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REGULAR ARTICLE

Nutritional evaluation of herbaceous peony (*Paeonia lactiflora* Pall.) petals

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ABSTRACT

Herbaceous peony (*Paeonia lactiflora* Pall.) is a kind of plant with ornamental, edible and medicinal values, and few studies were concerned to edible aspect of herbaceous peony petals. The aim of this research is to establish edible quality evaluation system of herbaceous peony flowers. Petals of 46 *P. lactiflora* cultivars at full bloom period were used to determine the content of soluble sugar, organic acid, protein, Vc (Vitamin C), total phenolics, total flavonoids, mineral elements and SOD (superoxide dismutase) activity and screen out evaluation index for edible herbaceous peony. The results showed that flower petals of herbaceous peony contained lots of nutrients and the contents varied with different cultivars. The soluble sugar content was 66.55-177.28 mg/g FW, organic acid 2.19-6.90 mg/g FW, soluble protein 6.53-121.56 mg/g FW, Vc 9.77-30.24 mg/100 g FW, total phenolics 9.41-33.01 mg/g DW, total flavonoids 3.50-17.56 mg/g DW, SOD activity 305.62-520.42 U/g FW, total amino acids 6.43-11.99 g/100 g DW. The average content of Na, Mg, K, Ca, Mn, Fe, Ni, Zn, Mo, Cr were 55.88 ± 14.90 μg/g DW, 1218.22 ± 349.60 μg/g DW, 11252.23 ± 2477.54 μg/g DW, 1975.40 ± 706.58 μg/g DW, 8.30 ± 6.55 μg/g DW, 103.56 ± 182.72 μg/g DW, 10.73 ± 37.94 μg/g DW, 22.80 ± 16.68 μg/g DW, 1.84 ± 5.89 μg/g DW and 17.36 ± 44.89 μg/g DW, respectively. Based on principal component analysis and cluster analysis, we found 'Dielian Qihua', 'Zhushapan', 'Xueyuan Honghua', 'Wulong Jisheng', 'Honglou', 'Bingshan', 'Hongyan Yushuang', 'Zituo Ronghua', 'Zifengyu', 'Fenlou Dianchun' had better edible quality. The results will provide some information for the comprehensive utilization of herbaceous peony petals and the breeding of edible herbaceous peony cultivars.

Keywords: Bioactive compound; Flower; Nutritional component; *Paeonia lactiflora*

INTRODUCTION

Edible flowers contribute to the increase of aesthetic appearance of food, they are used during the cooking preparation, but more often they are mentioned in connection with numerous nutritional and bioactive phytochemicals which contribute to their health benefits, and consumption of edible flowers has increased significantly in recent years (Mlcek and Rop, 2011; Xiong et al., 2014; Lu et al., 2016). The renewed interest in cooking and garnishing with flowers has also prompted extensive researches in the nutritional value of edible flowers (Cunningham, 2015). Edible flowers are rich in sugar, organic acid, protein, amino acid, mineral element, flavonoids, polyphenols, anthocyanins, carotenoids, fibers, volatiles and so on (Sotelo et al., 2007; Matthaus and Ozcan, 2011; Rop et al., 2012; Chen et al., 2015; Bayram et al., 2015; Benvenuti et al., 2016; Feng et al., 2016; Grzeszczuk et al., 2016), some of which are known to have biological activities and high antioxidant capacities (Shi et al., 2009; Jin et al., 2013; He et al., 2015; Koike et al., 2015; Tundis et al., 2015 ; Loizzo et al., 2016).

Herbaceous peony (*Paeonia lactiflora* Pall.) is a kind of plant with ornamental, edible and medicinal functions, and has lots of cultivars with different flower colors and types (Jia et al., 2008). The roots, leaves and flowers of herbaceous peony can be used to extract different components (Jia et al., 2008; Zhou et al., 2011; Ning et al., 2015; Jin et al., 2013; Feng et al., 2016). The medical function of herbaceous peony was recorded in ancient Chinese literatures which believed that herbaceous peony flower tea can nourish liver, regulate female endocrine and improve body immunity. For a long time, researches of herbaceous peony were mainly focused on flower ornamental characteristics (Jia et al., 2008) and root medicinal value (Hou et al., 2012),

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especially the underlying mechanisms of flower coloration (Zhao et al., 2014; Wu et al., 2016; Zhao et al., 2016). However, few studies were concerned to edible value of herbaceous peony petals. Yu (2011) and Liu (2014) found that herbaceous peony petals containing lots of chemical compositions such as vitamins, protein, sugar, organic acid, as well as rich mineral elements and amino acids. In addition, herbaceous peony petals also contained a large number of total phenolics, flavonoids and other bioactive substances, which have a strong ability to eliminate free radicals (Jin et al., 2013). In this study, petal nutritional qualities of different cultivars at full bloom stage were investigated to screen out peony varieties with better edible quality. The research results may lay the foundation for the comprehensive utilization of herbaceous peony petals and edible herbaceous peony cultivation and development.

PLANT MATERIALS AND METHODS

Plant materials

Flowers of 46 *P. lactiflora* cultivars at full bloom stage were sampled from April to May, 2015 (Fig. 1). All the flower materials were collected from Peony Germplasm Resource Garden, College of Horticulture and Plant Protection, Yangzhou University, Jiangsu Province, China (32°30' N, 119°25' E). The petals were detached from flowers, some petals were dried to a constant weight in an oven at 60 °C, and the rest petals were immediately frozen with liquid nitrogen and stored in a ultra-low temperature refrigerator under -80 °C until use.

Methods

Determination of nutritional and bioactive component

Soluble sugar content was determined by anthrone colorimetry at 630 nm wavelength (Liu & Li, 2007). Organic acid content was determined by acid-base titration with 0.02 mol/L NaOH (Liu & Li, 2007). Protein content was determined by Coomassie brilliant blue G-250 staining under 595 nm wavelength (Liu & Li, 2007). Vitamin C (Vc) content was determined using 2,6-dichloro-indigo colorimetry until the solution color changed from blue to pink (Ahmed et al., 2014). Mineral element content was determined with a Thermo Fisher ICAP 6300 ICP instrument (Thermo Fisher, USA) according the method of Du et al. (2012) after nitric acid (HNO_3) digestion of dried petal samples. Amino acid content was determined with Biochrom 30 automatic amino acid analyzer (Biochrom, UK) after hydrochloric acid hydrolysis of dried petal samples according the method of Qureshi et al. (2014). The analyzed amino acid include threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, aspartic acid, serine, glutamic acid, glycine, alanine, cysteine, tyrosine, arginine and proline. Total flavonoids were determined by Al $(NO_3)_3$-$NaNO_2$ colorimetry method (He et al., 2015). Total phenolics were determined using Folin-Ciocalteu procedure (Huang et al., 2005). Superoxide dismutase (SOD) activity was measured with reagent kits from Nanjing Jiancheng Biological Co. Ltd. (Nanjing, China) according to the operation instruction. The amount corresponding to 50% SOD inhibition rate in 1 mL reaction mixture per gram fresh weight of petals. All above analysis were performed in triplicate.

Statistical analysis

Evaluation index screening was carried out based on cultivar variation and quality correlation analysis of 46 *P. lactiflora* cultivars using IBM SPSS 20 software (IBM, USA). The corresponding values of the principal components were obtained according to the expression calculation of the principal components. Case (Q type) analysis of principal components and cluster analysis of each cultivar were performed on the selected evaluation indexes with Ward's minimum-variance method and Euclidean distance, and then cultivars with better eating qualities were obtained.

RESULTS

Evaluation index screening of nutritional components

The contents of four nutritional quality indexes in flower petals of 46 herbaceous peony cultivars and their average value, standard deviation and variation coefficient were listed in Table 1. The data showed that the average content of soluble sugar, organic acid, protein and Vc on fresh weight (FW) basis were 118.40±28.26 mg/g FW, 4.34±1.04 mg/g FW, 51.39±30.28 mg/g FW, and 14.88±4.94 mg/100 g FW, respectively. The contents of four nutritional components varied with different cultivars, and their variation coefficient also differed from each other. Variation coefficient is the difference between cultivars, the higher the value, the greater the difference among cultivars. The variation coefficient of soluble sugar (23.87%) and organic acid (23.96%) was smaller. The variation coefficient of Vc was centered, with the value of 33.17%. The variation coefficient of protein was the largest, reaching 58.92%. The results showed that the difference of soluble sugar and organic acid content was smaller between cultivars, while the difference of protein and Vc content was much bigger. Protein and Vc content had great influence on the edible quality of different cultivars. Therefore, protein and Vc were screened as evaluation indexes of nutritional components.

Evaluation index screening of bioactive components

The content of three bioactive component quality indexes in flower petals of 46 herbaceous peony cultivars and their average value, standard deviation and variation

Fig 1. Flowers of 46 cultivars of *P. lactiflora* at full bloom stage.

Cultivars were ranged in order according to the color of flower petal from light to deep, with complex colors in the end. V1, 'Yulou Hongxing'; V2, 'Bingshan'; V3, 'Taohua Feixue'; V4, 'Zhushapan'; V5, 'Xishifen'; V6, 'Qili'; V7, 'Shengtaohua'; V8, 'Zhusha Dianyu'; V9, 'Fenpan Chengyan'; V10, 'Jingling Piaoxiang'; V11, 'Taohua Xijin'; V12, 'Fenlou Dianchun'; V13, 'Lanyu Huancui'; V14, 'Chenxi'; V15, 'Fenyinzhuang'; V16, 'Zilankui'; V17, 'Lanyu Jiaohui'; V18, 'Zhongshengfen'; V19, 'Taoli Yangzhuang'; 20, 'Ziyulian'; V21, 'Fenlanlou'; V22, 'Xixia Yinxue'; V23, 'Zhaoyuanhong'; V24, 'Hongyan Yushuang'; V25, 'Dadi Lushuang'; V26, 'Wulong Jisheng'; V27, 'Hongmanao'; V28, 'Dielian Qihua'; V29, 'Ziling Jinxing'; V30, 'Dafugui'; V31, 'Honglou'; V32, 'Niaochao'; V33, 'Hongyan Zhenghui'; V34, 'Zituo Ronghua'; V35, 'Huangguanfen'; V36, 'Honglou Piaoxiang'; V37, 'Yanzi Xiangyang'; V38, 'Xueyuan Honghua'; V39, 'Liehuo Jingang'; V40, 'Zifengyu'; V41, 'Zihong Jianrong'; V42, 'Huangxiuzhen'; V43, 'Jinlian Xianyu'; V44, 'Tailian'; V45, 'Zilou Xianjin'; V46, 'Zitan Xiangyu'.

Table 1: Variation of nutritional components in different *P. lactiflora* cultivars

No.	Soluble sugar (mg/g FW)	Organic acid (mg/g FW)	Protein (mg/g FW)	Vc (mg/100g FW)	No.	Soluble sugar (mg/g FW)	Organic acid (mg/g FW)	Protein (mg/g FW)	Vc (mg/100g FW)
V1	177.28±2.61	4.05±0.05	11.06±2.34	9.90±0.66	V25	111.62±3.73	4.67±0.18	95.97±2.25	10.86±0.43
V2	85.89±0.22	4.50±0.05	71.90±3.17	11.52±0.75	V26	103.40±3.09	3.90±0.18	87.47±2.45	16.42±1.18
V3	103.53±3.77	4.43±0.08	53.30±4.44	10.08±0.16	V27	120.05±3.23	6.59±0.15	57.67±2.81	15.01±1.01
V4	166.88±10.27	4.50±0.05	60.34±1.75	11.13±0.85	V28	119.49±3.53	5.41±0.11	77.50±3.07	15.17±0.79
V5	75.13±5.23	2.50±0.23	48.02±2.61	13.02±0.66	V29	142.82±1.39	4.59±0.14	33.82±10.39	19.33±1.46
V6	104.16±3.47	4.35±0.05	85.01±2.72	12.81±1.19	V30	102.80±4.43	6.60±0.13	56.86±1.22	15.95±1.46
V7	130.82±11.52	2.25±0.05	36.43±1.07	10.72±0.30	V31	107.66±1.54	6.30±0.03	72.50±6.84	12.97±0.12
V8	166.04±5.26	4.77±0.18	36.94±0.25	10.34±0.49	V32	82.11±2.65	4.33±0.18	121.56±1.73	20.09±0.28
V9	141.62±9.94	4.87±0.14	48.33±0.75	14.67±0.96	V33	110.99±3.46	4.51±0.03	58.44±1.43	19.12±0.70
V10	93.41±0.84	2.71±0.03	46.85±5.21	12.26±0.09	V34	108.99±0.60	4.89±0.16	49.38±4.06	20.24±1.19
V11	98.49±3.15	4.35±0.15	26.27±1.29	12.29±0.67	V35	93.81±3.40	3.07±0.04	54.16±2.37	17.74±1.46
V12	111.13±1.58	6.00±0.35	103.07±2.83	14.51±0.98	V36	116.00±4.59	6.90±0.24	74.26±2.49	30.23±0.99
V13	93.04±2.45	2.70±0.10	28.87±1.72	11.23±0.18	V37	109.12±1.66	4.95±0.10	50.15±3.89	24.02±1.03
V14	127.48±1.71	2.72±0.03	7.39±0.36	12.00±0.16	V38	109.99±3.64	5.67±0.18	98.39±2.19	25.59±1.95
V15	132.45±1.05	2.98±0.21	23.83±0.95	10.52±0.38	V39	148.99±2.60	5.89±0.14	107.62±2.23	30.24±0.87
V16	175.16±3.72	4.80±0.18	16.11±1.55	12.88±0.88	V40	166.85±1.92	5.58±0.24	6.53±0.59	20.45±0.37
V17	66.55±4.62	2.60±0.10	40.26±1.50	14.80±0.71	V41	156.81±2.41	4.88±0.11	21.03±1.87	12.87±0.12
V18	97.94±2.17	4.38±0.13	12.21±0.43	10.56±1.13	V42	115.79±4.46	2.19±0.05	45.73±0.60	14.74±0.32
V19	72.15±1.58	4.35±0.15	32.60±2.01	14.39±0.55	V43	113.19±3.09	4.14±0.08	82.20±1.22	12.05±0.47
V20	115.24±2.92	4.68±0.24	34.70±2.66	12.52±0.13	V44	106.26±3.62	2.73±0.07	40.57±3.54	11.86±0.09
V21	100.06±0.77	3.48±0.13	21.30±1.02	9.77±0.38	V45	90.67±1.90	2.68±0.06	10.97±1.99	12.04±1.10
V22	130.19±2.63	3.30±0.15	79.36±3.12	13.31±0.17	V46	168.04±3.00	4.53±0.10	8.20±1.36	12.33±0.62
V23	153.63±5.29	5.88±0.40	28.40±2.41	14.98±1.10	Average	118.40±28.26	4.34±1.04	51.39±30.28	14.88±4.94
V24	122.54±1.56	3.60±0.20	100.29±2.63	15.07±0.61	CV(%)	23.87	23.96	58.92	33.20

All analysis were carried out triplicate and based on fresh weight (FW), the average content was the mean value of 46 cultivars, CV means cultivar variation

Table 2: Variation of active ingredients in different *P. lactiflora* cultivars

No.	Total phenolics (mg/g DW)	Total flavonoids (mg/g DW)	SOD (U/g FW)	No.	Total phenolics (mg/g DW)	Total flavonoids (mg/g DW)	SOD (U/g FW)
V1	16.62±0.54	14.40±0.42	456.84±7.47	V25	21.41±1.26	7.93±1.45	398.63±15.20
V2	21.28±0.10	7.44±0.09	500.00±4.34	V26	23.46±0.90	7.08±0.25	456.84±7.47
V3	20.18±1.31	6.47±0.41	379.34±11.61	V27	23.39±1.00	11.53±1.33	377.29±1.81
V4	25.41±0.90	8.52±0.08	455.54±8.13	V28	14.55±1.82	6.21±0.29	418.33±4.63
V5	12.79±0.38	8.75±0.40	462.60±7.88	V29	15.06±0.63	5.50±0.06	402.13±3.79
V6	15.72±1.02	12.69±0.25	472.85±3.53	V30	16.69±0.69	6.38±0.51	426.27±12.17
V7	23.06±0.71	11.37±0.04	386.76±18.95	V31	21.10±0.20	7.42±0.07	442.95±7.65
V8	22.02±1.47	16.45±0.37	447.50±6.32	V32	11.30±0.69	9.19±1.30	429.16±9.63
V9	17.99±0.34	3.50±0.29	345.05±12.23	V33	33.01±0.50	8.59±0.72	464.85±9.36
V10	15.43±1.35	11.81±0.46	496.45±9.07	V34	16.08±1.87	6.92±0.38	480.16±10.21
V11	21.12±0.15	11.82±1.09	456.90±9.47	V35	31.10±0.19	7.92±0.94	498.30±3.79
V12	32.23±0.61	10.30±0.75	442.49±5.88	V36	23.16±0.83	6.82±0.35	381.57±9.72
V13	14.22±0.64	6.35±0.53	466.57±9.50	V37	21.37±1.51	7.68±0.19	439.31±7.88
V14	9.41±0.84	8.51±0.64	434.76±6.11	V38	28.53±0.60	6.64±0.55	465.00±12.50
V15	24.70±0.06	7.88±0.41	413.00±6.78	V39	22.41±2.10	5.49±0.29	305.62±16.20
V16	20.48±1.31	7.12±0.07	469.40±10.00	V40	14.74±1.77	5.52±0.42	443.73±13.99
V17	21.51±0.37	8.22±0.23	490.90±6.16	V41	30.51±2.05	7.34±0.20	475.40±10.28
V18	27.69±1.73	8.29±0.45	462.60±7.88	V42	31.98±0.92	9.48±0.53	463.36±8.68
V19	20.23±0.84	8.28±0.36	449.08±6.18	V43	18.35±1.15	8.97±0.17	520.42±7.05
V20	21.72±0.70	8.17±0.40	447.15±2.67	V44	30.92±0.76	8.66±0.19	474.53±7.50
V21	11.97±1.53	8.63±0.30	356.97±9.20	V45	12.72±0.77	7.71±0.64	415.48±9.51
V22	11.16±0.87	17.56±1.02	448.63±5.48	V46	13.84±0.83	8.52±0.52	399.51±9.20
V23	12.51±1.91	8.53±0.09	448.63±5.48	Average	19.17±6.36	8.27±2.83	433.18±44.79
V24	15.83±0.20	13.66±0.08	504.35±5.50	CV(%)	33.18	34.22	10.34

All analysis were carried out triplicate, total phenolics and total flavonoids analysis were based on dry weight (DW), while SOD (Superoxide dismutase) analysis were basesd on fresh weight (FW), the average content was the mean value of 46 cultivars, CV means cultivar variation coefficient were listed in Table 2. The data showed that the average content of total phenolics and flavonoids were 19.17±6.36 mg/g DW and 8.27±2.83mg/g DW, respectively. The average value of SOD activity was 433.18±44.79 U/g DW. Among different cultivars, the variation coefficient of SOD activity (10.34%) was smaller, while those of total phenolics and flavonoids were much bigger, with the value of 33.18% and 34.22%, respectively. The results showed that the difference of SOD activity was smaller between cultivars, while the difference of total phenolics and flavonoids were much bigger. Therefore, total phenolics and flavonoids were screened as evaluation indexes of bioactive components.

The correlation coefficient analysis was performed between 7 quality indexes in Table 1 and Table 2. The larger the correlation coefficient between two indexes, the more related between them. Therefore, one of them can be selected as a representative index of evaluation, as the basis for the simplified index (Yang et al., 2011). From the results, we found that the correlation coefficients between 7 quality indexes were all less than 0.5 whether it is positive or negative correlation (Table 3). The correlation between Vc, protein, total phenolics and flavonoids were lower and can't be simplified. Combined with the data of Table 1, Table 2 and Table 3, protein, Vc, total phenolics and total flavonoids were screened as the evaluation indexes of the nutritional components and the bioactive ingredients.

Evaluation index screening of mineral elements

The contents of 10 mineral elements in the flower petals of different herbaceous peony cultivars were shown in Table 4. Na, Mg, K, Ca, Mn, Fe, Ni and Zn were found in the flower petals of 46 cultivars, and Mo, Cr were detected in the flower petals of most cultivars. The variation coefficients of Na, Mg, K and Ca (22.67%, 28.70%, 22.02% and 35.77%) were lower than those of other mineral elements. The variation coefficients of Mn and Zn arranged in the middle, with the value of 78.92% and 73.16%. The variation coefficients of Fe, Ni, Mo and Cr were larger and all more than 100%. The results indicated that six mineral elements including Fe, Ni, Mo, Cr, Mn and Zn had a greater effect on cultivar differences.

The correlation between ten analyzed mineral elements was carried out (Table 5). There was significant correlation $p<0.01$ between Mn and Fe, Ni, Cr, Mo, and the correlation coefficients were all more than 0.9. There was also significant correlation $p<0.01$ between Mg and K, Ca, Zn, and the correlation coefficients were all more than 0.7. Na had no obvious relation with other mineral elements. Mn, Fe, Ni, Cr and Mo had close correlation, Mg, K, Ca, Zn also had close correlation, so one element can be selected from each group to represent them. Because Fe and Zn have a very important role in the human body, so Fe and Zn were screened to represent the 6 elements. Combined with the data of Table 4 and Table 5, Fe and Zn were selected as the evaluation indexes of mineral elements.

Evaluation index screening of amino acids

All 17 amino acids were found in the flower petals of 46 herbaceous peony cultivars, and individual amino acid content and proportion varied with different cultivars. The total amino acids was from 8.68 g/100g DW to 9.09 g/100g DW, with essential amino acids accounting for about 42%. The variation coefficients of 17 amino acids varied with different cultivars (Table 6). The difference of Thr (threonine), Val (valine), Ile (isoleucine), Leu (leucine), Gly (glycine), His (histidine) and Arg (arginine) between cultivars were smaller, the difference of Asp (aspartic acid), Ser (serine), Glu (glutamic acid), Ala (alanine), Cys (cysteine) and Tyr (tyrosine), Pro (proline) between cultivars were in the middle, while the variation coefficients of Lys (lysine), Met (methionine) and Phe (Phenylalanine) between cultivars differed greatly.

The correlation analysis between 17 amino acids was performed (Table 7). There was significant correlation $p<0.01$ between threonine, valine, isoleucine, leucine, lysine, aspartic acid, serine, glutamic acid, glycine, alanine, proline, and the correlation coefficients were more than 70%, with most more than 85%. There was also significant correlation $p<0.01$ between tyrosine and histidine, and the correlation coefficients was 80%. There was no obvious relation between methionine, phenylalanine, cysteine, and arginine acid, as well as between them and other amino acids. This showed that 17 amino acids can be represented by 6 amino acids. Combined with the data of Table 6 and

Table 3: Correlation matrix of the 7 quality parameters in different *P. lactiflora* cultivars

	Soluble sugar	Organic acid	Protein	Vc	Total phenolics	Total flavonoids	SOD
Soluble sugar							
Organic acid	0.278**						
Protein	–0.272**	0.296**					
Vc	–0.003	0.472**	0.408**				
Total phenolics	–0.020	0.098	0.140	0.126			
Total flavonoids	0.102	–0.247**	0.058	–0.350**	–0.082		
SOD	–0.227**	–0.302**	–0.014	–0.234**	0.147	0.274**	

**Means significant correlation at the 0.01 level (2‑tailed)

Table 4: Variation of mineral elements concents in different *P. lactiflora* cultivars (μg/g DW)

No.	Na	Mg	K	Ca	Mn	Fe	Ni	Zn	Mo	Cr
V1	29.94±4.03	1346.23±12.30	11710.79±106.01	3233.20±56.34	8.96±0.47	60.59±3.67	0.51±2.13	22.51±1.22	0.31±0.03	5.09±0.47
V2	36.91±13.89	975.48±31.56	10821.84±345.16	1264.00±35.80	5.05±0.02	36.74±6.76	5.12±5.02	16.46±0.54	0.46±0.15	5.01±2.39
V3	15.39±1.02	1008.05±50.36	12313.88±270.73	2147.89±103.17	6.94±0.43	49.40±2.33	8.15±3.74	16.60±1.03	0.50±0.04	11.67±0.64
V4	35.58±10.33	1352.82±60.24	12963.71±283.41	2000.00±43.61	6.96±0.47	32.76±2.02	0.20±0.01	24.80±0.93	0.30±0.10	3.63±0.37
V5	36.54±16.20	1349.26±69.70	12844.73±359.76	1571.12±51.08	6.92±0.69	62.61±5.13	7.20±5.83	22.89±2.05	0.60±0.10	8.46±1.36
V6	23.92±8.49	631.02±70.20	6300.85±734.72	1230.69±159.55	3.64±0.53	39.87±8.10	0.00±0.00	13.28±1.46	0.35±0.25	3.03±0.53
V7	10.49±8.68	628.55±194.95	5992.52±1943.22	978.26±284.80	4.52±1.30	34.77±3.78	0.45±0.45	12.41±3.76	0.30±0.00	3.67±0.25
V8	49.25±2.58	1105.50±25.86	10942.58±65.57	1864.11±75.81	8.92±0.65	54.04±17.85	3.00±1.38	23.72±3.26	1.07±0.66	8.88±3.24
V9	38.77±3.72	760.78±200.03	7372.08±1940.04	1154.42±314.26	4.10±1.36	42.42±4.24	2.33±1.32	16.18±4.62	0.91±0.31	6.13±2.39
V10	41.26±9.44	852.63±228.69	9114.66±2712.64	1413.81±444.62	6.54±1.09	92.11±4.16	22.06±17.54	17.26±3.93	1.21±0.00	16.22±2.67
V11	73.68±15.57	945.68±30.67	12961.20±415.56	1420.17±31.73	7.21±0.21	54.32±2.90	1.46±0.34	21.12±0.88	0.50±0.10	6.39±1.62
V12	79.02±1.69	1210.28±35.18	11713.57±276.33	1810.85±64.90	8.85±1.05	167.52±18.54	25.11±14.99	25.13±0.63	3.39±0.65	34.93±3.96
V13	12.69±0.49	1017.05±286.87	8227.82±2310.31	1399.16±357.92	5.49±1.16	49.00±9.45	8.36±8.04	17.44±4.46	0.62±0.29	8.71±3.26
V14	37.35±12.75	1098.29±226.61	9909.68±2043.76	1797.14±335.45	5.71±0.97	62.02±0.38	0.59±0.81	19.50±3.78	0.40±0.30	6.21±2.06
V15	79.57±16.79	1086.04±78.95	10564.58±833.81	1448.74±99.55	5.50±0.74	37.92±7.25	0.96±0.45	23.40±1.95	0.20±0.10	5.20±0.47
V16	45.27±19.62	1269.59±4.06	13955.90±38.06	2241.12±77.79	7.48±0.07	61.53±10.02	1.20±0.40	22.94±0.30	0.80±0.40	8.93±1.89
V17	27.22±5.11	1072.92±146.96	10859.23±1399.80	2282.48±312.90	6.00±0.93	50.52±6.30	9.45±7.82	19.21±2.07	0.60±0.10	8.87±2.28
V18	23.95±10.90	872.93±25.45	8894.57±224.87	1331.17±28.14	6.57±0.21	56.23±13.00	2.88±1.36	16.63±0.57	1.11±0.61	9.15±0.77
V19	14.99±14.99	896.15±156.17	9403.40±1642.88	1424.70±249.35	4.62±0.81	35.93±16.39	1.71±1.11	20.99±1.95	0.45±0.35	5.03±3.02
V20	53.11±2.20	1095.69±60.62	11908.82±936.87	1499.50±112.73	6.01±0.30	51.85±6.66	0.90±0.60	19.64±1.60	0.30±0.10	5.06±2.25
V21	124.06±14.12	1628.87±13.41	15687.04±24.39	2260.77±13.78	9.33±0.01	133.86±11.82	2.73±3.18	27.23±0.18	0.55±0.35	9.63±4.92
V22	7.09±0.46	960.37±20.01	10588.11±166.42	1381.41±0.89	6.13±0.09	50.45±2.26	0.65±0.35	16.99±0.12	0.35±0.05	5.38±0.15
V23	28.48±6.06	1270.40±2.33	11107.73±6.72	2659.14±8.54	7.65±0.28	74.18±30.54	2.86±2.16	20.95±0.37	1.00±0.80	12.82±7.16
V24	130.36±10.03	1391.78±20.33	12324.65±231.46	2897.80±102.11	49.60±0.51	1236.47±10.21	57.82±0.14	31.16±0.13	38.78±2.03	30.90±2.32
V25	112.81±1.90	1695.31±18.84	15227.19±267.76	2167.34±85.19	14.47±0.13	259.70±10.30	0.00±0.00	33.15±0.19	0.51±0.01	6.89±1.53
V26	25.18±7.49	916.28±91.74	9453.36±1007.56	1360.54±128.44	5.00±0.51	38.13±7.36	3.28±1.23	17.09±1.35	0.20±0.20	5.66±1.16
V27	203.89±51.57	1510.61±71.21	14464.65±727.27	2519.70±157.07	9.60±0.40	101.36±18.94	4.70±2.27	31.67±1.87	0.76±0.35	10.15±4.09
V28	96.62±14.29	1375.76±26.26	11858.59±141.41	2321.72±13.64	7.42±0.35	73.23±17.58	5.81±4.19	22.53±0.91	0.61±0.20	8.79±3.03
V29	63.13±17.45	1103.07±170.57	11334.51±1683.6	1870.72±304.33	5.84±1.41	53.07±8.20	1.06±0.15	21.38±4.68	0.60±0.20	8.10±1.06
V30	55.41±0.88	760.23±50.31	6431.96±527.90	955.26±22.70	6.42±1.71	52.81±6.07	1.19±0.16	16.43±1.06	0.00±0.00	0.00±0.00
V31	63.07±0.02	1726.65±77.56	11757.46±672.26	3012.37±148.27	9.38±0.15	232.89±69.44	37.98±17.09	33.70±1.34	5.01±2.50	47.07±18.65
V32	12.93±0.02	1684.85±13.68	11595.96±153.37	3203.03±67.32	9.60±0.34	47.68±8.35	0.71±0.17	27.98±0.43	0.20±0.00	6.16±0.01
V33	47.87±0.49	1052.53±27.94	9874.93±480.46	1397.21±55.00	6.96±1.14	87.18±11.88	1.69±0.46	17.64±0.94	0.00±0.00	0.00±0.00
V34	52.76±6.10	1602.43±1.82	15453.54±180.26	2088.31±3.80	9.64±0.12	52.25±6.00	1.56±0.95	33.15±0.45	0.45±0.15	6.71±1.34
V35	31.68±0.25	1313.25±4.02	11561.24±155.62	1710.34±74.80	9.49±1.36	91.47±36.75	9.64±7.63	22.69±0.30	1.31±0.50	15.86±7.13
V36	96.66±4.05	1348.93±33.67	14210.38±425.24	1506.77±52.95	7.76±0.13	70.61±10.06	6.26±3.45	25.71±0.71	0.96±0.36	9.44±2.51
V37	77.25±15.63	1027.56±60.86	11025.91±772.87	1663.07±142.83	7.00±0.42	51.09±10.75	5.22±3.89	19.02±1.51	0.51±0.30	10.44±4.85
V38	22.71±0.68	1259.67±46.34	13951.12±353.22	2014.26±80.31	7.54±0.35	393.38±10.02	17.21±2.31	22.20±0.57	13.14±0.37	90.33±2.17
V39	177.02±19.45	1147.88±203.63	10908.99±808.18	2540.32±1457.66	9.54±3.09	156.59±31.09	14.53±3.95	31.90±10.53	2.12±0.30	24.92±4.52
V40	103.89±68.74	2082.32±437.88	12808.08±808.08	3318.69±665.15	6.87±0.41	29.70±9.32	1.41±0.30	22.22±0.42	0.30±0.02	3.84±0.07

(Contd...)

Table 4: (*Continued*)

No.	Na	Mg	K	Ca	Mn	Fe	Ni	Zn	Mo	Cr
V41	16.81±1.30	1104.39±38.47	11917.67±376.09	1591.27±36.50	6.82±0.33	46.14±6.48	1.31±0.01	19.90±0.42	0.56±0.05	9.68±3.50
V42	77.63±62.64	1763.50±186.19	11207.11±1076.59	3332.92±256.62	10.10±0.66	49.54±6.99	0.96±0.25	41.24±12.67	0.25±0.15	5.53±0.09
V43	20.77±4.13	891.03±218.41	7432.95±1889.34	1455.88±345.33	5.29±1.23	36.13±9.15	0.00±0.00	15.93±3.15	0.25±0.05	3.83±1.09
V44	57.49±24.05	1298.05±238.46	10435.95±2109.69	2281.15±387.21	7.04±1.38	67.14±18.25	8.67±7.05	31.78±0.44	0.61±0.51	10.03±4.88
V45	40.69±0.83	1659.56±18.15	14017.46±219.48	2982.46±28.65	10.62±0.22	68.15±9.06	1.86±0.85	27.84±0.27	0.65±0.35	8.75±4.00
V46	59.42±1.70	1887.78±85.17	12189.38±786.57	2863.23±149.80	10.62±0.30	78.41±26.00	3.01±0.60	25.15±1.20	0.60±0.20	7.36±0.85
Average	55.88±14.90	1218.22±349.60	11252.23±2477.54	1975.40±706.58	8.30±6.55	103.56±182.72	10.73±37.94	22.80±16.68	1.84±5.89	17.36±44.89
CV(%)	26.67	28.70	22.02	35.77	78.92	176.44	353.59	73.16	320.11	258.58

All analysis were carried out triplicate and based on dry weight (DW), the average content was the mean value of 46 cultivars, CV means cultivar variation

Table 7, Lys, Tyr, Met and Phe were choosed to on behalf of the 17 amino acids in the flower petals of herbaceous peony.

In summary, protein, Vc, total phenolics, total flavonoids, Fe, Zn, Lys, Tyr, Met and Phe were screened as physiological indexes for evaluating flower petal edible quality of herbaceous peony. The SPSS software was used to perform the principal component analysis and cluster analysis of 10 kinds of nutrients in the flower petals of 46 herbaceous peony cultivars.

Analysis of principal component characteristic value, contribution rate and cumulative contribution rate

The SPSS software was used to perform the principal component analysis of 10 kinds of nutrients in the flower petals of 46 herbaceous peony cultivars, and the cumulative variance contribution rate of the main component reached 82.77%, which explained the vast majority of the original information (Table 8). Eigenvalue of the first principal component was 2.547, and variance contribution rate was 19.164%, which represented19.164% of all quality traits information. Eigenvalue of the second principal component was 1.501, and variance contribution rate was 16.677%, which represented16.677% of all quality traits information. Eigenvalue of the third principal component was 1.364, and variance contribution rate was 13.664%, which represented13.664% of all quality traits information. Eigenvalue of the fourth principal component was 1.024, and variance contribution rate was 12.477%, which represented 12.477% of all quality traits information. Other principal component contribution rate were 10.399% and 10.385%, and they decreased gradually. The variance contribution rate of principal components showed that flower petal quality of herbaceous peony was influenced by many kinds of quality indexes, and the weight of each principal component was no much difference.

Analysis of principal component factor load matrix

The load matrix of the principal components and the original quality indexes clarified the weight of each quality index in the principal component. Therefore, the comprehensive quality index represented by principal component was judged according to the load of each quality index in each principal component. The load matrix of principal components on each quality index was showed in Table 9, and effects of the first 6 principal components reflected indexes were different in the determination of the nutritional quality of peony petals. The first principal components had greater load value on tyrosine and lysine contents, which showed that the first principal components mainly reflect the comprehensive index level of various amino acid contents in flower

Table 5: Correlation matrix of the mineral elements

	Na	Mg	K	Ca	Mn	Fe	Ni	Zn	Mo	Cr
Na										
Mg	0.413**									
K	0.421**	0.747**								
Ca	0.333**	0.833**	0.545**							
Mn	0.371**	0.318**	0.288**	0.401**						
Fe	0.320**	0.168*	0.192*	0.255**	0.933**					
Ni	0.262**	0.086	0.067	0.213*	0.930**	0.951**				
Zn	0.560**	0.724**	0.607**	0.689**	0.421**	0.298**	0.216*			
Mo	0.228**	0.098	0.124	0.212*	0.898**	0.979**	0.958**	0.211*		
Cr	0.248**	0.109	0.131	0.228**	0.910**	0.981**	0.970**	0.229**	0.997**	

**Means significant correlation at the 0.01 level (2-tailed), and * means significant correlation at the 0.05 level (2-tailed)

petals. The second principal components had greater load value on phenylalanine and protein contents. The third principal components had greater load value on total flavonoids and Vc contents, and the total flavonoids had larger positive correlation coefficient, and Vc had larger negative correlation coefficient. The fourth principal components had greater load value on Fe and Zn contents, which showed that the fourth principal components mainly reflect the comprehensive index level of various mineral elements in flower petals. The fifth principal components had greater load value on methionine content. The sixth principal component had greater load value on total phenolics content.

Comparison of the quality scores of principal components

The data of factor load matrix between the principal components and the quality indexes were input SPSS data editing window, and 6 principal component variables were named as al, a2, a3, a4, a5 and a6. Standard feature vector tij was constructed, which was represented by tij, and was calculated by the formula $tij=aij/\sqrt{\lambda i}$. At the same time, the original data of 10 quality indexes of 46 peony cultivars were standardized, eliminating the influence of different measurement unit and data dimension. The principal components were calculated with eigenvector matrix and standardized data with the formula $F=t\times ZX$, where F1~F6 was the 6 principal component, and ZX1~ZX10 was the standardized numerical value of the original data of 10 quality indexes in Table 10.

According to variance contribution rate of each principal components (the first principal component 19.164%, the second principal component 16.677%, the third principal component 13.664%, the fourth principal component 12.477%, the five principal component 10.399%, the six principal component 10.385%), the comprehensive score function (F) was calculated with following formula:

$$F=0.19\times F1+0.17\times F2+0.14\times F3+0.12\times F4+0.10\times F5+0.10\times F6.$$

Plugged the corresponding principal components into above formula, we got the following comprehensive score formula.

$$F=0.15\times Tyr + 0.12\times Lys + 0.14\times protein + 0.12\times Phe + 0.11\times total\ flavonoids - 0.01\times Vc + 0.15\times Zn + 0.15\times Fe + 0.11\times Met + 0.13\times total\ phenolics.$$

The principal components comprehensive score of each cultivar and their rank was listed in Table 11. The higher the comprehensive score, the better the quality. On the contrary, the lower the score, the worse the quality. In order to facilitate subsequent comparison, the ranking table was divided into three sections. Cultivars in the top ten were in the first section. Cultivars in the last ten were in the third section. Rest cultivars were in the second section. The flower petal qualities of 46 herbaceous peony cultivars were evaluated according to the comprehensive score of the principal component analysis. Cultivars in the first section included 'Dielian Qihua', 'Zhushapan', 'Xueyuan Honghua', 'Wulong Jisheng', 'Honglou', 'Binshan', 'Hongyan Yushuang', 'Zituo Ronghua', 'Zifengyu' and 'Fenlou Dianchun'. Cultivars in the third section included 'Zhongshengfen', 'Honglou Piaoxiang', 'Dafugui', 'Taoli Yanzhuang', 'Zilankui', 'Jinling Piaoxiang', 'Chenxi', 'Shengtaohua', 'Fenpen Chengyan' and 'Yulan Huancui'. Rest cultivars ranked in the middle and were in the second section.

Cluster analysis of different herbaceous peony cultivars

Principal component cluster analysis of different cultivars was demenstrated in Fig. 2. 46 herbaceous peony cultivars can be divided into different types with different class separation distance. When the class separation distance was ten, 46 herbaceous peony cultivars can be divided into three categories. The category closer to the top of the figure aggregated 10 cultivars, including V14, V19, V16, V9, V30, V11 V22, V7, V10 and V13, containing lower contents of total flavonoids, total phenolics, mineral elements such as iron, zinc and amino acid, with poorer

Table 6: Variation of amino acids in different *P. lactiflora* cultivars (g/100 g DW)

No.	Thr	Val	Met	Ile	Leu	Phe	Lys	Asp	Ser	Glu	Gly	Ala	Cys	Tyr	His	Arg	Pro	E	T
V1	0.37	0.62	0.16	0.49	0.70	0.65	0.44	0.82	0.47	1.06	0.44	0.44	0.11	0.33	0.23	0.45	0.27	3.52	8.14
V2	0.44	0.73	0.15	0.59	0.87	1.25	0.55	0.93	0.56	1.24	0.53	0.55	0.12	0.41	0.27	0.45	0.34	4.69	10.10
V3	0.39	0.61	0.15	0.49	0.73	0.67	0.46	0.84	0.49	1.10	0.44	0.46	0.13	0.36	0.23	0.46	0.29	3.60	8.40
V4	0.45	0.70	0.18	0.55	0.79	1.23	0.54	0.92	0.52	1.21	0.51	0.54	0.12	0.42	0.26	0.49	0.33	4.54	9.85
V5	0.42	0.67	0.14	0.55	0.82	0.41	0.52	0.88	0.49	1.36	0.50	0.52	0.10	0.38	0.18	0.43	0.35	3.60	8.80
V6	0.39	0.59	0.14	0.48	0.74	0.93	0.44	0.80	0.46	0.95	0.43	0.44	0.11	0.36	0.23	0.38	0.31	3.83	8.29
V7	0.42	0.59	0.13	0.52	0.79	0.37	0.51	0.85	0.51	1.07	0.48	0.51	0.11	0.36	0.16	0.37	0.33	3.36	8.11
V8	0.42	0.69	0.16	0.57	0.84	0.45	0.52	0.89	0.52	1.17	0.51	0.52	0.11	0.42	0.22	0.46	0.35	3.72	8.89
V9	0.43	0.66	0.14	0.54	0.80	0.38	0.50	0.90	0.49	1.18	0.48	0.50	0.15	0.38	0.17	0.40	0.31	3.51	8.46
V10	0.39	0.62	0.08	0.51	0.76	0.37	0.45	0.84	0.48	1.14	0.45	0.45	0.10	1.98	0.15	0.37	0.29	3.25	9.50
V11	0.31	0.45	0.03	0.36	0.59	0.62	0.39	0.61	0.37	0.80	0.38	0.39	0.11	0.28	0.12	0.39	0.24	2.75	6.43
V12	0.42	0.59	0.11	0.52	0.79	0.82	0.47	0.86	0.49	1.10	0.48	0.47	0.12	0.39	0.20	0.45	0.31	3.84	8.71
V13	0.35	0.59	0.13	0.44	0.65	0.34	0.40	0.75	0.42	1.10	0.39	0.40	0.10	0.25	0.14	0.35	0.29	2.94	7.13
V14	0.38	0.68	0.15	0.52	0.76	0.37	0.49	0.78	0.46	0.99	0.48	0.49	0.13	0.37	0.15	0.38	0.29	3.37	7.88
V15	0.36	0.56	0.12	0.46	0.68	0.71	0.41	0.78	0.45	0.98	0.40	0.41	0.12	0.35	0.19	0.39	0.25	3.39	7.72
V16	0.40	0.61	0.16	0.50	0.75	0.36	0.47	0.86	0.49	1.18	0.46	0.47	0.11	0.35	0.15	0.39	0.28	3.27	8.01
V17	0.35	0.41	0.01	0.33	0.56	0.43	0.41	0.73	0.44	0.91	0.41	0.41	0.11	0.31	0.23	0.42	0.29	2.62	6.89
V18	0.40	0.67	0.08	0.52	0.76	0.42	0.48	0.81	0.48	1.02	0.44	0.48	0.11	0.40	0.20	0.41	0.30	3.42	8.09
V19	0.42	0.66	0.16	0.53	0.80	0.37	0.50	0.87	0.50	1.09	0.47	0.50	0.11	0.41	0.16	0.39	0.29	3.48	8.28
V20	0.52	0.83	0.21	0.66	0.98	0.46	0.65	1.15	0.64	1.67	0.60	0.65	0.13	0.45	0.21	0.45	0.40	4.35	10.70
V21	0.55	0.78	0.15	0.68	1.03	0.51	0.65	1.28	0.65	1.80	0.64	0.65	0.17	0.49	0.23	0.51	0.39	4.39	11.20
V22	0.41	0.61	0.13	0.53	0.78	0.39	0.48	0.86	0.50	1.12	0.48	0.48	0.11	0.35	0.17	0.39	0.27	3.37	8.12
V23	0.48	0.78	0.16	0.62	0.91	0.44	0.62	1.01	0.61	1.39	0.55	0.62	0.14	0.46	0.19	0.43	0.35	4.00	9.74
V24	0.36	0.53	0.09	0.45	0.70	0.70	0.39	0.75	0.41	0.93	0.42	0.39	0.10	0.36	0.13	0.43	0.30	3.30	7.52
V25	0.46	0.70	0.16	0.59	0.88	0.43	0.56	1.09	0.55	1.63	0.55	0.56	0.15	0.41	0.18	0.45	0.36	3.82	9.75
V26	0.45	0.58	0.01	0.49	0.81	0.73	0.50	1.01	0.61	1.44	0.63	0.50	0.13	0.43	0.27	0.57	0.32	3.76	9.68
V27	0.46	0.69	0.16	0.55	0.83	0.50	0.53	0.96	0.56	1.31	0.53	0.53	0.11	0.44	0.30	0.50	0.36	3.84	9.45
V28	0.50	0.74	0.14	0.61	0.93	1.31	0.60	1.05	0.60	1.33	0.58	0.60	0.16	0.48	0.28	0.52	0.36	4.95	10.90
V29	0.41	0.60	0.11	0.51	0.75	0.65	0.46	0.86	0.50	1.14	0.47	0.46	0.13	0.35	0.20	0.46	0.31	3.62	8.50
V30	0.44	0.61	0.03	0.50	0.81	0.39	0.57	0.93	0.54	1.46	0.53	0.57	0.13	0.41	0.17	0.41	0.33	3.33	8.80
V31	0.39	0.61	0.13	0.50	0.77	0.97	0.47	0.82	0.47	1.11	0.46	0.47	0.12	0.38	0.24	0.50	0.29	3.96	8.81
V32	0.48	0.74	0.15	0.63	0.95	0.47	0.59	1.03	0.59	1.41	0.58	0.59	0.15	0.45	0.20	0.45	0.37	4.04	9.87
V33	0.47	0.76	0.13	0.62	0.93	0.45	0.58	1.00	0.58	1.50	0.57	0.58	0.12	0.45	0.19	0.42	0.40	3.99	9.79
V34	0.38	0.59	0.12	0.50	0.74	0.97	0.45	0.80	0.44	1.08	0.44	0.45	0.12	0.38	0.19	0.46	0.28	3.87	8.51
V35	0.60	0.80	0.06	0.62	1.03	0.49	0.74	1.40	0.69	2.27	0.67	0.74	0.14	0.53	0.25	0.48	0.44	4.37	11.99
V36	0.31	0.52	0.11	0.41	0.62	0.66	0.35	0.66	0.37	0.91	0.36	0.35	0.11	0.31	0.13	0.36	0.26	3.06	6.87
V37	0.35	0.57	0.12	0.47	0.70	0.89	0.42	0.81	0.42	1.20	0.43	0.42	0.13	0.36	0.25	0.46	0.25	3.68	8.41
V38	0.42	0.69	0.16	0.54	0.79	1.23	0.53	0.87	0.53	1.27	0.49	0.53	0.11	0.39	0.26	0.48	0.31	4.45	9.67
V39	0.41	0.62	0.12	0.55	0.83	0.67	0.46	0.87	0.48	1.14	0.46	0.46	0.12	0.42	0.21	0.43	0.34	3.80	8.73
V40	0.45	0.71	0.17	0.58	0.86	0.74	0.58	0.92	0.59	1.37	0.53	0.58	0.13	0.41	0.29	0.50	0.32	4.17	9.80

(*Contd...*)

Table 6: (*Continued*)

No.	Thr	Val	Met	Ile	Leu	Phe	Lys	Asp	Ser	Glu	Gly	Ala	Cys	Tyr	His	Arg	Pro	E	T
V41	0.35	0.64	0.17	0.48	0.69	0.42	0.44	0.68	0.43	1.03	0.42	0.44	0.12	0.33	0.23	0.45	0.22	3.26	7.62
V42	0.45	0.69	0.13	0.57	0.85	0.45	0.55	0.96	0.57	1.37	0.53	0.55	0.13	0.43	0.19	0.44	0.39	3.73	9.29
V43	0.36	0.55	0.12	0.47	0.72	0.74	0.40	0.78	0.44	0.98	0.41	0.40	0.10	0.37	0.14	0.42	0.29	3.45	7.77
V44	0.40	0.68	0.11	0.55	0.80	0.47	0.51	0.84	0.48	1.17	0.49	0.51	0.12	0.38	0.25	0.48	0.33	3.62	8.68
V45	0.51	0.80	0.16	0.64	0.96	0.48	0.64	1.11	0.61	1.68	0.58	0.64	0.13	0.48	0.20	0.45	0.42	4.19	10.49
V46	0.49	0.79	0.16	0.64	0.92	0.44	0.62	1.02	0.62	1.35	0.57	0.62	0.13	0.41	0.21	0.42	0.35	4.09	9.80
Average	0.42	0.65	0.13	0.53	0.80	0.62	0.51	0.90	0.51	1.23	0.49	0.51	0.12	0.44	0.20	0.44	0.32	3.73	8.88
CV(%)	14.29	13.85	38.46	13.21	13.75	43.55	35.29	16.67	15.69	21.95	14.29	15.69	16.67	18.18	10.00	11.36	15.63	13.67	13.63

Thr, Val, Met, Ile, Leu, Phe, Lys, Asp, Ser, Glu, Gly, Ala, Cys, Tyr, His, Arg, Pro reprsent threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, aspartic acid, serine, glutamic acid, glycine, alanine, cysteine, tyrosine, arginine and proline, respectively, E represents the content of essential amino acids, T represents total content of 17 amino acids, amino acid analysis was carried out triplicate and based on dry weight (DW), the average content was the mean value of 46 cultivars, CV means cultivar variation

Table 7: Correlation matrix of the 17 amino acids

	Thr	Val	Met	Ile	Leu	Phe	Lys	Asp	Ser	Glu	Gly	Ala	Cys	Tyr	His	Arg	Pro
Thr																	
Val	0.850**																
Met	0.221**	0.565**															
Ile	0.891**	0.957**	0.525**														
Leu	0.957**	0.913**	0.355**	0.968**													
Phe	−0.025	−0.034	0.096	−0.028	−0.036												
Lys	0.882**	0.763**	0.193*	0.790**	0.843**	0.264**											
Asp	0.975**	0.799**	0.172*	0.843**	0.927**	−0.061	0.846**										
Ser	0.966**	0.831**	0.195*	0.863**	0.920**	−0.024	0.880**	0.933**									
Glu	0.911**	0.755**	0.111	0.768**	0.862**	−0.111	0.791**	0.952**	0.876**								
Gly	0.955**	0.805**	0.136	0.846**	0.923**	−0.031	0.882**	0.940**	0.960**	0.897**							
Ala	0.964**	0.892**	0.260**	0.895**	0.943**	−0.079	0.842**	0.923**	0.950**	0.894**	0.936**						
Cys	0.588**	0.520**	0.171*	0.565**	0.601**	0.100	0.744**	0.608**	0.569**	0.566**	0.603**	0.579**					
Tyr	0.482**	0.358**	0.034	0.387**	0.439**	0.448**	0.529**	0.473**	0.523**	0.455**	0.573**	0.433**	0.393**				
His	0.409**	0.360**	0.132	0.336**	0.345**	0.506**	0.743**	0.367**	0.469**	0.334**	0.445**	0.393**	0.297**	0.802**			
Arg	0.149	0.138	−0.116	0.162	0.160	−0.119	0.091	0.149	0.147	0.140	0.114	0.109	−0.076	−0.094	−0.067		
Pro	0.881**	0.762**	0.193*	0.801**	0.864**	−0.073	0.775**	0.860**	0.838**	0.813**	0.841**	0.854**	0.419**	0.385**	0.304**	0.102	

**Means significant correlation at the 0.01 level (2-tailed), and * means significant correlation at the 0.05 level (2-tailed); Thr, Val, Met, Ile, Leu, Phe, Lys, Asp, Ser, Glu, Gly, Ala, Cys, Tyr, His, Arg, Pro reprsent threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, aspartic acid, serine, glutamic acid, glycine, alanine, cysteine, tyrosine, arginine and proline, respectively

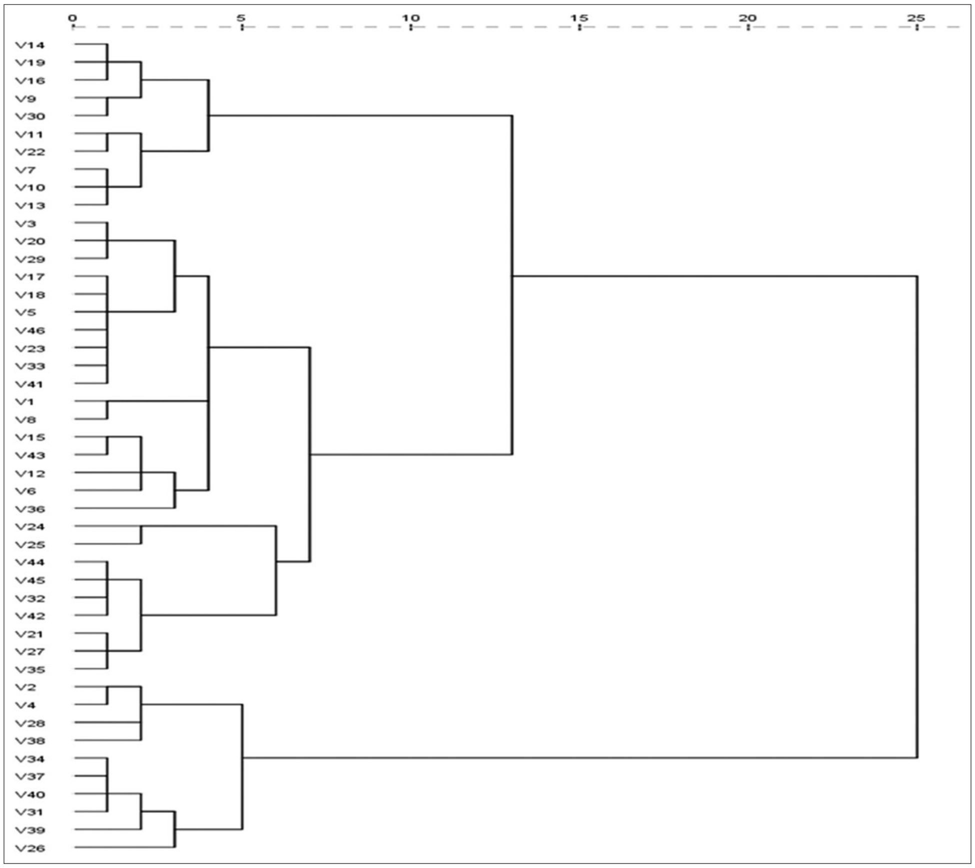

Fig 2. Cluster analysis of 46 *P. lactiflora* cultivars. 46 cultivars of P. lactiflora from V1 to V46 were same as in Fig. 1.

Table 8: Eigenvalue, contribution rate and accumulative contribution rate of quality evaluation

Components	Eigen value	Contribution rate (%)	Accumulative contribution rate (%)
PC1	2.547	19.164	19.164
PC2	1.501	16.677	35.841
PC3	1.364	13.664	49.505
PC4	1.024	12.477	61.982
PC5	0.982	10.399	72.381
PC6	0.860	10.385	82.766

edible quality, which were basically agreement with cultivars in the third section of principal components analysis. The category closer to the bottom of the figure aggregated other 10 cultivars, including V2, V4, V28, V38, V34, V37, V40 V31, V39 and V26, which contained higher contents of total flavonoids, total phenolics, mineral elements such as iron, zinc and amino acid, and suited for consumption. These cultivars were basically agreement with cultivars in the first section of principal components analysis. The category located in the middle of the figure gathered the remaining 26 cultivars, which were basically agreement with cultivars in the second section of principal components analysis (cultivars not listed).

Table 9: Rotated component matrix of the principle component analysis

Factors	Principle components					
	PC1	PC2	PC3	PC4	PC5	PC6
Protein	0.160	0.838	–0.044	0.119	–0.105	0.051
Vc	–0.056	0.498	–0.721	0.146	–0.064	0.049
Fe	–0.120	0.561	0.254	0.563	–0.006	–0.126
Zn	0.204	0.026	–0.101	0.869	0.068	0.132
Total flavonoids	–0.143	0.154	0.866	0.061	0.012	–0.027
Total phenolics	0.068	0.063	–0.045	0.072	–0.044	0.976
Lys	0.890	0.050	–0.080	0.061	0.112	–0.016
Met	0.070	–0.042	0.046	0.057	0.980	–0.044
Tyr	0.917	0.152	–0.037	0.110	–0.037	0.106
Phe	0.412	0.589	–0.092	–0.336	0.207	0.183

DISCUSSION

Our preliminary experiment found that herbaceous peony petals at full bloom period had the best edible quality considering nutrients including soluble sugar, organic acid, protein, vitamin C, total phenolics, total flavonoids, mineral elements and SOD activity (Unpublished data). Therefore, the nutrients in flower petals of *P. lactiflora* cultivars were

Table 10: Principal component expression of different *P. lactiflora* cultivars

Principal component	Calculation formula
F1	0.57×ZX1+0.56×ZX2+0.10×ZX3+0.26×ZX4–0.09×ZX5–0.04×ZX6+0.13×ZX7-0.08×ZX8+0.04×ZX9+0.04×ZX10
F2	0.12×ZX1+0.04×ZX2+0.68×ZX3+0.48×ZX4+0.13×ZX5+0.41×ZX6+0.02×ZX7+0.46×ZX8-0.03×ZX9+0.05×ZX10
F3	–0.03×ZX1–0.07×ZX2–0.04×ZX3-0.08×ZX4+0.74×ZX5–0.62×ZX6–0.09×ZX7+0.22×ZX8+0.04×ZX9–0.04×ZX10
F4	0.11×ZX1+0.06×ZX2+0.12×ZX3–0.33×ZX4+0.06×ZX5+0.14×ZX6+0.86×ZX7+0.56×ZX8+0.06×ZX9+0.07×ZX10
F5	–0.04×ZX1+0.11×ZX2–0.11×ZX3+0.21×ZX4+0.01×ZX5–0.06ZX6+0.07×ZX7+0.01×ZX8+0.99×ZX9–0.04×ZX10
F6	0.11×ZX1–0.02×ZX2+0.05×ZX3+0.20×ZX4–0.03ZX5+0.05×ZX6+0.14×ZX7–0.14×ZX8–0.05×ZX9+1.05×ZX10

Table 11: Comprehensive scores and ranking of 46 *P. lactiflora* cultivars for analysis

Cultivar	Score	Ranking	Cultivar	Score	Ranking
V28	1.61	1	V6	–0.07	24
V4	1.17	2	V43	–0.07	25
V38	1.13	3	V3	–0.07	26
V26	1.02	4	V20	–0.08	27
V31	0.97	5	V46	–0.21	28
V2	0.84	6	V23	–0.23	29
V24	0.72	7	V5	–0.32	30
V34	0.62	8	V33	–0.34	31
V40	0.52	9	V15	–0.35	32
V12	0.52	10	V41	–0.47	33
V25	0.47	11	V22	–0.49	34
V27	0.47	12	V11	–0.51	35
V21	0.45	13	V17	–0.55	36
V35	0.38	14	V18	–0.60	37
V37	0.31	15	V36	–0.67	38
V8	0.23	16	V30	–0.79	39
V1	0.20	17	V19	–0.81	40
V39	0.18	18	V16	–0.83	41
V44	0.14	19	V10	–0.86	42
V45	0.11	20	V14	–0.94	43
V32	0.09	21	V7	–0.97	44
V42	0.01	22	V9	–1.00	45
V29	–0.03	23	V13	–1.38	46

measured at full bloom stage to screen edible cultivars. Results showed that the contents were differed between cultivars. Although variation existed in the petal color of different varities, the nutrient contents weren't directly proportional to the flower color.

The soluble sugar content was 66.55-177.28 mg/g FW, organic acid 2.19-6.90 mg/g FW, soluble protein 6.53-121.56 mg/g FW, Vitamin C 9.77-30.24 mg/100 g FW, total phenolics 9.41-33.01 mg/g DW, total flavonoids 3.50-17.56 mg/g DW, SOD activity 305.62-520.42 U/g FW, total amino acids 6.43-11.99 mg/100 g DW. Zhang et al. (2016) detected 18 kinds of amino acids in ornamental peach flowers and found that Asp and Pro were two amino acids with much higher content. From our results, we showed that the contents of Glu and Asp were much higher in herbaceous peony petals, while that of Pro was much lower (Table 6). Nunes and Carvalho (2013) found that total amino acid (T) content varied from 28 - 49 mg/g and essential amino acids (E) from 8-20 mg/g for flowers and leaves of *Erica australis* L., respectively, with different distributions within the plant, which was lower than those in herbaceous peony petals with the average level of 8.88 g/100g (88.8 mg/g) and 3.78 g/100g (37.8 mg/g). Furthermore, peach flowers contained higher contents of Mg, Ca, K and Mn, which are beneficial for human health (Zhang et al., 2016). In this study, the average content of Na, Mg, K, Ca, Mn, Fe, Ni, Zn, Mo, Cr were 55.88±14.90 μg/g DW, 1218.22±349.60 μg/g DW, 11252.23±2477.54 μg/g DW, 1975.40±706.58 μg/g DW, 8.30±6.55 μg/g DW, 103.56±182.72 μg/g DW, 10.73±37.94 μg/g DW, 22.80±16.68 μg/g DW, 1.84±5.89 μg/g DW and 17.36±44.89 μg/g DW, respectively (Table 4). Mg, Ca and K contents were also higher, while Mn content was much lower.

Gao (2013) made a comprehensive assessment on biological traits, glucosinolate, carotenoids and flavor quality of Chinese cabbage with fuzzy synthetic evaluation. Yang (2014) carried out overall evaluation on several quality indexes of *Hemerocallis* by fuzzy mathematics membership function. Jiang (2014) comprehensively analyzed the nutritional value of apple fruit with principal component analysis. Moreover, some researchers conducted comprehensive analysis with the combined method of principal component analysis and cluster analysis (Schnackenberg, 2010; Derek, 2012; Geőcze, 2012; Gong, 2014). Jin et al. (2010) determined the nutritional quality of 20 kinds of chrysanthemum by principal component analysis, and selected 3 types of edible chrysanthemum with high nutritional quality. Yang et al. (2014) confirmed the nutritional quality of 25 varieties of sweet-scented osmanthus by principal component analysis, and selected 4 edible osmanthus varieties with high nutritional quality. This research mainly adopted the principal component analysis combined with cluster analysis to perform comprehensive evaluation, with the following four category evaluation indexes including nutritional components, bioactive ingredients, amino acids and mineral elements. The relationship analysis between quality indexes showed that soluble sugar, organic acid, protein, Vc, total phenolics, total flavonoids and SOD had no significant difference between each other. The contents of soluble sugar, organic acid and SOD showed a small difference among cultivars. Therefore, protein, Vc, total phenolics and total flavonoids were selected on behalf of nutritional quality and bioactive components of herbaceous peony flower. There was significant correlation between the content of Mn, Fe, Ni and that of Cr, and the content of Mg and that of K, Ca, Zn. However, the content of other mineral element had little difference between cultivars. Fe and Ca were selected on behalf of mineral elements. There was significant correlation between the content of Thr, Val, Ile, Leu, Lys, Asp, Ser, Glu, Gly, Ala and that of Pro, and the content of Tyr and that of His. However, the content of other amino acid had little difference between cultivars. Phe, Met, Lys and Tyr were selected on behalf of amino acids. Overall, we selected 10 components including protein, Vc, total phenolics, total flavonoids, Fe, Zn, Lys, Tyr, Met and Phe on behalf of basic nutrients, mineral elements and amino acids in herbaceous peony flower petal, and as edible quality evaluation index.

Principal component analysis of 10 kinds of nutrients in flower petals of 46 cultivars were conducted using SPSS, and six principal components were obtained. The first and the five principal component were the comprehensive index of amino acid content in peony petals. The second principal component mainly reflected the index of protein content. The third principal component was the index of Vc and total flavonoids content. The fourth principal component mainly reflected the comprehensive index of mineral element content in peony petals. the sixth principal component was the index to reflect the total phenolics content. Finally, ten cultivars with better edible quality were screened, including 'Dielian Qihua', 'Zhushapan', 'Xueyuan Honghua', 'Wulong Jisheng', 'Honglou', 'Bingshan', 'Hongyan Yushuang', 'Zituo Ronghua', 'Zifengyu' and 'Fenlou Dianchun'.

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Authors' contribution

C. Z. and J. T. designed this study. W. L. and H. C. wrote the article and corrected it. S. Y. and Y. H. conducted the experimental work.

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