/w) with stirring speed of 400 rpm (Shao et al., 2012). After extraction, the hexane extract (oil solution) was separated from the solid residue (tomato seed) by centrifugation (Eppendorf 5804 R, Government Scientific Source, Reston, VA, USA) at 5000 rpm for 10 min at 4 °C. The hexane was removed by a rotary vacuum evaporator (Buchi Rotavapor R-205, BUCHI Analytical Inc., New Castle, Penn.,USA) at room temperature.

2.2. Physicochemical analysis

2.2.1. Color characteristics

Color characteristics of oil were determined by using a Chroma meter (CR-200, Minolta Camera Co. Ltd., Chuo-ku, Osaka, Japan) according to the method described by Li, Pan, Atungulu, Zheng, Wood, Delwiche, and McHugh (2014). Lightness (L^*), redness (a^*), and yellowness (b^*) (CIE 1976) values were measured and the total color difference (ΔE^*) ($\Delta E^* = [(a^*\text{-}a_0)^2 + (b^*\text{-}b_0)^2 + (L^*\text{-}L_0)^2]^{1/2}$) values were calculated. The color values of extracted oil samples without heating or storage were determined as a_0, b_0, and L_0.

2.2.2. Antioxidant activity

The antioxidant activity of oil sample was determined with the 2, 2-diphenyl-1-picrylhydracyl (DPPH) radical scavenging method, according to an adapted colorimetric procedure (Kalantzakis et al., 2006).

2.2.3. Other physicochemical parameters

Density, refractive index, peroxide value (PV), iodine value (IV), acid value (AV) and saponification value (SV) were carried out according to AOAC procedures (AOCS, 2003).

2.3. Determination of thermal stability

The heating experiment was carried out by using the method described by Kalantzakis et al. (2006) with some modifications. A sample of 25 g of oil was placed into 50 mL open glass beaker (6 cm high, 4 cm i.d.). The oil was heated in batch at 180 °C for 10, 20, 30 and 50 h. The oils heated for different times were stored at −20 °C in sealed dark glass vials under nitrogen atmosphere until used for the analysis of color, antioxidant activity, PV, IV, AV and SV.

2.4. Determination of storage characteristics

The storage characteristics of tomato seed oil were determined according to methods described by Pristouri et al. (2010) with some modifications. To study the effect of storage temperature on the characteristics of tomato seed oil, 25 mL of unheated oil sample was placed into a 50 mL clear polypropylene centrifuge tube (PPT) and covered with aluminum foil (to avoid light). The samples were stored at 25 °C (room temperature, marked as 25 D1) or 35 °C (elevated ambient temperature, marked as 35D). Samples stored at 25 °C were analyzed initially and at every 30 day interval until 210 days of storage and the samples stored at 35 °C were analyzed after 0, 30, 60, 90 and 120 days of storage. To determine the effect of light, 25 mL of oil sample was placed into 50 mL clear PPT (25 L) or PPT covered with aluminum foil (25D1), and stored at 25 °C. The samples were intermittently exposed to light in day and night (12 h each) for 0, 30, 60 days and until 210 days, respectively. To study the effect of headspace volume of container, 25 mL of oil (25D1) or 40 mL of oil (25D2) sample was placed into 50 mL PPT covered with aluminum foil creating 25 or 10 mL of headspace, respectively. The samples in containers were stored at 25 °C for 0, 30, 60 days and until 210 days. The color characteristics, antioxidant activity, PV, IV, AV and SV of all oil samples stored by aforesaid storage conditions were determined to investigate the storage stability of tomato seed oil.

2.5. Statistical analysis

All trials were carried out in triplicate and the average values are reported. Duncan ($\alpha = 0.05$) test, using a SPSS software (Ver.17.0, SPSS Inc., Chicago, IL, USA) was performed to determine the significant differences between the values.

3. Results and discussion

3.1. Physicochemical properties

The physicochemical properties of tomato seed oil are presented in Table 1 along with several vegetable oils and Codex standard 210 which describes the standards of several vegetable oils in a crude form (CAC, 1999). It can be seen from Table 1 that the refractive index (1.47) and specific gravity (0.90) of tomato seed oil were similar to other vegetable oils and within the range of data reported by Codex standard 210. The IV expresses the unsaturation level of an oil and to some extent, a high IV represents better nutritional oil quality because the unsaturated fatty acids were reported to exhibit many biofunctions such as prevent thrombosis and atherosclerosis