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Chemical components of cold pressed kernel oils from different *Torreya grandis* cultivars

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ABSTRACT

The chemical compositions of cold pressed kernel oils of seven *Torreya grandis* cultivars from China were analyzed in this study. The contents of the chemical components of *T. grandis* kernels and kernel oils varied to different extents with the cultivar. The *T. grandis* kernels contained relatively high oil and protein content (45.80–53.16% and 10.34–14.29%, respectively). The kernel oils were rich in unsaturated fatty acids including linoleic (39.39–47.77%), oleic (30.47–37.54%) and eicosatrienoic acid (6.78–8.37%). The kernel oils contained some abundant bioactive substances such as tocopherols (0.64–1.77 mg/g) consisting of α-, β-, γ- and δ-isomers; sterols including β-sitosterol (0.90–1.29 mg/g), campesterol (0.06–0.32 mg/g) and stigmasterol (0.04–0.18 mg/g) in addition to polyphenols (9.22–22.16 μg GAE/g). The results revealed that the *T. grandis* kernel oils possessed the potentially important nutrition and health benefits and could be used as oils in the human diet or functional ingredients in the food industry.

1. Introduction

Torreya grandis is a large, evergreen and ornamental coniferous tree belonging to the Cephalotaxaceae family and Torreya genus. It is naturally distributed in the hilly areas of subtropical China, particularly in Zhejiang and Anhui Provinces (Dong et al., 2014). It has dioecious flowers and drupe-like fruits with nut seeds (Beatrice et al., 1999). In China, *T. grandis* leaves and fruits are traditional medicine materials that serve pharmacological functions such as expelling parasites, preventing malnutrition, moistening lung tissues, loosing bowels, preventing phlegm, stopping cough and curing rheumatism (Huang, Wang, Li, Zheng, & Su, 2001; Ni & Shi, 2014; Ni et al., 2015). Saeed et al. (2010) reported that the ethanol extracts of *T. grandis* leaves possessed hypoglycemic, anti-nociceptive and anti-inflammatory activity and revealed that the alkaloids, flavonoids, tannins, terpenoids and saponins contained in the plant were responsible for its pharmacological activity.

T. grandis seeds are one of the world's rarest dry nuts due to their high nutritional value, special texture, unique flavor and medicinal function (Li, Luo, Cheng, Feng, & Yu, 2005; Ni et al., 2015). They normally take 2–3 years before becoming edible (Ni & Shi, 2014). The seed kernels are rich in oil, fatty acids, protein, vitamins (i.e., nicotinic acid, folic acid) and mineral elements (i.e., Mg, Ca, Fe, Zn, Se) (Ni & Shi, 2014; Ni et al., 2015). Previous studies have demonstrated that *T. grandis* seeds have multiple biological properties including anti-oxidative, anti-inflammatory, antiviral, anti-atherosclerosis, anti-helminthic, antitussive, carminative, laxative, antifungal, antibacterial and antitumor properties due to their rich nutritive content and bioactive components (Chen, Chen, Hou, Xu, & Zheng, 2000; Chen et al., 2006; Dong et al., 2014; Huang et al., 2001; Ni & Shi, 2014; Ni et al., 2015). Therefore, *T. grandis* seeds can be considered important sources for the high-value food and nutraceutical supplement industries.

T. grandis seed kernels contain approximately 42.6–61.5% oil. Unsaturated fatty acids comprise 76.1–94.3% of the total fatty acids depending on the cultivar, of which linoleic and oleic acid predominate. *T. grandis* is widely cultivated as an important economic crop in Zhejiang and Anhui Provinces in Southern China. Although some studies have characterized *T. grandis* kernel oil from Zhuji (Dong et al., 2014), Shaoxing (Ni et al., 2015) and Fuyang (Ni & Shi, 2014) in Zhejiang Province, to the best of our knowledge, no research has compared the differences in physicochemical properties and functional compositions of *T. grandis* kernel oil from different regions of Southeastern China. Geographical origin is known to

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have a significant effect on seed composition and bioactive compound concentration (Ayerza & Coates, 2011).

Therefore, the objective of this study was to evaluate the variation in the physicochemical properties, fatty acids, tocopherol compositions and polyphenol contents of the seven *T. grandis* kernel oil cultivars from different geographical areas in China and better assess their potential as sources of functional oils in the food industries.

2. Materials and methods

2.1. Materials and chemicals

All of the mature *T. grandis* fruits used in this study were obtained from different regions in Zhejiang and Anhui Provinces in Southeastern China in October 2014. Among the seven *T. grandis* cultivars (Table 1), Zhuji cultivar grew in the hilly red soil of Zhuji region of Zhejiang Province with the average annual rainfall of 1373.6 mm and average annual temperature of 16.3 °C; Panan cultivar was from the hilly yellow-red soil region of central Zhejiang with the average annual rainfall of 1527.8 mm and average annual temperature of 17.4 °C; Shengzhou1, Shengzhou2, Dazinai and Tedanai cultivars were from the hilly red and lithomorphic soil of Shengzhou area of Zhejiang with the average annual rainfall of 1446.8 mm and average annual temperature of 16.4 °C; Huangshan cultivar located in the middle-lower mountain lands with yellow soil of Huangshan area of Anhui Province with the average annual rainfall of 1702 mm and average annual temperature of 15.5 °C (Pan, Xia, Lin, Wang, & Li, 2015; Zeng, Zhou, Li, Yu, & Dai, 2015).

The *T. grandis* seeds were separated manually from the fresh fruits and unshelled to obtain the seed kernels. Fruit pulps, seed shells and kernels were collected and weighed. The seed kernels were dried in open air for 1 week (moisture content close to 10%) and then stored at room temperature in sealed polyethylene bags for further analysis. Standards of 5α-cholestane (⩾97%), cholestan-3-ol (⩾95%), β-sitosterol (⩾97%), cholesterol (⩾90%), α-tocopherol (⩾96%), β+γ-tocopherol (⩾96%), δ-tocopherol (⩾90%) and gallic acid (98%) were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). All of the other reagents and chemicals, which were of chromatographic or analytical grade, were obtained from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China).

2.2. Proximate analysis

The crude protein, moisture, fat, carbohydrate and ash contents of the *T. grandis* seed kernels were determined according to the methods of the Association of Official Analytical Chemists (AOAC, 2000).

2.3. Oil extraction by cold pressing

The *T. grandis* seed kernels were directly pressed with a household ZYJ901 expeller (Bear Electric Appliance Co., Ltd., Jiangmen, China) at ambient temperature. The pressed oils with fine suspended solids were collected and clarified by centrifuging at 10,000*g* for 15 min at 4 °C. The oil yields of the seed kernels by cold pressing were in the range of 23.3–39.7%. The clarified oils were placed in brown glass bottles, flushed with nitrogen and stored in a refrigerator at 5 °C for further analysis.

2.4. Physicochemical properties of kernel oil

The refractive index of the kernel oils was measured at room temperature using a WYA-2S hand-held refractometer (Shenguang Instrument Co. Ltd., Shanghai, China). Other physicochemical properties including acid, iodine, saponification and peroxide values were determined using the methods described by the Association of Official Analytical Chemists (AOAC, 2000).

2.5. Fatty acid analysis

Fatty acid methyl esters (FAME) were prepared according to directions provided by Dong et al. (2014) with some modifications. 0.1 g of seed oil was weighed and put into a 10-ml glass tube. 2 ml of mixture of ethyl ether and *n*-hexane (1:1, v/v), 2 ml of 2-mol/l KOH in methanol solution and 2 ml of methanol were added to the glass tube. The mixture was shaken for 1 min, kept in a water bath at 50 °C for 30 min and then cooled before 2 ml of deionized water was added. After separation, the upper layer was collected and subjected to gas chromatography coupled with mass spectrometry (GC–MS) analysis. GC–MS analysis was performed on a VARIAN 1200L-GC–MS (Varian, Palo Alto, CA, USA) equipped with a silica capillary column (Agilent DB wax; 30 m × 0.25 mm × 0.25 μm). Helium was used as the carrier gas at a constant flow rate of 0.8 ml/min. The oven temperature was held initially at 170 °C for 0.5 min, then increased to 230 °C at a rate of 5 °C/min and

Table 1
Physicochemical properties of fruits, kernels and cold pressed kernel oils from seven *Torreya grandis* cultivars.[A]

Component	Zhuji	Panan	Shengzhou1	Shengzhou2	Dazinai	Tedanai	Huangshan
Weight fractions of fruits							
Pulp (% of fruit)	62.63 ± 0.52^{cd}	62.34 ± 0.38^{d}	63.28 ± 0.27^{bcd}	63.59 ± 0.81^{abcd}	64.61 ± 1.05^{a}	64.36 ± 0.93^{ab}	63.87 ± 0.76^{abc}
Seed (% of fruit)	37.37 ± 0.47^{a}	37.66 ± 0.18^{a}	36.72 ± 0.76^{ab}	36.41 ± 0.55^{bc}	35.39 ± 0.28^{d}	35.64 ± 0.11^{cd}	36.13 ± 0.90^{bcd}
Seed shell (% of seed)	27.14 ± 0.09^{e}	38.42 ± 0.65^{b}	28.53 ± 0.39^{d}	27.06 ± 0.68^{e}	41.38 ± 0.13^{a}	36.87 ± 0.85^{c}	38.79 ± 0.47^{b}
Seed kernel (% of seed)	72.86 ± 0.88^{a}	61.58 ± 0.76^{c}	71.47 ± 1.01^{a}	72.94 ± 0.95^{a}	58.62 ± 0.96^{d}	63.13 ± 0.51^{b}	61.21 ± 0.83^{c}
Chemical composition of kernels							
Oil–dry matter (%)	48.54 ± 1.02^{bc}	49.36 ± 0.25^{b}	45.80 ± 0.51^{e}	47.23 ± 0.92^{d}	49.09 ± 0.62^{b}	47.51 ± 0.87^{cd}	53.16 ± 0.66^{a}
Ash–dry matter (%)	2.52 ± 0.36^{d}	1.08 ± 0.32^{e}	2.96 ± 0.44^{cd}	2.52 ± 0.47^{d}	4.08 ± 0.01^{a}	3.53 ± 0.01^{b}	3.31 ± 0.07^{bc}
Moisture (%)	6.09 ± 0.12^{f}	8.97 ± 0.06^{b}	7.32 ± 0.06^{d}	8.46 ± 0.13^{c}	6.95 ± 0.20^{e}	11.07 ± 0.29^{a}	8.43 ± 0.11^{c}
Protein–dry matter (%)	13.81 ± 0.24^{b}	12.73 ± 0.29^{d}	13.21 ± 0.24^{c}	11.71 ± 0.14^{e}	14.29 ± 0.01^{a}	13.12 ± 0.02^{c}	10.34 ± 0.22^{f}
Carbohydrate–dry matter (%)	16.87 ± 0.56^{b}	14.84 ± 0.37^{c}	15.66 ± 0.42b^{c}	15.65 ± 1.51b^{c}	10.79 ± 0.52^{e}	12.16 ± 0.52^{d}	21.42 ± 0.23^{a}
Properties of kernel oils							
Refractive index (25 °C)	1.472 ± 0.002^{a}	1.472 ± 0.002^{a}	1.473 ± 0.001^{a}	1.474 ± 0.002^{a}	1.474 ± 0.001^{a}	1.474 ± 0.001^{a}	1.473 ± 0.002^{a}
Acid value (mg KOH/g)	0.54 ± 0.03^{d}	0.33 ± 0.03^{f}	0.70 ± 0.01^{b}	0.42 ± 0.01^{e}	0.80 ± 0.02^{a}	0.61 ± 0.02^{c}	0.31 ± 0.01^{f}
Iodine value (g I_2/100 g)	124.8 ± 23.19^{a}	119.37 ± 5.85^{a}	121.84 ± 2.14^{a}	126.85 ± 1.52^{a}	119.43 ± 1.77^{a}	119.37 ± 0.30^{a}	121.05 ± 3.00^{a}
Peroxide value (meq O_2/kg)	1.05 ± 0.05^{c}	0.64 ± 0.02^{e}	1.15 ± 0.03^{b}	1.19 ± 0.06^{b}	1.77 ± 0.04^{a}	1.72 ± 0.10^{a}	0.87 ± 0.04^{d}
Saponification value (mg KOH/g)	187.81 ± 0.60^{bc}	181.04 ± 1.71^{e}	182.62 ± 1.91^{de}	186.01 ± 4.38^{bcd}	184.04 ± 0.27^{cde}	190.5 ± 3.65^{b}	195.74 ± 3.58^{a}

[A] Values are expressed as the mean ± standard deviation. Different superscripts in the same row indicate significant differences ($p < 0.05$).