

Growth and Nutritional Quality Comparison Between Two Common Purslanes, *Portulaca granulatostellulata* and *P. edulis*

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Abstract: *Portulaca granulatostellulata* and *P. edulis* are two subspecies of common purslane. The biomass of both plants was similar; however, with long upright stems and a long vegetative period, *P. edulis* production was easier. Both subspecies were rich in vitamin C and flavonoids, main organic nutrients' contents in 25-d-old plants were higher than those in 15-d-old plants, and were higher in *P. granulatostellulata*. Both purslanes were rich in minerals, with the K content being the highest, and was higher in *P. edulis*, whereas the Ca content was higher in *P. granulatostellulata*. A similarly high content of polyunsaturated fatty acid, particularly α -linolenic acid, in both purslanes showed their high value in balancing the ω -6/ ω -3 intake ratio. Furthermore, all the contents of nitrate and heavy metals in this study were within the safe range, and the oxalic acid content in mature plants decreased to the high level of oxalic acid in vegetables. In brief, both purslanes are excellent reserve crops for use as vegetables and medicines. *P. edulis* has advantages over *P. granulatostellulata* regarding plant appearance and the K content. *P. granulatostellulata* has advantages regarding Vc, flavonoid and other mineral contents; Both purslanes are similar in fatty acid composition and are suitable for picking at a mature stage.

Keywords: Comparison, Growth, Nutrient, Anti-nutrient, *P. edulis*, *P. granulatostellulata*

1. Introduction

Purslane is an annual succulent herb which belonging to *Portulaca L.*, Portulacaceae. As a C₄ and facultative CAM plant, it is widely distributed in temperate and tropical regions all over the world, and has been ranked as the eighth most common plant in the world [1]. Purslane is rich in total flavonoids and K, contains high levels of vitamin C and beta-carotene, and also contains norepinephrine, melatonin etc [2]. In addition, purslane has been reported to be the richest vegetable source of omega-3 (ω -3) fatty acids (FA) yet examined [3]. The abundance of high levels of these nutrients in purslane lead to its multiple effects as improving blood circulation and human immunity, prevention and treatment of cardiovascular disease and inhibition of microbial growth and

so on [2, 4]. Although purslane is still considered as a wild weed in most countries, it is now known as one of the most promising green foods, the most used medicinal plants and the "power food for the future" [5, 6], and is eaten fresh, cooked, or dried and the interest of cultivating it as a food crop and herd-medicine has increased all over the world in recent years [5, 7].

There are various types of purslane available in different locations of the world [6]. Those variations are not only phenotypic or physiological but also genetic [6]. Although they may be different in their tolerance to stresses [8], or different in their nutrient contents [9], according to their cultivation purpose, purslane nowadays can be divided into two types, the common and the ornamental type. Common purslane usually has small yellow flowers and produce large amount of seeds, while

ornamental purslane usually has big and colorful flowers and does not produce seeds [5]. Chinese people only accept common purslane as vegetables and medicines. Currently, only two types of common purslane could be found in China, the wild type and the imported type which is called as "Dutch purslane". The wild common purslane grows prostrate with small leaves. Analysis with GC-MS and FT-IR spectroscopy method showed that wild common purslane samples from different places of China were consistent to great extent [10]. The "Dutch purslane" grows erect with large leaves, which also has names as "summer purslane" or "garden purslane" in European and American markets, and is the most common cultivated common purslane in the world. According to the seed size and seed coat micro-structure, purslanes from Sudan, Mediterranean etc. were divided into 19 subspecies by Danin and Raus [11]. And according to Danin and Raus [11], the wild common purslane from China was determined as *P. granulostellulata* Poelln. C. Ricceri et P.V. Arrigoni subspecies (4N=36), and the "Dutch purslane" was determined as *P. edulis* Danin and Bagella subspecies (6N=54) [12].

After thousands of years of usage on food and medicine, as well as its widely recognized beneficial nutrients, purslane's anti-nutrients such as oxalic acid and possible heavy metal accumulations has gradually attracted people's attention [13, 14]. Looking for subspecies with high yield, high nutritive value, low anti-nutrients is essential for common purslane usage. Up to now, there are a few literatures on the nutrition quality comparison among different sources [5, 15, 16, 17], or different stages [13, 18, 19, 20], or different parts of purslane [9, 17]. In these literatures, some materials were directly from the field or market, their germplasms were uncertain and their growing environments were unknown [15]; some comparisons were among ornamental and common purslanes [16], while the ornamental purslane is rarely eaten; or just scant indices were compared, such as antioxidant activity [5], or FA content [15, 20], or mineral contents [5] etc. All these literatures showed that variation in many traits, such as total flavonoids, mineral elements, FA etc. from different sources of purslane do exist, and it is possible to select for types with multiple desirable traits.

P. granulostellulata has been used in foods and medicines in China for thousand years and *P. edulis* has been planted in China for over 10 years. From the perspective of production and comprehensive quality, which one is more nutritive and which one is more suitable for deep development, no data has been published. Therefore, the objective of this study was to compare the differences in growth and nutritional quality between these two common purslanes which are grown under the same condition, and to select the more suitable for cultivation as a vegetable and medicinal crop.

2. Materials and Methods

2.1. Chemicals

Coomassie Brilliant Blue G250 was obtained from Sigma Chemical Co., USA. Research grade bovine albumin

(BSA, >99%) was purchased from Serva, Germany. Methylated fatty acid ester standards were supplied by AccuStandard Inc, USA. All other chemicals were of analytical grade obtained from Sinopharm Chemical Reagent Co., Ltd., China.

2.2. Plant Material and Plant Rearing

P. granulostellulata seeds were collected from the Botanical Garden in Xianlin Campus of Nanjing Normal University (118°95'E, 32°15'N). *P. edulis* seeds were purchased from Shangdong Hezhiyuan Seed Company (China). After the seeds of *P. granulostellulata* being soaked in 35°C water for 12h, both seeds were sowed onto the surface of pre-soaked 41mm-peats (Jiffy, Norway), and placed in an Adaptis A350 incubator (Conviron, Canada). The culture conditions were as follow: 14h/10h (light/dark), 32°C/28°C (light/dark), humidity 70%, and light intensity 500μmol·m⁻²·s⁻¹. The peats were watered every other day with water in the first week, and with 0.5‰ Peters Professional 1 (Scotts, USA) one week later. Growth indexes were measured on 20th day after the seeds being sowed, contents of mineral elements and fatty acids were detected on 25th day, and other indexes were detected on 15th and 25th day.

2.3. Growth Measurement

Plant height was measured on the main stem with a ruler. Stem diameter was measured 1cm above the ground with a vernier caliper. The area of the 2nd fully expanded leaf was measured with a Multi-purpose Leaf Area Analyzer (WinFOLIA, Regent Instruments Inc., Canada). Biomasses of aboveground parts (stem and leaf) and roots were measured after the samples being oven-dried first at 105°C for 15 min, and then at 75°C for 48 hours. The branch being calculated in the branch number was at least with leaves not less than 4.

2.4. Contents Determination of Main Organic Nutrients, Nitrate and Oxalic Acid

On 15th day and 25th day after sowing, stems and leaves were sampled and washed with distilled water through a fine sieve separately. The samples were fresh used, or oven-dried as above and powdered, or frozen in liquid nitrogen and stored at -80°C until used for subsequent analysis.

Soluble protein content was determined with fresh samples according to Bradford 1976 using Bovine Serum Albumin (BSA) as a standard [21]. Soluble sugar was extracted by boiling the fresh sample in water and content was estimated by the anthrone method [22]. A standard curve was prepared using D-glucose, and the soluble sugar was calculated and expressed as mg·g⁻¹ fresh weight (FW). For measurement of Vc content, 0.2 g fresh plant leaves were homogenized with ice-cold 5% (w/v) trichloroacetic acid using a cold mortar and pestle. The supernatant was removed after centrifugation at 14,000 g for 10 min at 48°C. Vc content was determined according to previous methods [23]. Anthocyanin was extracted by 0.1 M HCl from frozen samples and determined with the method described by Kong

et al 2003 [24]. One unit of anthocyanin was defined as 0.1 increases in the absorbance at 530 nm per g fresh weight. Carotenoids were extracted by 96% ethanol from fresh samples and its content was analyzed according to the method of Porra et al 1989 [25]. Flavonoids were extracted from 3 grams of powdered samples with methanol on a Soxhlet extractor according to the method of Alothman et al 2009 [26]. The filtrate was separated by a filter paper (Whatman number 1) and concentrated under reduced pressure using a rotator evaporator (Buchi Rotavapor R-210, Switzerland). Then the total flavonoid content was determined using a colorimetric method described by Alam et al 2014 [5], and results were expressed as milligrams of Rutin equivalent in 1 g of sample (mg RE.g⁻¹DW).

Nitrate was extracted from fresh samples by boiling water bath and contents were assayed according to the method of salicylic acid-sulphuric acid with KNO₃ as a standard [27]. The oxalic acid was extracted also from fresh samples by water, clarified with 0.5mol/L HCl in 75°C water bath for 30 min, and contents were determined using the method of sulfonic acid as described by Ilarslan et al. with oxalic acid as a standard [28].

2.5. Determination of Mineral Contents

Samples of leaves and stems from 25th day plants were taken for estimation of mineral contents. Fresh samples of plant material (0.5 g) were dried and powdered as above, and digested in 35% (v/v) HNO₃ at 100°C for 30 min; and mineral content (K, Ca, Mg, Fe, Cu, Zn, Pb As and Cd) was analyzed by Inductively Coupled Plasma Atomic Emission Spectrum (ICP)(Prodigy, Leeman Labs Inc. USA). Mineral content was normalized to the dry weight.

2.6. Fatty Acid Extraction, Methylation and Detection

Dried powdered samples of stems and leaves were obtained as above. FA were extracted on a Soxhlet extractor and methylated on a Rotary evaporator referring to the method of Liu et al 2000 [15]. Absorbent filter bag with 2 g powders in it were placed in a cylinder in a Soxhlet extractor. With ether as the solvent, the mixture was first in 50°C water bath for 18h, and then be filtered and evaporated to nearly dry in a round flask on a Rotary evaporator. Then, 3mL of 0.5mol/l NaOH-methanol solution was added to the flask and refluxed in 60 °C water bath for 20m, and then 3mL 13% boron trifluoride-methanol solution was added and refluxed for another 20m, and 1 mL hexane was added for oscillating

extraction. Finally, the saturated NaCl solution was added to the flask neck, and the supernatant liquid was taken after the static setting. After drying with anhydrous sodium sulfate, the supernatant liquid (1 mL) were injected via an autosampler onto a fused-silica capillary column (VARIAN company; SPTM-2560; 30 m×0.25 mm I.D., 20µm film thickness) in a Shimadzu Model GC-2010 Plus gas chromatography (Shimadzu, Japan) system fitted with a flame ionisation detector (FID) and eluted with H₂ at 30±1 mL /min with a split ratio of 1:17. The injector and detector were heated to 285°C. The column was temperature programmed from 150°C (hold 2 min) to 225°C (hold 46 min) at 5°C/min. FA methyl esters were identified by comparing GC retention time with those of a mixture of methylated FA ester standards. FA relative contents were quantified using peak areas. The unsaturated fatty acid index (IUFA) was calculated with the formula:

$$\text{IUFA}(\%) = 1 \times \text{monoenoic acid content}(\%) + 2 \times \text{diolefinic acid content}(\%) + 3 \times \text{triolefinic acid content}(\%)$$

2.7. Statistics

The data are presented as means in all tables and analyzed by one-way analysis of variance (ANOVA) using the statistical software Origin 7.0. Values of the same index followed by different capital letters denote significant difference at $p < 0.01$, and those followed by different small letters denote significant difference at $p < 0.05$.

3. Results and Discussion

3.1. Comparison of Growth and Biomass

Both *P. granulostellulata* and *P. edulis* grew well under 32°C/28°C (light/dark) in the incubator. Their flower buds appeared on the 40th and 50th day, respectively, suggesting a longer picking period of *P. edulis*. On the 20th day, the plant height, stem diameter and leaf area of *P. edulis* were 60.56%, 76.6% and 54.22% higher than those of *P. granulostellulata*, respectively (Table 1). *P. edulis* was tall and sturdy, but because *P. granulostellulata* had more branches, no obvious difference was observed in their biomass (Table 1). *P. granulostellulata* grows prostrate with small leaves, whereas *P. edulis* grows vertically with large leaves. This implies that *P. edulis* seedlings are more easily picked and bundled. All these observations show that *P. edulis* has more advantages in production.

Table 1. Comparison of growth and biomass between *P. granulostellulata* and *P. edulis* in their 20d-old plants (n=10).

Subspecies	Growth				Biomass(g seedling ⁻¹)		
	Stem height(cm)	Stem diameter (cm)	Area(cm ² leaf ⁻¹)	Branch number	Stem+leaf	Root	Plant
<i>P. granulostellulata</i>	8.62Bb	3.12Bb	0.83Bb	8Aa	0.34Aa	0.03Aa	0.37Aa
<i>P. edulis</i>	13.84Aa	5.51Aa	1.28Aa	4Bb	0.38Aa	0.04Aa	0.42Aa

Notes: Means followed by the same capital letter within columns are not significantly different at $P \leq 0.01$ (LSD), and followed by the same small letter are not significantly different at $P \leq 0.05$ (LSD).

3.2. Comparison of Nutritive Quality

3.2.1. Contents Comparison of General Nutrients and Anti-nutrients

In the reproduction stage, stem elongation of both purslanes stopped, and their bases began to become woody, which decreased their texture and quality. Therefore, this study selected the stems and leaves of 15-d-old (young stage) and 25-d-old (mature stage) plants as materials for detecting the contents of six types of conventional organic nutrients and two types of conventional anti-nutrients (Table 2).

Several studies have reported that the most important bioactive components of purslane are carotenoid, flavonoids,

and vitamins etc [6, 10, 18]. Table 2 showed that the contents of soluble sugar, soluble protein, and anthocyanin in both purslanes were not higher than those in conventional vegetables. Moreover, the contents of carotenoid, Vc, and total flavonoids, which have many functions, such as free radical scavenging, cardiovascular system regulation, anticancer functions, antiinflammatory functions and immune improvement [3], were extremely high. The contents of Vc and total flavonoids in the 25-d-old *P. granulostellulata* plants reached 0.31 mg g⁻¹FW and 45.4 mg g⁻¹DW, respectively, which are much higher than those in conventional vegetables [29].

Table 2. Comparison of nutrients and anti-nutrients contents between *P. granulostellulata* and *P. edulis* in their 15d-old and 25d-old plants (n=3).

No	Ingredients	<i>P. granulostellulata</i>		<i>P. edulis</i>	
		15d	25d	15d	25d
1	Soluble sugar (mg g ⁻¹ FW)	28.42Cc	33.78Aa	26.75Dd	31.11Bb
2	Soluble protein (mg g ⁻¹ FW)	0.46Bb	0.41Bb	0.68Aa	0.61Aa
3	Anthocyanins (U g ⁻¹ FW)	0.99Aa	1.04Aa	0.68Cc	0.85Bb
4	Vc (mg g ⁻¹ FW)	0.17Bb	0.31Aa	0.13 Cc	0.19Bb
5	Carotenoids (mg g ⁻¹ FW)	0.122Cc	0.132Bb	0.133Bb	0.148Aa
6	Total flavonoids (mg g ⁻¹ DW)	34.2Bb	45.4Aa	20.3Cd	22.3Cc
7	Nitrate (μg g ⁻¹ FW)	41.26Cc	88.86Bb	46.48Cc	145.25Aa
8	Soluble oxalic acid (mg g ⁻¹ FW)	17.40Aa	7.19Cc	15.33Bb	6.37Dd

Notes: Means followed by the same capital letter within indexes are not significantly different at $P \leq 0.01$ (LSD), and followed by the same small letter are not significantly different at $P \leq 0.05$ (LSD).

Contents of anthocyanin, Vc and total flavonoids in 15d-old and 25d-old *P. granulostellulata* plants were significantly higher than those in *P. edulis*, and contents of soluble protein and carotenoid were lower than those in *P. edulis*. Contents of five kinds of organic nutrients except for soluble protein in 25d-old plants of both purslanes were significantly higher than those in their 15d-old plants. All these suggested that the nutritive, healthy and drug effective values of *P. granulostellulata* were higher than those of *P. edulis*, and purslane picking should be at the mature stage.

Due to the appliance of large amount of nitrogen fertilizer, nitrate in vegetables has become the main source of nitrate in the human food; and the potential carcinogenic characteristic of nitrate has made it become the most important anti-nutrient in vegetables [30]. Nitrate content in *P. granulostellulata* was slightly lower than that in *P. edulis*. It increased by 115% and 212% from 15d to 25d in *P. granulostellulata* and *P. edulis*, and the increasing range in *P. edulis* was much higher. This suggested that although the nitrate contents in this experiment had not exceeded the food standards [31], if large amount of nitrogen fertilizer was added, the mature *P. edulis* would be the first one to exceed the standard.

Although no study has reported the standard content of oxalic acid in vegetables or foods worldwide and people from Europe and America consider purslane to be flavorful, the main obstacle inhibiting the widespread use of common

purslane is its high oxalic acid content, which can reduce the effectiveness of mineral nutrition and increase the risk of lithiasis in humans [13, 32]. Palaniswamy et al 2004 [13] had found that soluble oxalic acid contents in 16-true leaf purslane seedlings was about 36-45% lower than that in 8-true leaf purslane seedling. In this paper, soluble oxalic acid contents in both 15d-old common purslane plants were over 15 mg g⁻¹FW, and in 25d-old plants, they dropped by near 60% to less than 8 mg g⁻¹FW, the level of the high oxalic acid vegetable spinach [32]. This finding suggested that picking purslane at the mature period cannot only yield purslane with a high organic nutrient content but also avoid the shortcoming of high oxalic acid content.

The optimal picking period of purslane is at its mature period just as indicated by the contents of FA and α -linolenic acid (ALA) [19], the follow-up mineral content and FA composition were detected in 25-d-old plants.

3.2.2. Comparison of Mineral Contents

In addition to providing organic nutrients, vegetables provide a large amount of dietary minerals which is good for the human body, and accumulate heavy metals which can harm the human body [14]. As a promising green food and medicine, purslane is noted for its high contents of K, Ca and Mg, which play crucial roles in improving blood circulation and human immunity and reducing depression [2, 4]. Table 3

shows that dietary mineral contents in both common purslanes were higher than that in conventional vegetables; in particular, the K content was the highest [6, 20]. Regarding the K supply capacity, *P. edulis*, whose K content was 13% higher than that of *P. granulatostellulata*, had a greater advantage. By contrast,

P. granulatostellulata had obvious advantages in the mineral content, including not only a high K content but also relatively high contents of minerals such as Ca, Mg, Fe, and Cu.

Table 3. Comparison of mineral contents between *P. granulatostellulata* and *P. edulis* in their 25d-old plants ($n=3$).

Subspecies	Macronutrients (mg g ⁻¹ DW)			Macronutrients (μg g ⁻¹ DW)			Heavy metals(μg g ⁻¹ DW)		
	K	Ca	Mg	Fe	Cu	Zn	Pb	As	Cd
<i>P. granulatostellulata</i>	34.9Bb	5.6Aa	9.2Aa	143Aa	12Aa	105 Aa	1.21Bb	2.32Aa	0.22Bb
<i>P. edulis</i>	39.5Aa	5.2Aa	4.8Bb	103Bb	11.8Aa	11.8Bb	1.83Aa	1.33Bb	0.52Aa

Notes: Means followed by the same capital letter within a column are not highly significantly different at $P \leq 0.01$ (LSD), and followed by the same small letter are not significantly different at $P \leq 0.05$ (LSD).

Purslane has a capacity for heavy metal enrichment [14], and the dietary intake of heavy metals may lead to various diseases, including cancer, emphysema, bronchiolitis, and alveolitis [13]. However, the contents of Pb, Cd, and As in both common purslanes in this study did not exceed the food standards [34] (Table 3). Furthermore, the contents of Pb and Cd were lower in *P. granulatostellulata* than in *P. edulis*; the As content was higher in *P. granulatostellulata* than in *P. edulis*. These observations revealed that different purslanes may have different abilities of heavy metal enrichment; purslane growing in non polluted areas may not have the heavy metal accumulation problem. However, if purslane is to be planted in heavy metal-contaminated soil for food or medicinal purposes, appropriate purslane subspecies should be selected.

3.2.3. Comparison of Fatty Acid Composition

In addition to providing energy, different types of FA have different functions in human growth and development and in preventing diseases [35]. A balanced intake of FA has become one of the important factors affecting modern health. According to the ω -6/ ω -3 polyunsaturated fatty acid (PUFA) ratio in human milk and human erythrocyte membrane and because ω -6 and ω -3 are not interconvertible in the human body, the recommended intake ratio of ω -6/ ω -3 PUFA in diets is 1/1 to 2/1 [35]. However, because of the abundance of ω -6 PUFA and scarcity of ω -3 PUFA, the actual intake ratio of ω -6/ ω -3 PUFA was only 20 to 25/1 (Western countries) to 38 to 50/1 (India) [35]. This results in a high incidence of cardiovascular disease, diabetes, and other diseases [7] and the growing interest in introducing *P. oleracea* as a new

cultivable vegetable [5, 36].

Although Yan *et al* 2009 reported significant differences in the composition and content of FA among different *P. oleracea* accessions [17], Table 4 shows a similar total lipid content and FA composition in both common purslanes. Fifteen types of FA were detected in *P. granulatostellulata*, accounting for 99.745% of total FA, and 17 types of FA were detected in *P. edulis*, accounting for 99.141% of total FA. The FA composition of both purslanes was similar to that reported by Siriamornpun and Suttajit 2010 [9]. The most abundant FA was α -linolenic acid (ALA)(c18:3), followed by linoleic acid (c18:2) and palmitic acid (c16:0). The relative contents of total unsaturated fatty acids (UFAs) and PUFA and index of UFA of both purslanes were higher than those of conventional vegetables, as reported by Siriamornpun and Suttajit 2010 [9], whereas the UFA content in *P. granulatostellulata* was higher than that in *P. edulis*. The total saturated fatty acid (SFA) content in both purslanes was relatively low and that in *P. granulatostellulata* was lower. Furthermore, the ALA content in both stems and leaves was more than 51%, which is higher than that previously reported [9, 36]. The ω -6/ ω -3 PUFA ratios of *P. granulatostellulata* and *P. edulis* were 0.363/1 and 0.372/1, respectively, which are lower than the recommended ω -6/ ω -3 ratio and much lower than the actual ω -6/ ω -3 intake ratio [35]. These results prove that unlike fish oils with high contents of cholesterol and calories, purslane can provide an excellent source of ω -3 UFA to balance the ω -6/ ω -3 PUFA intake; by contrast, the slightly higher content of UFA and lower content of SFA in *P. granulatostellulata* showed that it has a slightly higher FA nutritive value than *P. edulis* does.

Table 4. Analysis of fatty acid composition between *P. granulatostellulata* and *P. edulis* in their 25d-old plants ($n=3$).

Fatty acid	Relative content (%)		Fatty acid	Relative content (%)	
	<i>P. granulatostellulata</i>	<i>P. edulis</i>		<i>P. granulatostellulata</i>	<i>P. edulis</i>
Lipid content(DW ⁻¹)	16.1 Aa	15.8 Aa	c20:0	0.804Aa	0.484Bb
c8:0	-Bb	0.157Aa	c18:3, ω 6	0.272Aa	0.286Aa
c12:0	0.277Ab	0.343Aa	c18:3, ω 3	51.667Aa	51.594Aa
c13:0	1.27Ab	1.697Aa	c20:2, ω 6	- Bb	0.331Aa
c14:0	0.54Aa	0.432Ab	c22:0	0.778Aa	0.521Bb
c15:1	0.937Bb	1.254Aa	c24:0	0.713Bb	0.935Aa
c16:0	12.887Ab	14.921Aa	Total FA ¹	99.475Aa	99.141Aa

Fatty acid	Relative content (%)		Fatty acid	Relative content (%)	
	<i>P. granulatostellulata</i>	<i>P. edulis</i>		<i>P. granulatostellulata</i>	<i>P. edulis</i>
c16:1	1.242Aa	1.029Bb	Total SFA ²	20.16Ab	21.809Aa
c17:0	-Bb	0.153Aa	Total UFA ³	79.585Aa	77.332Ab
c17:1	1.165Aa	- Bb	Total MUFA ⁴	9.165Aa	6.545Bb
c18:0	2.891Aa	2.166Bb	Total PUFA ⁵	70.42 Aa	70.787 Aa
c18:1	5.821Aa	4.262Bb	ω-6/ω-3	0.363 Aa	0.372 Aa
c18:2, ω6	18.481Aa	18.576Aa	IUFA ⁶	201.944Aa	199.999Aa

Notes: "-" indicates undetected. Means followed by the same capital letter within indexes are not significantly different at $P \leq 0.01$ (LSD), and followed by the same small letter are not significantly different at $P \leq 0.05$ (LSD). ¹FA: fatty acid; ²SFA: saturated fatty acid; ³UFA: unsaturated fatty acid; ⁴MUFA: monounsaturated fatty acid; ⁵PUFA: polyunsaturated fatty acid; ⁶IUFA: unsaturated fatty acid index.

4. Conclusions

Both *P. granulatostellulata* and *P. edulis* have high contents of Vc, total flavonoids, K, and ALA; *P. granulatostellulata* has advantages over *P. edulis* regarding Vc, flavonoid, and mineral contents, except for the K content. *P. edulis* has advantages over *P. granulatostellulata* in plant appearance, the K content, and producibility. Both subspecies are similar in FA composition and are suitable for picking at the mature stage (25d in this study) because they are more nutritious with a high content of main organic nutrients and low content of oxalic acid during this period.

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References

- [1] A. E. Abdel Moneim. The Neuroprotective Effects of Purslane (*Portulaca oleracea*) on Rotenone-induced Biochemical Changes and Apoptosis in Brain of Rat. *CNS Neurol. Disord. Drug Targets*. 2013, 12(6):830-41.
- [2] A. P. Simopoulos, D. X. Tan, L. C. Manchester, R. J. Reiter. Purslane, a Plant Source of Omega-3 Fatty Acids and Melatonin. *J. Pineal Res*. 2005,39(3):331-332.
- [3] A. P. Simopoulos. "Horticulture and Human Health", In B. Quebdeaux, F. Bliss eds, *Contribution of Fruits and Vegetables*, Prentice-Hall, Englewood Cliffs, NJ, USA. 1987, pp 93-107.
- [4] Y. X. Zhou, H. L. Xin, K. Rahman, S. J. Wang, C. Peng, H. Zhang. *Portulaca oleracea* L.: A Review of Phytochemistry and Pharmacological Effects. *BioMed Research International*, Volume 2015, Article ID 925631, <http://dx.doi.org/10.1155/2015/925631>
- [5] M. A. Alam, A. S. Juraimi, M. Y. Rafii, A. A. Hamid, F. Aslani, M. M. Hasan, M. A. M. Zainudin, M. K. Uddin. Evaluation of Antioxidant Compounds, Antioxidant Activities, and Mineral Composition of 13 Collected Purslane (*Portulaca oleracea* L.) Accessions. *BioMed Research International*, 2014, Article ID 296063, <http://dx.doi.org/10.1155/2014/296063>
- [6] M. A. Alam, A. S. Juraimi, M. Y. Rafii, A. A. Hamid, M. K. Uddin, M. Z. Alam, M. A. Latif. Genetic Improvement of Purslane (*Portulaca oleracea* L.) and Its Future Prospects. *Mol. Biol. Rep*. 2014,41(11): 7395-7411.
- [7] A. P. Simopoulos. The Importance of the Omega-6/Omega-3 Fatty Acid Ratio in Cardiovascular Disease and Other Chronic Diseases. *Exp. Biol. Med*. 2008, 233:674-688.
- [8] Ren, S. Weeda, O. Akande, Y. Guo, L. Rutto, T. Mebrahtu. Drought Tolerance and AFLP Based Genetic Diversity in Purslane (*Portulaca oleracea* L.). *Res. J. Biotechnol*. 2011, 3:51-61.
- [9] S. Siriamornpun, M. Suttajit. Microchemical Components and Antioxidant Activity of Different Morphological Parts of the Wild Purslane (*Portulaca oleracea*). *Weed Sci*. 2010,58(3): 182-188.
- [10] H. B. Zhu, Y. Z. Wang, H. Liang, Q. M. Chen, P. Zhao, J. Tao. Identification of *Portulaca oleracea* L. from Different Sources Using GC-MS and FT-IR Spectroscopy. *Talanta*. 2010,81: 129-135.
- [11] Danin, T. Raus. A Key to 19 Microspecies of the *Portulaca oleracea* Aggregate. In: "Plant Stories, Chapter G: *Portulaca oleracea* - a Complex Full of Riddles". *Flora of Israel Online*, 2010, http://flora.org.il/en/books/plant-stories-2/chapter-k/useful_plants_k2/
- [12] J. M. Du, J. J. Yun, Y. Y. Yang, L. J. Zhang, W. C. Hu, C. M. Lu. Provenance Identification and Comparison of Biological Characteristics and Ecological Adaptabilities between the Wild and Cultivated Types of Purslane. *Seed*. 2016, 34(1): 6-14.
- [13] U. R. Palaniswamy, B. B. Bible, R. J. McAvoy. Oxalic Acid Concentrations in Purslane (*Portulaca Oleraceae* L.) Is Altered by the Stage of Harvest and the Nitrate to Ammonium Ratios in Hydroponics. *Sci. Hortic*. 2004, 102: 267-275.
- [14] K. K. Tiwari, S. Dwivedi, S. Mishra, S. Srivastava, R. D. Tripathi, N. K. Singh, S. Chakraborty. Phytoremediation Efficiency of *Portulaca tuberosa* Rox and *Portulaca oleracea* L. Naturally Growing in an Industrial Effluent Irrigated Area in Vadodra, Gujrat, India. *Environ. Monit. Assess*. 2008,147:15-22.
- [15] L. X. Liu, P. Howe, Y. F. Zhou, Z. Q. Xu, C. Hocart, R. Zhang. Fatty Acids and B-Carotene in Australian Purslane (*Portulaca Oleracea*) Varieties. *J. Chromatogr A*. 2000, 893: 207-213.
- [16] Y. Y. Lim, E. P. L. Quah. Antioxidant Properties of Different Cultivars of *Portulaca oleracea*. *Food Chem*. 2007, 103: 734-740.
- [17] G. Yan, N. Aryamanesh, S. Wang. Purslane - a Potential Vegetable Crop. Rural Industries Research and Development Corporation (RIRDC), Australia. Publication No. 09/088, RIRDC Project No. PRJ-000348, 2009, pp 1-15.

- [18] M. O. Ezekwe, T. R. Omara-AlWala, T. Membrahtu. Nutritive Characterization of Purslane Accessions as Influenced by Planting Date. *Plant Foods Hum. Nutr.* 1999, 54:183-191.
- [19] U. R. Palaniswamy, R. J. McAvoy, B. B. Bible. Stage of Harvest and Polyunsaturated Essential Fatty Acid Concentrations in Purslane (*Portulaca oleracea*) Leaves. *J. Agric. Food Chem.* 2001,49:3490-3493.
- [20] M. K. Uddin, A. S. Juraimi, M. S. Hossain, M. E. Ali, M. R. Ismail. Evaluation of Antioxidant Properties and Mineral Composition of Purslane (*Portulaca oleracea* L.) at Different Growth Stages. *Int. J. Mol. Sci.* 2012,13:10257-10267.
- [21] M. Bradford. A Rapid and Sensitive Method for the Quantitation of Microgram Quantities of Protein Utilizing the Principle of Protein-Dye Binding. *Anal Biochem.* 1976,72: 248-254.
- [22] S. Watanabe, K. Kojima, Y. Ide, S. Sasaki. Effects of Saline and Osmotic Stress on Proline and Sugar Accumulation in *Populus euphratica* in vitro. *Plant Cell Tissue Organ Cult.* 2000, 63:199-206.
- [23] K. Hamed, A. Castagna, E. Salem, A. Ranieri, C. Abdelly. Sea Fennel (*Crithmum maritimum* L.) under Salinity Conditions: a Comparison of Leaf and Root Antioxidant Responses. *J. Plant Growth Regul.* 2007, 53:185-194.
- [24] Kong, L. Chia, N. Goh, T. Chia, R. Brouillard. Analysis and Biological Activities of Anthocyanins. *Phytochemistry*, 2003, 64: 923-933.
- [25] J. Porra, W. A. Thompson, P. E. Kriedman. Determination of Accurate Extinction Coefficients and Simultaneous Equations for Assaying Chlorophylls A and B Extracted with Four Different Solvents: Verification of Concentration of Chlorophyll Standards by Atomic Absorption Spectroscopy. *Biochim. Biophys. Acta.* 1989,975:384-394.
- [26] M. Alothman, R. A. Bhat, A. Karim. Antioxidant Capacity and Phenolic Content of Selected Tropical Fruits from Malaysia, Extracted with Different Solvents. *Food Chem.* 2009,115(3): 785-788.
- [27] A. Cataldo, M. Haroon, L. E. Schrader, V. L. Youngs. Rapid Colorimetric Determination of Nitrate in Plant Tissue by Nitration of Salicylic Acid. *Commun Soil Sci Plant Anal.* 1975, 6: 71-80.
- [28] Ilarslan, R. G. Palmer, J. Imsande, H. T. Horner. Quantitative Determination of Calcium Oxalate and Oxalate in Developing Seeds of Soybean (Leguminosae). *Am. J. Bot.* 1997, 84:1042-1046.
- [29] M. K. Uddin, A. S. Juraimi, M. S. Hossain, M. A. U. Nahar, M. E. Ali, M. M. Rahman. Purslane Weed (*Portulaca oleracea*): a Prospective Plant Source of Nutrition, Omega-3 Fatty Acid, and Antioxidant Attributes. *The Scientific World Journal*, Volume 2014, Article ID 951019, Hindawi Publishing Corporation. <http://dx.doi.org/10.1155/2014/951019>
- [30] Leonardo, E. Ulla, F. Georg, Å. Per. Liquid Chromatographic Determination of Residual Nitrite/Nitrate in Foods: NMKL Collaborative Study. *J. AOAC. Int.* 2000,83(2):365-375.
- [31] The Commission of the European Communities (2002) European Commission Regulation (EC) No. 563/2002. Official Journal of the European Communities L 86/5.
- [32] E. Koh, S. Charoenprasert, A. E. Mitchell. Effect of Organic and Conventional Cropping Systems on Ascorbic Acid, Vitamin C, Flavonoids, Nitrate, and Oxalate in 27 Varieties of Spinach (*Spinacia oleracea* L.). *J. Agr. Food Chem.* 2012, 60(12): 3144-3150.
- [33] G. Dziubanek, A. Piekut, M. Rusin, R. Baranowska, I. Hajok. Contamination of Food Crops Grown on Soils with Elevated Heavy Metals Content. *Ecotox. Environ. Safe.* 2015,118:183-189.
- [34] The Commission of the European Communities (2006) European Commission Regulation (EC) No. 1881/2006. Official Journal of the European Union, L 364/5.
- [35] A. P. Simopoulos. Evolutionary Aspects of Diet: The Omega-6/Omega-3 Ratio and the Brain. *Mol. Neurobiol.* 2011,44:203-215.
- [36] A. P. Simopoulos, N. J. Salem. Purslane: a Terrestrial Source of Omega-3 Fatty Acids. *New Engl. J. Med.* 1986,315: 833.