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RESEARCH ARTICLE

Nutrients, fatty acid composition and antioxidant activity of the flowers and seed oils in wild populations of *Paeonia ludlowii*

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ABSTRACT

Wild *Paeonia ludlowii* is considered as a traditional ornamental plant, but its flowers and seed oils are edible with important economic values, and the variation of nutrients, fatty acid composition in wild populations is scarcely known. Flowers and seeds of *P. ludlowii* were collected from two wild populations for evaluating the nutrients in flowers, composition of fatty acids in seed oils and the antioxidant activity. The flowers contained high composition of proteins, carbohydrates, amino acids, total flavonoids, phenolic compounds and essential minerals. Seed oil yield reached up to 21.95% using supercritical CO_2 fluid extraction, and it contained 14 fatty acids (up to 93.35 g/100 g seed oil), especially the unsaturated fatty acids (oleic acid, linoleic acid and α-linolenic acid) was up to 88.69% with low ω6/ω3 ratios of 0.58. The antioxidant capacity can be arranged in the order of trolox > flower extracts > seed oil according to the DPPH and ABTS free radical assay. Contents of nutrient in flowers and fatty acids in seed oils were significantly different between two wild populations due to the impact of different growing environments. These results indicate that flowers and seed oils of *P. ludlowii* are potential food resources in human diets.

Keywords: *Paeonia ludlowii*; Flowers; Nutrients; Seed oil; Antioxidant activity

INTRODUCTION

Paeonia, the only genus in the family *Paeoniaceae*, includes approximately 35 species that are divided into three sections (Moutan, Oneapia, and Paeonia) (He et al., 2014). *Paeonia ludlowii* belongs to the section Moutan (named tree peony), and it is one of wild species, and mainly distributed in sparse forests, woods and thickets of southeastern Tibet (Zhou, 2006). Because of the diverse growing environments, there are abundant genetic diversity among different wild populations (Tang et al., 2012).

Paeonia ludlowii is well known for its ornamental value due to the big and yellow flowers, and its morphological characters are distinctly different from the other species in section Moutan (Hong, 1997), and it has become an ornamental flower with local characteristics. Meanwhile, the flowers of *Paeonia* species are edible, and many of them are widely used as delicacies for refreshments (Shi et al., 2006). Edible flowers usually play an important role in human nutrition due to various nutrients, such as amino acids, proteins, mineral elements and antioxidants (Mlcek and Rop, 2011), but there is no information concerning the nutritional components of *P. ludlowii* flowers.

Paeonia ludlowii is also a medicinal plant, the roots contain paeonol which is a Chinese herbal medicine, and widely used in East Asia to treat female genital and cardiovascular diseases (Picerno et al., 2011). He et al. (2014) also analyzed the root cortex metabolic fingerprinting of tree peonies, and found that metabolic profiles of *P. ludlowii* had significant differences compared with other six species. Recently, Zhang et al. (2017a) found the seeds of tree peony were rich in phenolic compounds, which can be used as useful sources of natural antioxidants. Seed oil of tree peony has also attracted considerable attention, researchers reported that the seeds of some wild tree peony species were characterized by abundant unsaturated fatty acids (FA), such

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as α -linolenic acid, oleic acid, and linoleic acid (Yu et al., 2016; Zhang et al., 2017b). Li et al. (2015) also found six cultivars had high FA yield selected from 60 ornamental cultivars of tree peony. However, the diversity of FA content and composition remains unclear in *P. ludlowii* seed oils from different wild populations and locations, and the potential antioxidant activity of seed oil has not been assessed.

The objectives of the present study were to evaluate the nutritional value of flowers, fatty acid composition of seed oils and their antioxidant activity in two wild populations of *P. ludlowii*. This work could be helpful for the potential development and utilization of *P. ludlowii* as a new resource food.

MATERIAL AND METHODS

Plant materials

The flowers and seeds of *P. ludlowii* were collected from two different wild populations (Zhagonggou and Caimicun) in Tibet of China. More than 50 full-bloom flowers from different plants were harvested in each location in May 2016, and immediately dried in an oven at 50℃ for 48 h, and then crushed into powders, and stored at 4℃. Mature seeds were hand-picked in October of 2016, and dried in an oven at 50℃ until constant weight, and weighed, husked and ground to fine powders, then immediately extracted for seed oil. The plants in Zhagonggou population grow at an altitude of 3210 m on the slopes with enough sunshine, while the plants in Caimicun population grow at an altitude of 2939 m along the Yarlung Zangbo River, and they were under the tall trees.

Proximate composition of flowers

The nutritional value of flowers was calculated based on proteins, carbohydrates, fat, moisture and ash. Protein content (N×6.25) was calculated as nitrogen content by the Kjeldahl method (AOAC, 2000). Fat, moisture and ash contents were also determined using standard AOAC methods (AOAC, 2000). The carbohydrate content was determined according to James (1996).

Total phenolic content (TPC) and total flavonoid content (TFC)

The flower extraction using methanol was performed according to the method elaborated by Amri et al. (2017). Then, the Folin-Ciocalteu assay was used to determine the TPC following the description of Ado et al. (2015). TPC was expressed as g of gallic acid equivalent per 100 g of dried weight (g GAE/100 g DW). TFC was determined according to the method of Amri et al. (2017), and TFC was expressed as g of rutin equivalent per 100 g of dried weight (g REQ/100 g DW).

Content of mineral elements

The dried flower samples were digested with HNO_3-$HClO_4$ (v/v, 4:1) to determine the Ca, Mg, Zn, Fe, Cu and Mn concentrations as the methods of Gui et al. (2014). Flower sample (0.2 g) was put into a polyethylene bottle with 20 mL 1 mol/L of HCl, shaken for 2 h at a rate of 180 rpm, and then filtered to determine the Boron (B) concentration (Gui et al., 2014). The nutrient concentration of the flower was expressed in dry weight.

Amino acids analysis

Determination of hydrolytic amino acids in flowers was carried out using an automatic amino acid analyzer (Sykam S-433D, German) with analytical column (PEEK, 4.6 mm ×150 mm, 5 μm) according to the method of Zhang et al. (2014). Amino acid standards (Sigma-Aldrich) were used for identification and quantification. The amino acid composition was expressed as mg/g of the dry flower weight.

Seed oil extraction

The fatty acids (FA) of seeds were extracted by the method of supercritical CO_2 fluid extraction (SFE) using a HA120-50-02 SFE device (Hua' an Supercritical Fluid Extraction Corp., Nan-tong, China). Samples (120 g) of seed powders were placed into the extraction vessel. The liquid CO_2 was pumped into the extractor to soak the seed powders under 30 MPa at 45℃ for 2 h, and the CO_2 flow rate 25 kg/h. The amount of extracted oil was determined gravimetrically after collection, and the oil yield is expressed as the percent ratio of the mass of extracted oil to the mass of seed powders loaded in the extraction vessel.

Fatty acid methylation and GC-MS analysis

Fatty acids (FA) were transformed to their methyl esters (FAME) following the method of Wang et al. (2015). The FAME samples were analyzed by a gas chromatograph mass spectrometer (GC7890A-5975C, Agilent) equipped with a 7683 autosampler tray module and a 7683 autoinjector module (Agilent). The column was VF-WAXms (30 m × 0.25 mm, 0.25 μm film thickness, Agilent). Operating conditions of GC-MS were as follows: 80℃ for 2.5 min, 80–210℃ at 15℃/min, 210–230℃ at 2℃/min, and held at 230℃ for 10 min. The carrier gas was He at a flow rate of 1.0 mL/min, and the injection port was set at 250℃ for split injection at a split ratio of 20:1. The inject volume was 1 μL. The ionization potential of the mass-selective detector was 70 eV and the scanning range was 40–460 amu. Analyses were performed in four times (n=4). The peaks of FAME were identified by comparing the mass spectra database (NIST2011 Library), and authentic standards.

Qualitation and quantification of FA

Fatty acid methyl esters (FAME) were initially identified through a mass spectra database search. To avoid the

confusion of isomers, the five major compounds (palmitic acid methyl ester, stearic acid methyl ester, methyl oleate, linoleic acid methyl ester and linolenic acid methyl ester) were achieved by reference to corresponding authentic standards (Sigma). Other nine minor components were confirmed by comparing retention time and MS spectra with the 37-component FAME Mix (C_4–C_{24} unsaturates). The five major FAME in each sample were quantified in absolute terms by linear regression of their corresponding standards, while the nine minor FAME were measured using methyl tridecanoate (Sigma) as the internal standard. The content of each FAME was transferred to the corresponding FA content, and they were expressed as gram per 100 grams seed oil. All samples were analyzed in four times.

Assay of DPPH radical-scavenging activity

Flower powders (2 g) were soaked in 100 mL 50% ethanol and extracted in 60° Cwater bath for 1 h, the solution was cooled, weighed and replenished the lost weigh with 50% ethanol. After filtering, the flower extract was obtained. The concentration of flower extract was 20 mg flower powder in 1mL 50% ethanol, and then it was diluted into 0.03, 0.06, 0.125, 0.25, 0.50, 1.00 mg/mL for antioxidant activity test. The seed oil was also diluted into 5, 10, 20, 30, 40 and 60 mg/mL with ethanol for antioxidant activity test. The DPPH radical scavenging activity of samples were evaluated by the method of Li et al. (2011). A volume of 2 mL of each sample was incubated with 2 mL of DPPH solution (0.2 mM in ethanol) at 25 °C for 30 min in the dark, and the absorbance of the mixture was measured at 517 nm. Trolox (Sigma-Aldrich) was used as the control. The 50% inhibitory concentration (IC_{50}) was calculated using linear regression.

Assay of ABTS radical-scavenging activity

The ABTS free radical scavenging test was modified according to the method of Re et al. (1999). The ABTS diammonium salt (10 mg) was added to 2.6 mL 2.45 mM potassium persulfate, and this mixture was allowed to stand for 12–16 h at room temperature in the dark to create a dark blue–green radical solution. The solution was then diluted with anhydrous ethanol to an absorbance of 0.700 ± 0.001 at 734 nm to form the test reagent. A volume of 1 mL sample or Trolox was incubated with 3 mL test reagent at 25°C for 30 min in dark, and the absorbance was recorded at 734 nm, and IC_{50} was also calculated.

Statistical analysis

Analysis of variance (ANOVA) and Student's t-test were used to evaluate differences between two locations, all analyses were performed on the SAS software (version 8.0) and considered significant when $p < 0.05$.

RESULTS AND DISCUSSION

Chemical composition of flowers

Proximate analysis was conducted to examine the chemical composition and nutritional value of the flowers. The flowers of *P. ludlowii* contained high composition of ash, carbohydrates and protein (Table 1). The high ash content was indicative of the presence of large amounts of minerals. The ash content (5.1 – 5.6 g/100 g) was found to be higher than that of chestnut flowers (Carocho et al.,

Table 1: Proximate composition, effective components and mineral elements of *Paeonia ludlowii* flowers in two locations

	Components	Caimicun	Zhagonggou	Mean
Proximate composition (%)[a]	Moisture	9.9±0.3[a]	10.0±0.2[a]	9.95
	Ash	5.1±0.3[a]	5.6±0.3[a]	5.35
	Proteins	15.7±0.4[b]	18.4±0.5[a]	17.05
	Lipids	3.4±0.2[a]	2.4±0.3[b]	2.90
	Carbohydrates	65.8±2.1[a]	63.6±1.7[a]	64.70
	Energy[b]	356.6±3.1[a]	349.6±2.3[b]	353.10
Effective components (%)[a]	TFC	1.58±0.02[a]	1.38±0.02[b]	1.48
	TPC	8.92±0.14[a]	8.75±0.16[a]	8.84
Mineral elements[c]	K	1.67±0.00[b]	1.71±0.01[a]	1.69
	Ca	0.32±0.00[b]	0.45±0.00[a]	0.39
	Mg	0.19±0.00[b]	0.24±0.00[a]	0.22
	Mn	10.95±0.07[b]	16.35±0.07[a]	13.65
	Zn	32.50±0.71[b]	37.00±0.00[a]	34.75
	Fe	68.65±0.35[a]	66.55±1.91[a]	67.60
	Cu	9.95±0.07[a]	9.45±0.21[b]	9.70
	B	14.65±0.21[a]	14.15±0.49[a]	14.40

[a]Proximate composition and effective components are expressed as g per 100 g on dry weight, except energy which is expressed in kcal per 100 g on dry weight, [b]Energy was calculated using 4 kcal/g for proteins and carbohydrates and 9 kcal/g for lipids, [c]K, Ca and Mg are expressed as percentage of dry flower and for Mn, Zn, Fe, Cu and B as mg /kg of dry flower. TFC and TPC represents the content of total flavonoids and total polyphenols. All data was Mean ± SD, different letters with in a line indicate significant statistical differences ($p<0.05$).

2015). The protein content (15.7–18.4 g/100 g) was higher than that of *Crocus sativus* flowers (10.1 g/100 g) (Serrano-Díaz et al., 2013). The energy contribution of 100 g of whole flowers was low, ranging from 349.6 to 356.6 kcal, the consumption of 100 g of these flowers would provide an energy intake from 17.4% to 17.8% in a standard daily diet of 2000 kcal.

Total flavonoid content (TFC) and total phenolic content (TPC)

Increased consumption of flavonoids and phenolic compounds has been correlated with antioxidant and anti-inflammatory activities, and a reduced risk of cardiovascular disease and certain cancers (Mlcek and Rop, 2011; Chen et al., 2015). The results presented the differences of TFC and TPC extracted from dry flowers of *P. ludlowii* (Table 1), the accumulated quantities of TFC in Caimicun was significantly higher than that in Zhagonggou, but the TPC was insignificant. Compared with the other *Paeonia* species, the level of TFC found in *P. ludlowii* flowers was lower than that in four tree peony cultivars reported by Shi et al. (2006), whereas the content of phenolic compounds was higher here than that reported by the same authors. Meanwhile, Zheng et al. (2015) found that both of TFC and TPC increased firstly and then decreased during blooming, with the highest at full-bloom stage. In this study, *P. ludlowii* flowers were collected at full-bloom stage, its TFC in dry flowers was similar with loquat flowers, but the TPC in *P. ludlowii* flowers was nearly two times than that in loquat flowers.

Mineral elements content

Table 1 also shows the results regarding some nutritionally important minerals. The main difference of flowers was detected in the level of K, Ca, Mg and the minor nutritional elements (Mn, Zn and Cu). In Zhagonggou, flowers exhibited much higher levels of K, Ca, Mg, Mn and Zn, and the contents of Fe and B were insignificant between two locations. The content of K, Ca and Mg in this work were higher than *Crocus sativus* flowers (Serrano-Díaz et al., 2013), and similar with *Rosa laxa* pollen, while the content of Fe, Zn and Cu of *P. ludlowii* flower were higher than that in *Rosa laxa* pollen and hip described by Li et al. (1997), and Fe, Zn content was also similar with pear flowers (Ammar et al., 2014).

Amino acid composition

The amino acid composition of *P. ludlowii* flowers indicated the presence of 17 amino acids (Table 2). The content of total essential amino acids (EAA) in Zhagonggou and Caimicun were 45.03 mg/g and 39.41 mg/g in dry flower weight, respectively, and accounted for 34.91% and 35.85% of the total amino acid content, which is slightly lower than the reference value of 40% recommended by FAO/WHO (Pellett and Young, 1980). In addition, the ratio of EAA to non-essential amino acid (NAA) for Zhagonggou and Caimicun were 53.64% and 55.89%, which is slightly lower than the reference protein pattern of 60% recommended by FAO/WHO. It could be seen that glutamic (Glu) and aspartic acids (Asp) had the highest concentrations in two locations, while methionine (Met) and cysteine (Cys) recorded relatively lower. Both of the total contents of EAA and NAA in Zhagonggou were significantly higher than that in Caimicun. Similar results were found in the fruits of *Schinus terebinthifolius* and *Schinus mole* when they were collected from two locations in Tunisia (Tlili et al., 2018), and the possible reasons were the differences of climatic conditions and soil of an area.

Composition and content of fatty acids (FA)

The seeds of *P. ludlowii* were collected from two wild populations (Zhagonggou and Caimicun). The mean dry weight per 100 seeds in Zhagonggou was 85.42 ± 1.63 g, while Caimicun seeds was 83.19 ±1.55 g. The seed oil yield was 20.75 – 21.95%, according to the ratio of seed oil weight to dry seed weight.

The FA characterization of seed oil is shown in Fig 1. A total of 14 FA were found with 80.66 – 93.35 g in 100 g

Table 2: Amino acid compositions of *Paeonia ludlowii* flowers in two locations (mg/g of dry flower weight)

Essential amino acid (EAA)	Caimicun	Zhagonggou	Mean
Ile	5.20±0.01^a	5.70±0.07^a	5.45
Met	0.31±0.01^a	0.33±0.01^a	0.32
Val	6.40±0.00^b	7.10±0.01^a	6.75
Phe	4.90±0.00^b	5.60±0.07^a	5.25
Thr	4.90±0.02^b	5.50±0.07^a	5.20
Leu	8.40±0.00^b	9.35±0.11^a	8.88
Lys	6.50±0.02^b	8.30±0.01^a	7.40
His	2.80±0.00^b	3.15±0.01^a	2.98
Total	39.41±0.02	45.03±1.00	42.22
Non-essential amino acid (NAA)			
Asp	12.10±0.01^b	15.60±0.14^a	13.85
Ser	5.95±0.07^b	6.75±0.04^a	6.35
Glu	20.05±0.07^b	23.20±0.28^a	21.63
Pro	6.20±0.00^b	7.05±0.11^a	6.63
Gly	5.50±0.00^b	6.15±0.04^a	5.83
Ala	9.50±0.00^b	10.45±0.11^a	9.98
Cys	0.71±0.01^b	0.85±0.00^a	0.78
Tyr	3.10±0.00^b	3.50±0.07^a	3.30
Arg	7.40±0.00^b	10.40±0.07^a	8.90
Total	70.51±0.16	83.95±1.70	77.23
EAA/(EAA+NAA)	35.85%	34.91%	35.38%
EAA/NAA	55.89%	53.64%	54.77%

All data was Mean ± SD, different letters within a line indicate significant statistical differences ($p<0.05$).

seed oil (Table 3). Palmitic acid (C16:0, peak 3), stearic acid (C18:0, peak 7), oleic acid (C18:1$^{\Delta 9}$, peak 8), linoleic acid (C18:2$^{\Delta 9,12}$, peak 9) and α-linolenic acid (C18:3$^{\Delta 9,12,15}$, peak 11) were the five dominant FA, together comprising 96.6% – 97.8% of total FA, respectively. Especially, the oleic acid content was the highest, and reached 32.83 – 37.74 g per 100 g oil, and followed with α-linolenic acid (23.40 – 26.49 g per 100 g oil), which was line with the results of 11 species of *Paeonia* and 60 ornamental cultivars of tree peony (Yu et al., 2016; Li et al., 2015). Nine other minor FA were also found in *P. ludlowii* seed oil, but their contents of every 100 g oil were below 0.5 g, this was different with the report that only four minor FA were found in the seeds of 60 tree peony cultivars (Li et al., 2015), and Zhang et al. (2018) found ten minor FA in the seed oil of four *Paeonia* species (*P. ostii*, *P. rockii*, *P. veitchii* and *P. lactiflora*). These results indicated that the seeds of different *Paeonia* species contained diverse minor FA except the five main FA. In addition, the content of unsaturated FA (UFA) varied from 88.05% – 88.69% in seed oil, which was higher than that of Canola, Sunflower and Cardoon (Carvalho et al., 2006).

The composition and content of FA was often affected by environmental factors, especially temperature. Angeloni et al. (2017) indicated that oleic acid percentage in sunflower oil was closely related to minimum night temperature during a short period of grain filling. Rondanini et al. (2014) found that temperature during oil synthesis was negatively related to final oil concentration of olive. Tlili et al. (2018) found that temperature can affect fatty acid composition of *Schinus terebinthifolius* and *Schinus molle* fruits, particularly palmitic, oleic and linoleic acids. In this study, location explained an important proportion of variability of seed oil when comparing *P. ludlowii* from fairly high

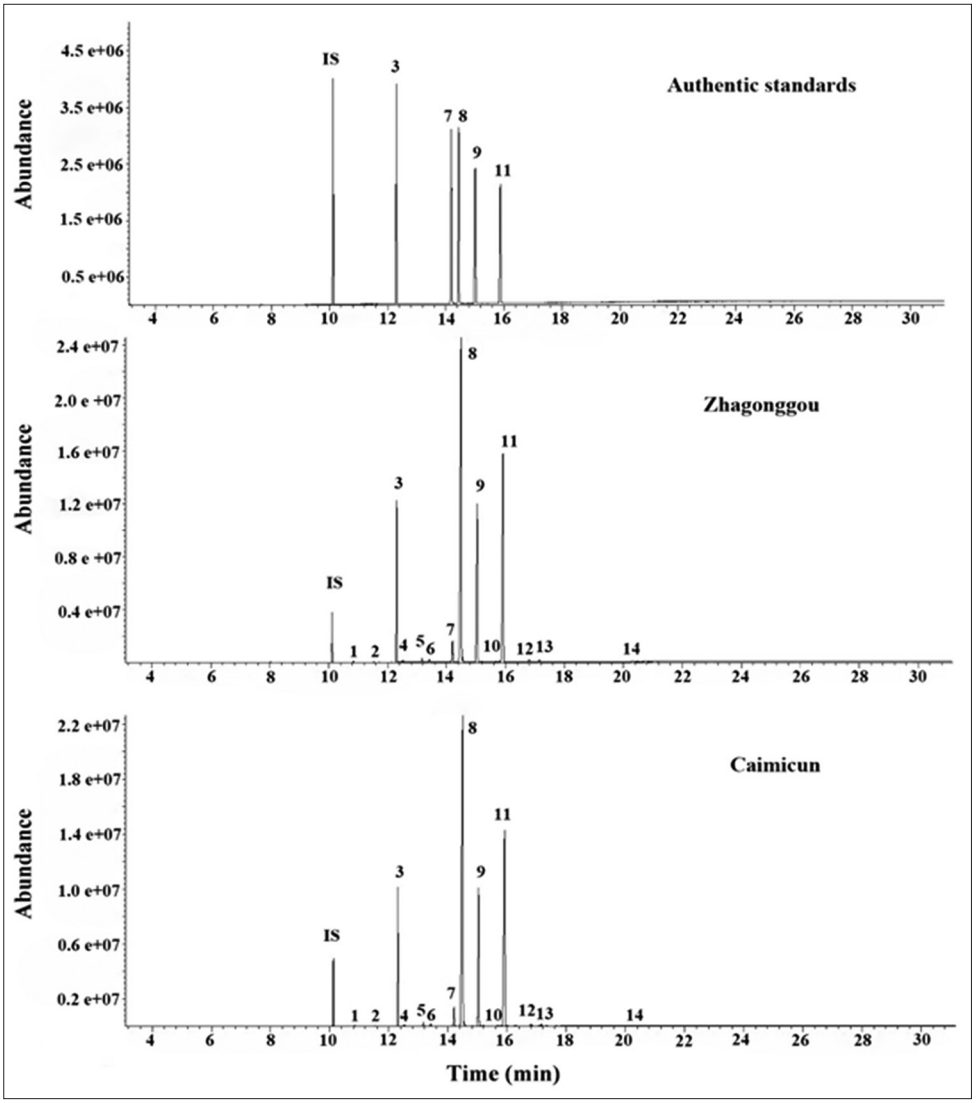

Fig 1. GC–MS of fatty acids in the seed oils of *Paeonia ludlowii* from two locations. Peaks: IS = C13:0 (internal standard). 1 = C14:0; 2 = C15:0; 3 = C16:0 (Palmitic acid); 4 = C16:1$^{\Delta 9}$; 5 = C17:0; 6 = C17:1$^{\Delta 10}$; 7 = C18:0 (stearic acid); 8 = C18:1$^{\Delta 9}$(oleic acid); 9 = C18:2$^{\Delta 9,12}$ (linoleic acid); 10 = C19:1$^{\Delta 10}$; 11 = C18:3$^{\Delta 9,12,15}$ (α-linolenic acid); 12= C20:0; 13 = C20:1$^{\Delta 11}$; 14 = C22:0.

mountainside (Zhagonggou, 3210 m asl) with a lower elevation river valley (Caimicun, 2939 m asl), the higher content of FA, especially unsaturated FA, may be related to the lower temperature in Zhagonggou. Moreover, plants of *P. ludlowii* grew under the tall trees in Caimicun, the low FA content of them could be also relative to insufficient light, which was in agreement with the results of Han et al. (2018), who indicated that light shading could improve seed weight and content of unsaturated FA in seed oil of *P. ostii* 'Feng Dan', while moderate or severe shading was opposite.

The ω6 and ω3 FA are commonly in the form of linoleic acid and α-linolenic acid, and they have reciprocal biological activities. Table 3 also showed that the ratios of ω6/ω3 FA ranged from 0.58 to 0.65 in two locations, which agreed with the report that ω6/ω3 ratio in peony seed oil was less than 1.0 in all observed species (Yu et al., 2016), and this ratio was also significantly lower than the seed oils of some crops (with the ω6/ω3 ratio of 1.8-78.6) (Carvalho et al., 2006). High ω6/ω3 ratio usually could promote the pathogenesis of many diseases, including cardiovascular disease, cancer, inflammatory and autoimmune diseases, whereas increased levels of ω3 UFA (a low ω6/ω3 ratio) exert suppressive effects (Simopoulos, 2002).

Antioxidant activities

A dose-dependent capacity for radical scavenging activity of DPPH and ABTS radicals were examined for oil and flower samples, and the IC_{50} values were calculated and listed in Table 4. The antioxidant capacity can be arranged in the order, trolox > flower extracts > seed oil. The high antioxidant activity of flowers could be due to the bioactive component of flavonoids and phenolic compounds, which was also demonstrated in sunflower and 23 species of cultivated edible flowers (Ye et al., 2015; Chen et al., 2015). In addition, the DPPH and ABTS scavenging rate of seed oil reached above 90%, which was higher than olive, sunflower, soybean and cotton seed oils (28.4–78.9% radicals reduction) reported by Kalantzakis et al. (2006). However, there was no significant difference in seed oil and flower extract between two locations according to the IC_{50} values.

Table 3: Fatty acid content of *Paeonia ludlowii* seed oil in two locations

Fatty acids	Retention time (min)	Content (g/100 g seed oil)		Mean
		Caimicun	Zhagonggou	
C16:0	12.308	6.87±0.17^b	8.79±0.29^a	7.83
C18:0	14.202	1.27±0.04^b	1.53±0.06^a	1.40
C18:1$^{\Delta 9}$	14.489	32.83±0.85^b	37.74±1.13^a	35.29
C18:2$^{\Delta 9,12}$	15.039	13.54±0.42^b	17.26±0.59^a	15.40
C18:3$^{\Delta 9,12,15}$	15.916	23.40±0.74^b	26.49±0.82^a	24.95
C14:0	10.842	0.07 ±0.01^b	0.09 ±0.004^a	0.08
C15:0	11.544	0.04 ±0.01^a	0.05 ±0.01^a	0.05
C16:1$^{\Delta 9}$	12.537	0.14±0.02^b	0.18 ±0.01^a	0.16
C17:0	13.179	0.34 ±0.03^b	0.42 ±0.02^a	0.38
C17:1$^{\Delta 10}$	13.413	0.28 ±0.04^a	0.33 ±0.02^a	0.31
C19:1$^{\Delta 10}$	15.672	0.12 ±0.02^a	0.13 ±0.01^a	0.13
C20:0	16.821	0.28 ±0.04^b	0.37 ±0.02^a	0.33
C20:1$^{\Delta 11}$	17.152	0.28 ±0.05^a	0.33 ±0.03^a	0.31
C22:0	20.331	0.10 ±0.02^a	0.15 ±0.02^a	0.13
TFA amounts		80.66±1.37^b	93.35±2.83^a	87.01
SFA amounts		9.13±0.18^b	11.15±0.33^a	10.14
UFA amounts		71.53±1.20^b	82.20±2.51^a	76.87
% SFA of TFA		11.31	11.94	11.63
%UFA of TFA		88.69	88.05	88.37
ω 6/ω 3		0.58	0.65	0.62

TFA: Total fatty acids; SFA: saturated fatty acids; UFA: unsaturated fatty acids. Values represent means ± SD, and the different letters indicate significant difference at *P<0.05* level.

Table 4: Comparison of antioxidant activity of seed oils and flower extracts

Samples	Scavenging of DPPH, IC_{50}, (mg/mL)		Scavenging of ABTS, IC_{50}, (mg/mL)	
	Seed oil	Flower extract	Seed oil	Flower extract
Zhagonggou	8.043± 0.055^b	0.031± 0.000^b	13.160±0.174^b	0.334±0.024^b
Caimicun	8.079 ± 0.041^b	0.032± 0.001^b	13.509±0.351^b	0.346±0.008^b
Trolox	0.004 ± 0.000^a	0.004 ± 0.000^a	0.006 ± 0.000^a	0.006 ± 0.000^a

The data are the means ± SD (n = 3). Different letters in the same column indicate significant statistical differences (*p<0.05*).

CONCLUSIONS

The results presented in this study were the first data on the effect of location on the nutrition composition of flowers, seed oil and antioxidant activity of *P. ludlowii*. The results indicated that flowers of *P. ludlowii* contained lots of beneficial nutrients to the human body, and also exhibited a high antioxidant activity. Seed oil was rich in unsaturated FA, especially with high oleic acid, α-linolenic acid and linoleic acid. It could be concluded that flowers and seed oils have the potential for healthy food in human diets. Content of nutrient in flowers and FA in seed oils were significantly different between two locations due to the impact of different growing environments, and detailed compounds of phenols and flavonoids in flowers will be studied in future work.

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Authors' contributions

Li J. designed research, performed research, analyzed data, and both of Li J. and Wang Z. H. wrote the paper.

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