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Physicochemical property, chemical composition and free radical scavenging capacity of cold pressed kernel oils obtained from different *Eucommia ulmoides* Oliver cultivars

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ABSTRACT

In this study, chemical profiles of six cultivars of *Eucommia ulmoides* Oliver kernels, and physicochemical properties, chemical compositions, and free radical scavenging capacities of the prepared cold pressed *Eucommia ulmoides* Oliver kernel oils were investigated and compared. *Eucommia ulmoides* Oliver kernels contained high contents of protein (26.50 ± 0.78–28.38 ± 1.01%) and oil (38.17 ± 1.31–39.54 ± 0.77%), thus demonstrating that these underutilized crops can be identified as potential protein and oil resources with huge economic value. *Eucommia ulmoides* Oliver kernel oils were abundant in essential fatty acids such as α-linolenic acid (60.06 ± 2.12–61.19 ± 2.02%) and linoleic acid (13.21 ± 1.20–14.45 ± 1.14%). Further, *Eucommia ulmoides* Oliver kernel oils contained high amounts of tocopherol/tocotrienol, phytosterol, and polyphenol, thus resulting in their excellent free radical scavenging capacities. The results observed in the present work illustrated that the *Eucommia ulmoides* Oliver kernels and kernel oils can be regarded as high-quality sources and ingredients for dietary food and health care product industries.

1. Introduction

Eucommia ulmoides Oliver (EUO, also known as Tuchong in Japanese and Du-zhong in Chinese) (Zhu and Sun, 2018) is the unique living deciduous tree belonging to *Eucommiaceae* family and *Eucommia* genus (Liang et al., 2017), which has dioecious flower and dark brown flattened elliptical samara at maturity (Liang et al., 2017; Wu et al., 2016; Zhu and Sun, 2018). EUO is mainly distributed in a wide area of Central China (altitude: 300–1300 m), such as Hubei, Henan, Jiangxi, Shanxi, and Yunnan provinces (Zhu and Sun, 2018). Besides, a small quantity of EUO has also been cultivated in Eastern Asia like Japan and Korea (Hao et al., 2016). Leaves, barks, and stems of the EUO are important crude materials in traditional folklore medicine to cure numbness and tinea cruris, to reinforce muscle and lung, to improve tone of kidney and liver, as well as to increase longevity (Cho et al., 2018; Hussain et al., 2016; Qiang et al., 2007). Meanwhile, extracts obtained from the different parts of the EUO plant are well-known to exhibit multiple pharmacological benefits, such as antioxidant, anti-obesity, anti-hypertensive, anti-hyperglycemic, and hepatoprotective effects (Cho et al., 2018; Fujiwara et al., 2016; Hao et al., 2016; Wu et al., 2016; Yukihiro et al., 2012). Additionally, it is the primary source for isolating and producing gutta-percha (Suzuki et al., 2012), which has been broadly utilized in the rubber industry to produce electrical insulation tool and filling material for false teeth (Suzuki et al., 2012; Tokumoto et al., 2016; Zhu et al., 2017). On account of these advantaged merits and other properties of rapid growth and strong adaptability, EUO has been regarded as an economic plant that should be vigorously cultivated (Zhang et al., 2018).

EUO has recently drawn attention in China, due to the announcement (No. 12/2009) promulgated by the National Health Commission of the People's Republic of China (China, 2009), identifying the oil (recommended dosage: 3 mL per day) obtained from the EUO kernel can be considered as a new resource food (defined as the new developed, discovered, and imported matter that is usually not treated as food and consumed traditionally, which meets the basic requirement of food and is non-toxic and harmless to human body) with potential

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underutilized edible value. Usually, oil content of the EUO samara is about 7–15%, while the amount increases to 30–40% in the kernel (Zhang et al., 2018). The kernel is the most valuable part of the EUO samara, with the relative proportion ranges from 30% to 40% depending on the cultivar (Zhang et al., 2018). Nowadays, the planting area of the EUO in China is estimated at 350, 000 ha (accounted for more than 95% of the world total EUO planting areas), thus resulting in the annual production of the EUO kernel is about 945, 000 tons (equivalently to 330, 000 tons of the EUO kernel oils). Apart from the oil, EUO kernel is also rich in protein, carbohydrate, fiber, and trace element, which can be intensively utilized by human beings (Zhang et al., 2018). EUO kernel oil (an oil product extracted from the EUO kernel) exhibits great nutritional value, because of its high percentages of polyunsaturated fatty acids (α-linolenic and linoleic acids) and phytochemicals (Zhang et al., 2010, 2018). An extensive range consumption of beneficial micronutrients is significant in daily diet in terms of body fitness. Thanks to these helpful molecules and distinguished characteristics, people's requirement for EUO kernel oil is steady enhancing and the oil has been accepted as a nutritional product with good promoting effect and potential advantage in food and pharmacal applications (Zhang et al., 2018).

It is obvious that the EUO kernel and kernel oil are excellent sources of macronutrients and bioactive components (Zhang et al., 2018). However, as far as we know, properties of the EUO kernel remain scantily investigated. To effectively utilize this valuable plant resource, it is necessary to understand its character. Based on a literature review, previous published studies have mainly concentrated on certain medicinal and industrial applications of the extracts of the EUO leaves and barks (Cho et al., 2018; Hussain et al., 2016; Kwon et al., 2014; Lee et al., 2018; Tokumoto et al., 2016; Wu et al., 2016), thus neglecting the chemical composition of the EUO kernel. Furthermore, there is apparently few references available in the literature regarding the measurement of physicochemical property, chemical composition, and free radical scavenging capacity of the precious oil obtained from the EUO kernel. Zhang et al. (Zhang et al., 2018) pointed out that the dominant fatty acids in the EUO kernel oil were linolenic acid (61.36%), oleic acid (17.02%), and linoleic acid (12.04%). Meanwhile, total vitamin E content of the test oil was 190.96 mg/100 g, which were mainly γ- and δ-tocopherol analogues. Although the paper published by Zhang and coworkers (Zhang et al., 2018) had foremost investigated the chemical component of the EUO kernel oil, only one oil sample had been analyzed and it was different from the EUO cultivars investigated in this study. It is well known that cultivar of the EUO plant is an important issue that plays an significant role in the chemical composition and physicochemical property of the final oil product. However, no study has been focused on this subject, resulting in a scarcity of data on the comparison of the above mentioned characteristics of the kernel oils obtained from the different EUO cultivars. Further, free radical scavenging capacity of the EUO kernel oil has not been investigated and published before. Hence, analysis and comparison studies on these underutilized EUO kernel and kernel oil resources are the needs of the hour.

In the light of the above evidences and in the lack of attainable data, the goal of our investigation is two-fold: i) to compare the chemical compositions of six cultivars of the EUO kernels collected from the different production areas; ii) to evaluate the differences among the EUO kernel oils in terms of their physicochemical properties, fatty acid compositions, phytochemicals, and free radical scavenging capacities. In brief, this work attempts to gather more useful information on the component and property present in the EUO kernels and kernel oils from different cultivars, thus further favouring their popularization and utilization in domestic and international commercial markets.

2. Materials and methods

2.1. Materials and chemicals

A mix of thirty-seven fatty acid methyl ester standard, tocopherol mix standard, phytosterol mix standard, and 5α-cholestane were purchased from Sigma-Aldrich (Bellefonte, PA, USA). HPLC grade methanol, ethanol, *n*-hexane, and isopropanol, as well as other analytical grade inorganic reagents were purchased from Sinopharm Medicine Holding Co., Ltd. (Shanghai, China). EUO samara samples were collected from Hunan (cultivar: Cili, longitude: E111°08′1.05″, latitude: N29°25′56.09″), Yunnan (cultivar: Yanjin, longitude: E104°13′56.59″, latitude: N28°06′43.28″), Henan (cultivar: Lingbao, longitude: E110°56′23.23″, latitude: N34°31′52.76″), Guizhou (cultivar: Zunyi, longitude: E106°54′41.20″, latitude: N27°42′3.78″), Shanxi (cultivar: Lueyang, longitude: E106°04′42.13″, latitude: N33°20′34.95″), and Jiangxi (cultivar: Pingxiang, longitude: E114°06′18.38″, latitude: N27°41′31.26″) provinces of China, respectively, and preserved at −80 °C.

2.2. Preparation of EUO kernels and kernel oils

EUO samaras were manually dehusked and the corresponding kernels were separated subsequently, and both of the husks and kernels were weighed individually. The prepared EUO kernels were independently pressed using an IBG screw-type oil expeller, and the obtained cloudy oils were centrifuged at 8000 *g* for 10 min. The liquid oils were reserved in brunet glass vessel at 4 °C.

2.3. Chemical composition of the test EUO kernels

Chemical compositions such as crude oil, protein, fiber, carbohydrate, and ash contents, and amino acid composition and moisture of the selected EUO kernels were measured following the methods of the Association of Official Analytical Chemists (AOAC, 2000). Minerals of the selected EUO kernels were measured using the atomic absorption spectroscopy method recommended by the AOAC (AOAC, 2000).

2.4. Physicochemical property, chemical composition, and free radical scavenging capacity of the test EUO kernel oils

Refractive index of the prepared EUO kernel oils was determined using a Mettler Toledo Refracto hand-held refractometer. Other physicochemical parameters were measured according to the methods specified by the Association of Official Analytical Chemists (AOAC, 2000).

Chemical composition and free radical scavenging capacity of the studied EUO kernel oils were analyzed according to our formerly studies (Shi et al., 2018, 2017a; Shi et al., 2017b). Detailed procedures of the sample preparations were showed in the supplementary material.

2.5. Data analysis

Sample determinations were operated in triplicate, and results were reported as means ± standard deviations. Statistical analysis was calculated using Origin 8.5. Data were compared by one-way analysis of variance (ANOVA), and significant differences among the variables of the test EUO kernels and kernel oils were assessed by Duncan's multiple-range tests at $P < 0.05$. All variables were standardized to produce the statistical values, and then hierarchical cluster analysis (HCA) was used to analyze the differences and similarities of the test oil samples