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Research Article

Effects of Different Harvest Times on Nutritional Component of Herbaceous Peony Flower Petals

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Herbaceous peony (*Paeonia lactiflora* Pall.) flowers can be used as edible flowers, but few studies concerned about their edible values and the optimal harvest season. In this study, petals of three herbaceous peony cultivars including "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu" at four different development stages were used as materials to measure the content of soluble sugar, organic acid, protein, vitamin C (Vc), total phenolics, total flavonoids, mineral elements, and superoxide dismutase (SOD) activity, with the aim to understand the variation tendency of the nutritional ingredients and bioactive components in herbaceous peony flower petals during development and to determine the optimal harvest time for herbaceous peony flowers with better edible qualities. The results demonstrated that the content of individual nutritional and bioactive components was varied with cultivars and developmental stages. The soluble sugar content was 63.69–225.97 mg/g FW, organic acid 10.13–24.60 mg/g FW, soluble protein 9.83–39.17 mg/g FW, Vc 12.31–33.52 mg/100 g FW, total phenolics 83.23–136.19 mg/g DW, total flavonoids 10.20–24.98 mg/g DW, and SOD activity 62.92–284.09 U/g FW. For mineral elements, the content of Na, Mg, K, Ca, Mn, Fe, Ni, and Zn was 20.96–65.51 μg/g DW, 810.85–1342.36 μg/g DW, 6723.68–12253.63 μg/g DW, 848.67–3038.46 μg/g DW, 1.14–8.44 μg/g DW, 48.70–149.72 μg/g DW, 1.20–2.17 μg/g DW, and 16.69–25.50 μg/g DW, respectively. The content of soluble sugar, protein, total flavonoids, and SOD activity in flower petals was the highest, and the content of organic acid was the lowest at the full bloom period (S3) for all three cultivars, while the highest Vc and total phenolics were at the early bloom stage (S2) and flower bud stage (S1), respectively. In conclusion, it is recommended to harvest herbaceous peony flowers at S3 with the best edible quality considering nutrients and bioactive components.

1. Introduction

Edible flowers have been used in culinary preparations for centuries to improve the nutritional, sensorial, and aesthetic qualities of food [1–3] and are popular topics of different magazine articles, making an excellent illustration opportunity [4]. Moreover, they also have been used in Chinese traditional medicine since ancient times, but its nutritional value has not been studied in depth [5]. Previous studies demonstrated that edible flowers contain numerous phytochemicals, including sugar, acid, protein, amino acid, minerals, flavonoids, polyphenols, anthocyanins, carotenoids, and fiber [2, 6–14], which contribute to their biological activity and high antioxidant capacity [12–19], and are eventually beneficial to consumers' health [1]. In recent years, consumption of edible flowers has increased significantly [4, 20]. Previous investigations revealed that collection stage of the flowers had a significant effect on the content of chemical compositions [21–23]. Herbaceous peony (*Paeonia lactiflora* Pall.) is a wonderful ornamental plant and has various cultivars with different flower colors and types [24]. The roots, leaves, and flowers of herbaceous peony contain different components and have edible and medicinal values [24–30]. Until now, research studies of herbaceous peony were mainly involved in flower ornamental value [24] and root medicinal value [31], especially the underlying mechanisms of flower pigmentation [32–34]. The herbaceous peony flowers harvested at unfold-peta stage had longer vase life and opening life with no significantly reduced ornamental quality [35]. However, few studies concerned about the edible value of herbaceous peony petals and the optimal harvest season. In this study, petals of three cultivars were selected to perform nutritional quality analysis to understand the variation tendency of the nutritional ingredients and bioactive components in herbaceous peony flower petals at different developmental stages and finally to determine the optimal flower petal harvest time for herbaceous peony flowers with better edible qualities.

2. Materials and Methods

2.1. Plant Materials. Three *P. lactiflora* cultivars including "Dafugui" (rose red), "Hongyan Zhenghui" (purple), and "Yangfei Chuyu" (white) were used as materials at first (Figure 1). Flowers of three cultivars were sampled at four different developmental stages, i.e., flower bud stage (S1), early bloom stage (S2), full bloom (S3) stage, and flower decline stage (S4) from March to May, 2014. All the plant materials were collected from Peony Germplasm Resource Garden of Yangzhou University (Yangzhou, China). The petals were detached from flowers, some petals were dried to a constant weight in an oven at 60°C and used to determine the contents of mineral elements, total phenolics, and total flavonoids, and the rest petals were immediately frozen with liquid nitrogen and stored in −80°C ultralow temperature refrigerator used to measure the contents of soluble sugar, organic acid, protein, Vc, and SOD activity.

2.2. Methods

2.2.1. Determination of Nutritional and Bioactive Components. Soluble sugar content was measured with an anthrone colorimetry at 630 nm wavelength [36]. Organic acid content was determined by acid-base titration with 0.02 mol/L NaOH [36]. Protein content was obtained by Coomassie brilliant blue G-250 staining under 595 nm wavelength [36]. Vc content was analyzed using 2,6-dichloro-indigo colorimetry until the solution color changed from blue to pink [37]. Mineral element content was determined with a Thermo Fisher ICAP 6300 ICP instrument (Thermo Fisher, USA) according the method of Du et al. [38]. Total flavonoid content was determined using the $Al(NO_3)_3$-$NaNO_2$ colorimetry method with rutin as standard [16]. Total phenolic content was determined using Folin–Ciocalteu reagent with gallic acid as standard [39]. SOD activity was measured with reagent kits from Nanjing Jiancheng Biological Co. Ltd. (Nanjing, China) according to the operation instruction. SOD inhibition rate was calculated in 1 mL reaction mixture per gram fresh weight of petals. All above analyses were repeated three times.

2.2.2. Statistical Analysis. Single factor variance analysis was performed on nutritional quality data of three main cultivated varieties with IBM SPSS 20 software, and multiple comparison was conducted on average value of three repeats using Duncan's new multiple range difference method, and thus, the best harvest period of herbaceous peony flower was established.

3. Results

3.1. Nutritional Component

3.1.1. Soluble Sugar. The soluble sugar content variation in petals of three cultivars during development showed similar tendency, with initial increase and then decrease. The highest level appeared in the period of S3, with the value of 202.93 ± 1.53 mg/g FW, 133.21 ± 2.07 mg/g FW, and 225.97 ± 0.99 mg/g FW for "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu," respectively, which is more than 1.8 times compared with the lowest content of S1 period. Between three cultivars, the order of soluble sugar content from top to bottom was "Yangfei Chuyu," "Dafugui," and "Hongyan Zhenghui" (Figure 2).

3.1.2. Organic Acid. Sugar, acid, and their interactions have an important effect on food flavor. The sugar acid ratio determines whether people love food, especially fresh food varieties. Acidity is determined by organic acid content, which is an important factor of flavor. During flower development, organic acid content in petals was firstly reduced and then increased. The lowest level appeared at the S2 period, with the amount of 11.70 ± 0.45 mg/g FW, 14.40 ± 1.35 mg/g FW, and 10.13 ± 1.13 mg/g FW for "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu," respectively (Figure 3). Organic acid content of flower petals at S1 and S2 periods varied significantly for all three cultivars. S2 and S3 periods, as well as S1 and S4 periods, had no significant difference in organic acid content for "Dafugui." Between S2, S3, and S4, some differences existed in "Hongyan Zhenghui" and "Yangfei Chuyu." "Yangfei Chuyu" contained the minimum level of organic acid for all four periods among three cultivars. The sugar acid ratio was calculated with soluble sugar and organic acid content from Figures 2 and 3, and the order of sugar acid ratio from top to bottom was S3, S2, S4, and S1. Sugar acid ratio of the S3 period reached the maximum level for all three cultivars, which is 14.09, 5.88, and 16.14 times of the S1 value for "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu," respectively.

3.1.3. Protein. As an important nutrient needed by human body, protein content has become one of the important indexes to evaluate the quality of horticulture product. With flower development, protein content in petals of three cultivars was firstly increased and then reduced, with the minimum and maximum levels at S4 and S3, respectively. The highest amount at the S3 period for "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu" is 39.17 ± 0.39 mg/g FW, 44.94 ± 0.37 mg/g FW, and 22.98 ± 1.01 mg/g FW, respectively. In addition, there was no significant difference in protein content of petals from "Dafugui" between the first 3 developmental stages, while the other 2 varieties showed significant difference of petal protein content in each period (Figure 4).

FIGURE 1: Petals of three *P. lactiflora* cultivars at different developmental stages.

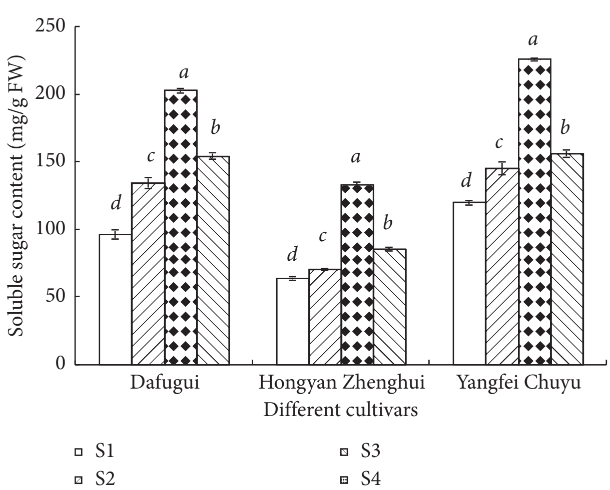

FIGURE 2: Soluble sugar content of developmental *P. lactiflora* petals (mg/g FW). *Statistical analysis was carried out within each cultivar, respectively. Different letters within each cultivar indicated significant differences at 5% level.

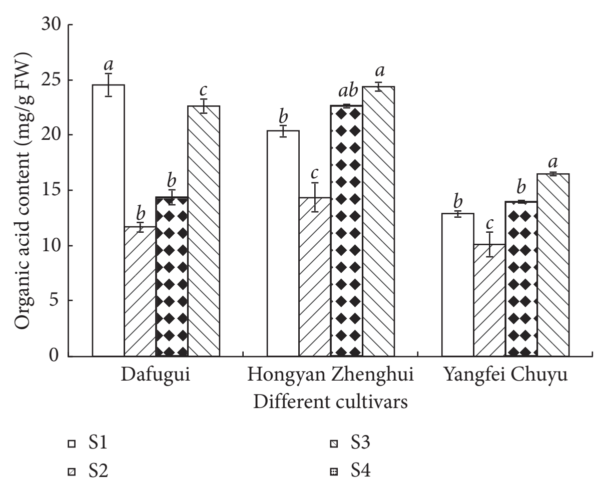

FIGURE 3: Organic acid content of developmental *P. lactiflora* petals (mg/g FW). Different letters within each cultivar indicated significant differences at 5% level.

3.1.4. Vitamin C. Vitamin C (V_C) is an essential nutrient for human body, which has antioxidant activity, and can reduce the threat of free radicals to human health (Pharmacopoeia of the People's Republic of China, 2005). The data in Figure 5 showed that V_C content of petals increased initially and then reduced during flower development. The order of V_C content from maximum to minimum was S2, S1, S3, and S4 for all three cultivars. The highest V_C amount for "Dafugui," "Yangfei Chuyu," and "Hongyan Zhenghui" was 19.81 ± 1.22 mg/100 g FW, 13.04 mg/100 g FW, and 33.52 ± 0.47 mg/100 g FW, respectively.

3.1.5. Mineral Element. The contents of ten mineral elements, including four macroelements potassium (K), calcium (Ca), sodium (Na), and magnesium (Mg) and six trace

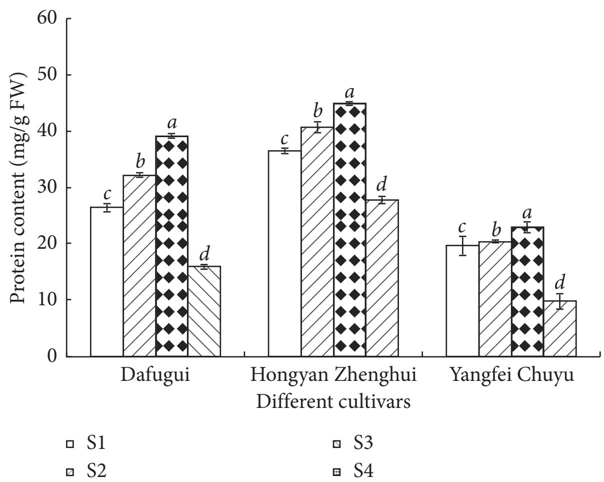

Figure 4: Protein content of developmental *P. lactiflora* petals (mg/g FW). Different letters within each cultivar indicated significant differences at 5% level.

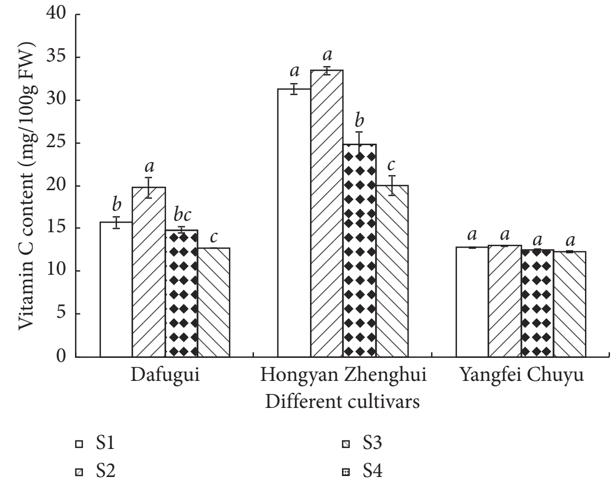

Figure 5: Vitamin C content of developmental *P. lactiflora* petals (mg/100 g FW). Different letters within each cultivar indicated significant differences at 5% level.

elements iron (Fe), manganese (Mn), zinc (Zn), molybdenum (Mo), nickel (Ni), and chromium (Cr), were analyzed with petals of "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu" at four different developmental stages. The results showed that there was no Cr existing in herbaceous peony flower petals. Mo was only found in flower petals of "Dafugui" at the S1 period with the amount of $1.92 \pm 0.01\ \mu$g/g DW. Petals of three cultivars at the S1 period contained the highest Zn content and the lowest Na, Mg, and Fe content. Petals of three cultivars at the S3 period contained the lowest Mg content and the highest Mn content. The contents of Ca, Fe, and Ni in flower petals reached their highest level at the S4 period. K content had no obvious tendency. The contents of other mineral elements also varied with cultivar (Table 1).

3.2. Bioactive Component

3.2.1. Total Phenolics. Total phenolic content of petals was between 83.23 ± 0.25 mg/g DW and 136.19 ± 8.22 mg/g DW and showed slow reduction tendency with flower development (Figure 6). For the same cultivar, the total phenolic content at different stages demonstrated a certain degree of difference and that of S3 and S4 periods was significantly lower than that of S1 and S2 periods. Total phenolic content of S3 and S4 had no obvious difference for "Dafugui" and "Hongyan Zhenghui." Among three cultivars, "Hongyan Zhenghui" contained the highest amount of total phenolics, "Dafugui" had the lowest level of total phenolics, while "Yangfei Chuyu" was in between.

3.2.2. Total Flavonoids. Flavonoids have important health care function and can inhibit the free radical activity, thus delaying aging. Total flavonoid content of flower petals was between 10.20 ± 0.07 mg/g DW and 10.20 ± 0.07 mg/g DW for three varieties (Figure 7). Total flavonoid content of different harvest seasons existed obvious difference for each cultivar. S1 period had the lowest amount of total flavonoids for three cultivars. The highest level appeared at the S3 period for "Dafugui" and "Yangfei Chuyu" and at the S4 period for "Hongyan Zhenghui." In addition, for different harvest times, the total flavonoid content of "Dafugui" and "Yangfei Chuyu" was higher than that of "Hongyan Zhenghui."

3.2.3. SOD Activity. As shown in Figure 8, the SOD activity of petals was increased initially and then reduced during flower development for all three cultivars, with the minimum amount at the S1 stage and the maximum amount at the S3 stage. The SOD activity in S3 was 233.35 ± 5.61 U/g FW, 284.09 ± 15.00 U/g FW, and 157.95 ± 7.93 U/g FW for "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu," respectively, which has obvious difference with those of other stages. In addition, for different harvest times, the SOD activity of "Dafugui" and "Hongyan Zhenghui" was higher than that of "Yangfei Chuyu."

4. Discussion

The nutrient composition of herbaceous peony petals at different developmental stages was analyzed, and the results showed that the content of soluble sugar and protein displayed similar trend, with initial increase and then decrease with the highest amount appearing at the full bloom stage (S3). The result was similar to the conclusion of Yu [40]. Organic acid contents were firstly reduced and then increased, with higher amount at S1 and S4 and lower amount at S2 and S3. The contents of soluble sugar and organic acid can affect the eating quality of peony flowers. Petal and its processed products taste better with a higher sugar acid ratio [41]. The sugar acid ratio in flower petals reached the highest amount at S3 with the value of 14.09, 5.88, and 16.14 for "Dafugui," "Hongyan Zhenghui," and "Yangfei Chuyu," respectively. The Vc content of herbaceous peony petals was 12.31–33.52 mg/100 g FW, which was much higher than that of some Lamiaceae edible flowers (1.14–2.57 mg/100 g FW) [42] but lower than that of apricot flowers (24.97–43.75 mg/

Table 1: The mineral elements content of developmental *P. lactiflora* petals (μg/g DW).

Element	Cultivar	S1	S2	S3	S4
	Dafugui	30.34 ± 0.03^{c}	44.72 ± 0.02^{c}	54.62 ± 0.09^{b}	82.82 ± 0.18^{a}
Na	Hongyan Zhenghui	42.70 ± 0.18^{b}	65.51 ± 0.12^{a}	48.61 ± 0.08^{b}	62.36 ± 0.16^{a}
	Yangfei Chuyu	20.96 ± 0.10^{d}	41.06 ± 0.11^{c}	64.05 ± 0.24^{a}	49.17 ± 0.09^{b}
	Dafugui	1342.36 ± 37.04^{a}	959.55 ± 47.38^{bc}	810.85 ± 24.55^{c}	1178.99 ± 38.93^{ab}
Mg	Hongyan Zhenghui	1091.03 ± 20.34^{b}	1127.32 ± 30.42^{b}	1063.27 ± 40.31^{b}	1273.48 ± 20.46^{a}
	Yangfei Chuyu	1264.32 ± 50.31^{a}	1171.43 ± 20.54^{b}	1134.75 ± 20.12^{b}	1262.63 ± 10.44^{a}
	Dafugui	10514.52 ± 20.32^{a}	8194.57 ± 40.15^{b}	6723.68 ± 40.23^{b}	7871.38 ± 36.56^{b}
K	Hongyan Zhenghui	9633.46 ± 20.35^{c}	10859.27 ± 10.66^{b}	10167.22 ± 10.54^{bc}	12253.63 ± 20.01^{a}
	Yangfei Chuyu	11643.75 ± 30.63^{a}	10432.46 ± 40.54^{b}	10583.33 ± 20.36^{ab}	11392.76 ± 10.59^{ab}
	Dafugui	1342.37 ± 10.44^{b}	1193.35 ± 7.33^{cd}	993.87 ± 30.01^{d}	2304.77 ± 11.20^{a}
Ca	Hongyan Zhenghui	848.67 ± 10.66^{d}	1012.54 ± 10.41^{c}	1476.46 ± 20.22^{b}	2493.13 ± 13.03^{a}
	Yangfei Chuyu	1634.11 ± 20.66^{d}	1882.43 ± 13.05^{c}	2319.76 ± 31.03^{b}	3038.46 ± 8.79^{a}
	Dafugui	1.71 ± 0.01^{d}	2.92 ± 0.01^{c}	7.78 ± 0.02^{a}	3.73 ± 0.00^{b}
Mn	Hongyan Zhenghui	1.14 ± 0.00^{c}	5.16 ± 0.02^{b}	8.44 ± 0.02^{a}	4.72 ± 0.00^{b}
	Yangfei Chuyu	1.84 ± 0.02^{c}	4.64 ± 0.01^{b}	6.67 ± 0.01^{a}	4.61 ± 0.01^{b}
	Dafugui	53.50 ± 0.05^{c}	72.72 ± 0.62^{b}	57.25 ± 0.08^{c}	138.99 ± 0.11^{a}
Fe	Hongyan Zhenghui	50.33 ± 0.28^{c}	56.24 ± 0.18^{c}	77.42 ± 0.11^{b}	149.72 ± 0.10^{a}
	Yangfei Chuyu	48.70 ± 0.25^{c}	64.91 ± 0.08^{b}	49.39 ± 0.11^{c}	95.72 ± 0.11^{a}
	Dafugui	1.44 ± 0.03^{a}	1.71 ± 0.05^{a}	1.20 ± 0.01^{a}	2.17 ± 0.03^{a}
Ni	Hongyan Zhenghui	1.52 ± 0.01^{b}	1.93 ± 0.01^{ab}	1.68 ± 0.00^{ab}	1.99 ± 0.01^{a}
	Yangfei Chuyu	1.71 ± 0.01^{bc}	1.54 ± 0.01^{c}	1.96 ± 0.01^{ab}	2.33 ± 0.00^{a}
	Dafugui	25.50 ± 0.09^{a}	20.53 ± 0.11^{bc}	18.67 ± 0.23^{c}	23.19 ± 0.06^{bc}
Zn	Hongyan Zhenghui	22.44 ± 0.10^{a}	18.71 ± 0.02^{bc}	16.69 ± 0.03^{c}	20.76 ± 0.01^{ab}
	Yangfei Chuyu	26.50 ± 0.01^{a}	24.41 ± 0.01^{b}	22.76 ± 0.01^{c}	24.54 ± 0.07^{b}
	Dafugui	1.92 ± 0.01	—	—	—
Mo	Hongyan Zhenghui	—	—	—	—
	Yangfei Chuyu	—	—	—	—
	Dafugui	—	—	—	—
Cr	Hongyan Zhenghui	—	—	—	—
	Yangfei Chuyu	—	—	—	—

Note: — means not detected.

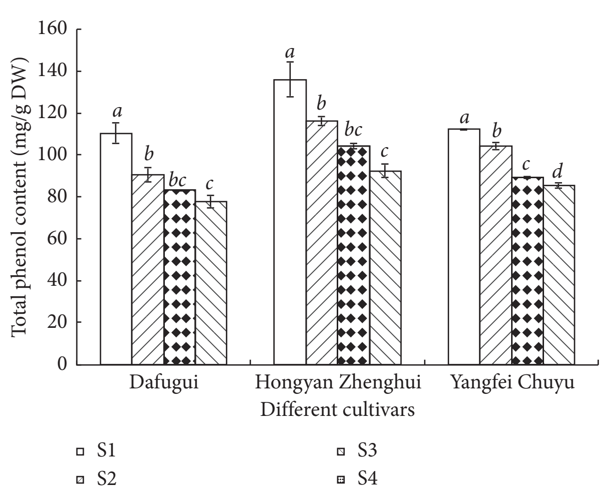

Figure 6: Total phenol content of developmental *P. lactiflora* petals (mg/g DW). Different letters within each cultivar indicated significant differences at 5% level.

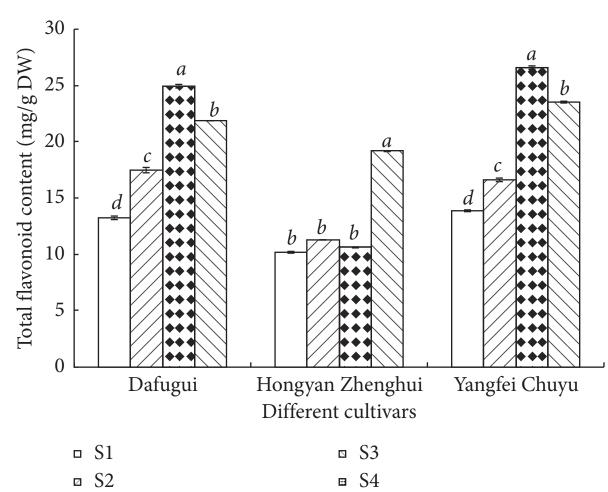

Figure 7: Total flavonoid content of developmental *P. lactiflora* petals (mg/g DW). Different letters within each cultivar indicated significant differences at 5% level.

100 g FW) [43]. We also investigated the content of bioactive components in flower petals at different periods and found that total phenolic content was higher at S1 and S4 while lower at S2 and S3. This result was similar to that of Wang and Liu [44]. According to the opinion of Zhang et al. [45], the taste and color are better with less phenolics; therefore, the petal picked at S2 and S3 was much better. The flavonoid content and SOD activity of flower petals were the highest at

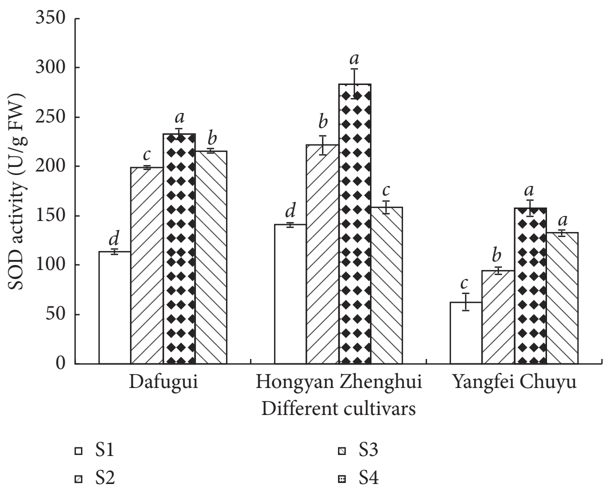

FIGURE 8: SOD activity of developmental *P. lactiflora* petals (U/g FW). Different letters within each cultivar indicated significant differences at 5% level.

S3 and had significant difference with those of other three developmental periods. The contents of individual mineral element varied with cultivar and developmental stage. At S1, the content of Zn was the highest, while the contents of Na, Mg, and Fe were the lowest. At S3, the content of Mg was the highest, while the content of Mn was the lowest. The content of Ca, Fe, and Ni was the highest at S4. The content of other elements in the three cultivars showed different trends with variety distinctness.

Besides above detected ingredients, the amino acid in protein and the individual components of phenolics and flavonoids should further be characterized and quantified. Furthermore, biological activity and toxicology also need to be investigated in the near future.

5. Conclusions

In summary, herbaceous peony petals at S3 had the best edible quality considering nutrients and bioactive components analyzed in this research. At this stage, herbaceous peony petals contained the highest soluble sugar, protein, total flavonoids, and SOD activity, which may contribute to their nutritional and biological values. Thus, S3 was recommended to be the optimal harvest time for edible herbaceous peony flowers.

Data Availability

All the data are included in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors made considerable contributions to the manuscript. CZ, JT, and WL designed the study. WL, YH, and XS performed the experiments. WL, XS, and YH interpreted the results. WL, XS, JT, and CZ wrote the manuscript. All authors revised the manuscript and approved it for publication.

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