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Research Article

Nutritional compositions in young leaves and stem from quinoa (*Chenopodium quinoa* Willd.) grown in Korea

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Abstract Quinoa (*Chenopodium quinoa* Willd.) leaves and stem grown in Korea were analyzed to determine their nutritional compositions. Quinoa leaves exhibited significantly higher levels of crude protein, crude lipid, crude ash, carbohydrate, and dietary fiber than those of the quinoa stem. Fructose and glucose were only detected in stem, and they contents were 44.25 mg% and 107.62 mg%, respectively. Acetic acid was the most plentiful organic acid in leaves and stem of quinoa, with their higher levels determined in leaves (428.40 mg%). The major minerals of quinoa were potassium and calcium, especially potassium was verified as having the highest level in leaves (750.65 mg%) and stem (869.15 mg%) of quinoa. In addition, linolenic acid (C18:3, n-3) contained as highest level was detected only in leaves (176.09 mg%) but no identified in stem. It was found that quinoa leaves contained many kinds of vitamin such as vitamin B_1 (293.35 μg/100 g), B_2 (256.54 μg/100 g), C (2.02 mg/100 g), and E (2.25 mg/100 g). These findings suggest that quinoa leaves and stem are an excellent source for developing of salads and various processed products, further this study presents the application prospect of quinoa to various food industry fields.

Keywords *Chenopodium quinoa*, nutritional composition, proximate, quinoa leaves, quinoa stem

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1. Introduction

The young leaves of the plant are sought-after as raw vegetables in Europe, America, Australia, and Asia due to their various nutrients, bioactive substances, and soft sensory characteristics (Colonna et al., 2016). They are abundant in nutrients including vitamins, minerals, amino acids, and peptides. In addition, foods such as salads and fresh convenience products made with young-leaves are good for health because of minimize destruction of nutrients. Salad markets as well as fresh convenience products markets has recently grown rapidly around the world, and among them, the market for leaf and stem vegetables are becoming more and more advanced (Kwack et al., 2015).

Quinoa (*Chenopodium quinoa* Willd.) is a flowering plant belonging to the amaranth family and is known as one of the three major crops of the ancient Inca Empire (Bazile et al., 2014). Currently, it is cultivated in more than 70 countries around the world, and in Korea, it is also grown all over the country according to attention is focused on the excellent nutritional properties of quinoa. Quinoa is mainly grown in alpine areas, but it has strong adaptability to various climatic environments and is easy to cultivate in dry soil (Shultz et al., 1989). Therefore, it has the high productivity.

Quinoa is mainly used as a food raw material for noodles, confectionery, and soup. However, not only the seeds but also the leaves of quinoa are vary used in the form of salad vegetables and green juice in the America, Mexico, Chile, China, and other countries. In Korean, only seeds are used as food raw materials, so there is a lack of research on leaves of quinoa, and cultivation of quinoa is still not popular. In addition, most of the research on quinoa leaves conducted so far is on adult leaves, which are relatively tough and cannot be consumed in salads (Le et al., 2021; Pathan et al., 2019; Vazquez-Luna et al., 2019). Accordingly, it is urgently necessary to secure nutritional data on young leaves grown in Korea.

Therefore, in the present study, the nutritional compositions of young leaves and stems of quinoa grown in Korea was investigated in order to improve the popularization and sitological value of quinoa leaves, and to provide basic data for the cultivation and utilizing as salad vegetables.

2. Materials and methods

2.1. Samples and reagents

The leaves and stem of quinoa (*C. quinoa*) were obtained by sowing and cultivating the quinoa seed which is gained from National Institute of Crop Science, Rural Development Administration located in Pyeongchang. The quinoa cultivated in a farm situated on the Gimpo, northwestern Gyeonggi. Leaves and stem were collected from 50 quinoa aged 1-month year old (height, 20-25 cm), and we removed roots and washed three times with cold water, immediately. Leaves and stem were divided and chopped into slices using a chopper (TC-8B, Techon Co., Bucheon, Korea). Then, all samples stored in a deep freezer set to the temperature of -70℃. Various kinds of standards such as free sugars, organic acids, fatty acid methyl ester, β-carotene, vitamins B_1, B_2, B_3, B_5, B_6, and B_{12}, ascorbic acid, and α-, β-, γ-, and δ-tocopherol were obtained from Sigma Chemical Co. (St. Louis, MO, USA). The standards for analyzing mineral content were obtained from AccuStandard (New Haven, CT, USA).

2.2. Proximate composition and quantitative analysis of dietary fiber

Quinoa leaves and stem were determined and compared for proximate composition and dietary fiber content according to instructions on the Association of Official Analytical Chemists (AOAC, 2005). The moisture content was determined by air oven method, and the moisture content (%) was calculated as follows: (fresh weight - dry weight) / sample weight × 100. The crude protein content was analyzed according to the Kjeldahl method. The crude lipid content was determined by Soxtec extraction system (Soxtec 1043, Foss Tecator AB, Höganäs, Sweden), and the crude ash content was evaluated according to the direct muffle-furnace method, and the ash content (%) was calculated as follows: (before incinerated weight - after incinerated weight) / sample weight × 100. The crude fiber

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content was measured using a fiber extractor (FIWE 6, Velp Scientifica, Usmate, Italy). The carbohydrate content (%) was calculated as follows: 100 - the moisture, crude ash, crude protein, and crude lipid content (%). Measurement of the dietary fiber content was performed by a simplified enzymatic-gravimetric method.

2.3. Quantitative analysis of free sugar and organic acids

The contents of free sugar and organic acid in leaves and stem were measured using Agilent 1100 series liquid chromatography (Agilent Technologies, Palo Alto, CA, USA). Sample 5 g were blended with distilled water of 50 mL and centrifuged at 11,300 ×g for 20 min using a centrifuge (Supra-21K, Hanil, Incheon, Korea). The supernatant was filtered with a 0.45 μm filter in order to obtain the pure extracts. This filtrate was used as to sample. To analyze the fructose, glucose, sucrose, maltose, and lactose, we infused the sample of 20 μL into the high-performance liquid chromatography installed with a carbohydrate analysis column (4.6×250 mm, Waters Co., Milford, MA, USA). Five free sugar were separated with an isocratic elution at a flow rate of 1.0 mL/min and a mobile phase of an acetonitrile (80): water (20) mixture (v/v). The peaks were detected with a refractive index (RI) detector and each compound were identified by comparison with standards and the content was calculated with peak area. The sample of 20 μL were injected into the high-performance liquid chromatography installed with a Shodex Rs Pak KC-811 column (8.0×300 mm, Shodex, Tokyo, Japan), in order to analyze the organic acids (malic acid, citric acid, oxalic acid, acetic acid, formic acid, and succinic acid). Six organic acids were separated using a mobile phase of 0.1% H_3PO_4 and an isocratic elution at a 1.0 mL/min as flow rate. Each peak was detected with an ultraviolet (UV) detector and each compound were identified by comparing the standards and the content was calculated with peak area.

2.4. Quantitative analysis of minerals

Minerals evaluated in leaves and stem of quinoa were calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), zinc (Zn), and selenium (Se). Each sample was pre-treated by the following procedures. Leaves and stem were dissolved in a 90% HNO_3/H_2O_2 mixture and then digested using a microwave digestion system for 30 min, respectively. The solution obtained from each sample was filtrated with a filter paper. This filtrate was used for analyzing. Seven elements (Ca, Cu, Fe, K, Mg, Na, and Zn) were evaluated using an inductively coupled plasma (ICP) spectrometer (Perkin Elmer Co., Shelton, CT, USA) and another elements (Se) was analyzed by ICP-mass spectrometry. The operating conditions of the ICP spectrometer were as follows: 1.4 kW reflected power, 10 L/min argon plasma gas flow rate, 0.2 L/min auxiliary gas flow rate, and 0.55 L/min nebulizer gas flow rate. The operating conditions of the ICP-mass spectrometry as follows: 1.4 kW reflected power, 9.6 V lens voltage, 18 L/min plasma flow rate, 1.5 L/min auxiliary gas flow rate, and 0.92 L/min nebulizer gas flow rate.

2.5. Fatty acid composition and quantitative analysis of fatty acid

Fatty acids content and composition were analyzed according to the method of Jang et al. (2016). Each sample 10 g were obtained with organic solvent, and the 25 mg extracted fat was dissolved in 0.5 N NaOH-methanol of 2 mL and changed to its fatty acid methyl esters using 14% BF_3-methanol of 2

mL. Gas chromatography (Agilent 6890N/5975 MSD series, Avondale, PA, USA) installed with an SP™ 2560 column (100 m×0.25 mm, Supelco Inc., Bellefonte, PA, USA) was used for analyzing the fatty acid contents. The column oven temperature was increased sequentially by 170℃ to 245℃. Carrier gas was helium (He) and it's a flow rate was 0.75 mL/min. The injector temperature was 250℃ and the flame ionization detector (FID) temperature was 285℃. A FID conversion factor was used for calculating the fatty acid contents.

2.6. Quantitative analysis of vitamins

Vitamins evaluated in leaves and stem of quinoa were β-carotene, vitamin B complex, vitamin C, and vitamin E, and they were determined according to the AOAC method (2005).

Samples for analyzing the β-carotene were dissolved in ethanol 30 mL and 10% pyrogallol 1 mL. Then, KOH 3 mL was added to the sample solution and heated for 30 min. The sample was cooled and 30 mL distilled water were added for obtaining the ether layer. And then, the ether layer was dehydrated and evaporated. The dehydrated product and n-hexane 20 mL were compounded, and its was used as the sample. The sample was injected into an Agilent 1100 series HPLC system installed with a Nova-Pak silica column (3.9×150 mm, Waters Co., Milford, MA, USA). The operating conditions were following as: n-hexane and isopropyl alcohol (99:1, v/v) of mobile phase, 1.0 mL/min of flow rate, and 20 μL of injection volume.

Samples for analyzing the vitamin B complex were extracted with 75 mM ammonium formate solution (pH 7.0) 20 mL for 1 h. The extracts were centrifuged in order to separate the supernatant and precipitate for 15 min, and the supernatant was obtained. The obtained supernatant was filtered with a Millipore 0.45 μm membrane filter. The filtrate was used as the test sample, and its injected into an HPLC-tandem mass spectrometer (Agilent 1200 series, Agilent Technologies, Santa Clara, CA, USA) connected with a Luna C_{18} column (3.0×150 mm, Phenomenex, Torrance, CA, USA). The operating conditions were following as: the mobile phase A was 5 mM ammonium dissolved in distilled water, and mobile phase B was 5 mM ammonium dissolved in methanol. They were eluted through the gradient system as follows: 0 min (90% A, 10% B); 0-8 min (55% A, 45% B); 8-15 min (90% A, 10% B). In addition, the samples were analyzed by the conditions such as 0.3 mL/min flow rate and 35℃ temperature.

Samples for analyzing the vitamin C were prepared adding 5% meta-phosphoric acid. The extracts were filtered through a Millipore 0.45 μm membrane filter, and was injected into an Agilent 1200 series HPLC system connected with a Shiseido Capcell Pak C_{18} column (4.6×250 mm, Shiseido, Tokyo, Japan). The operating conditions were following as: 0.05 M KH_2PO_4 and acetonitrile (99:1, v/v) of mobile phase, 0.9 mL/min of flow rate, and 254 nm of UV detector wavelength.

The extraction of samples for analyzing the vitamin E were conducted in the same way as that for β-carotene. However, flow rate of mobile phase was 0.5 mL/min.

2.7. Statistical analysis

All experiments except for dietary fiber were carried in triplicate or more, and the statistical analysis of results were performed using the Statistical Package for Social Sciences statistics 25.0 (SPSS Inc., Chicago, IL, USA). In order to compare the between samples data of the two groups (leaves and stem), independent sample

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t-test was used.

3. Results and discussion

3.1. Proximate composition and dietary fiber

The proximate composition in leaves and stem of quinoa (*C. quinoa*) differed significantly ($p<0.01$, Table 1). The moisture accounts in the majority of proximate composition in leaves and stem (88.95% and 92.72%, respectively). The moisture content of stem higher than that of leaves, and which was significantly different ($p<0.001$). Quinoa leaves exhibited significantly higher levels of crude ash, crude protein, crude lipid, and carbohydrate than those of the quinoa stem ($p<0.01$). However, the crude fiber content (1.13%) of leaves showed significantly lower levels than that (2.10%) of stem ($p<0.001$). The dietary fiber content of leaves and stem were 3.32% and 3.10%, respectively. Briefly, the dietary fiber was exhibited higher in quinoa leaves than stem.

These results are exhibited similar tendency with that of a previous study of *Datura innoxia*, in which the *D. innoxia* stem showed a higher moisture compared to the its leaves (Ayuba et al., 2011). In addition, the stem of *Epiphyllum oxypetalum* had a higher moisture content than that of leaves (Ingale and Sajid, 2015). However, the studies of several scholar were demonstrated that leaves exhibited a higher moisture than stem (Anyasor et al., 2014; Asuk et al., 2015; Kpomah and Odokwo, 2020; Lohdip et al., 2015). According to the study of Lohdip et al. (2015), the plant belonging to *Chenopodium* sp. showed a higher ash, crude fat, and carbohydrate content in leaves than stem, while crude fiber exhibited a higher in stem than leaves. These results were very much like our results. A vast majority of reports verified that the proximate composition including dietary fiber content can vary from growth conditions such as season, soil composition, climatic conditions (Jang et al., 2011; Rohloff et al., 2015). Therefore, this study suggests that the proximate composition including dietary fiber content of quinoa can depend on various factor and their different parts.

Table 1. Proximate composition and dietary fiber content in leaves and stem of *Chenopodium quinoa*

Components (% fresh weight)	Leaves	Stem	t-value
Moisture	88.95±0.03[1)]	92.72±0.12	-51.249[***2)]
Crude protein	3.92±0.03	1.29±0.05	74.903[***]
Crude lipid	0.53±0.01	0.17±0.00	71.574[***]
Crude ash	2.42±0.03	1.98±0.06	12.153[***]
Crude fiber	1.13±0.04	2.10±0.07	-22.073[***]
Carbohydrate	4.19±0.02	3.84±0.12	4.811[**]
Dietary fiber	3.32	3.10	-

[1)]Results are presented as mean±SD (n=3).
[2)]Significantly different between leaves and stem by the two independent sample t-test ([**]$p<0.01$, [***]$p<0.001$).

3.2. Free sugars

The free sugar content in leaves and stem of quinoa is given in Table 2. Fructose, glucose, sucrose, maltose, and lactose were analyzed but most free sugar had not detected in samples. Only

Table 2. Free sugar content in leaves and stem of *Chenopodium quinoa*

Components (mg% fresh weight)	Leaves	Stem	t-value
Fructose	ND[1)]	44.25±8.33[2)]	-9.198[**3)]
Glucose	ND	107.62±17.81	-10.464[***]
Sucrose	ND	ND	-
Maltose	ND	ND	-
Lactose	ND	ND	-

[1)]ND, not detected.
[2)]Results are presented as mean±SD (n=3).
[3)]Significantly different between leaves and stem by the two independent sample t-test ([**]$p<0.01$, [***]$p<0.001$).

fructose and glucose were detected in stem, and they contents were 44.25 mg% and 107.62 mg%, respectively. That is to say, the content of glucose was twice times or more of the content of fructose. Free sugars are closely related to sweetness, and intensity of sweetness depends on the kind of free sugar and amount (Nam et al., 2018). For example, the free sugar content was similar with the trend of °Brix (Lee et al., 2013), and Moskowitz (1970) was reported that the sweetness of glucose was only ~50% of the that of sucrose, and fructose has a sweetness 60-70% higher than sucrose. Therefore, it can be said that stem of quinoa has a higher sweet taste than leaves and its sweetness originate from fructose and glucose. According to several research (Ackerson, 1981; Guy et al., 1992), a part of free sugars and its synthesis are related to metabolic adaptations from the low temperature, and the water stress in plant was showed to increase the content of free sugar. Moreover, the free sugar content varied on climate conditions such as temperature, relative humidity, the amount of light, and the amount of rainfall (Anderson, 1986). Consequently, it is forecasted that the intensity of sweetness by the amount and composition of free sugar may differ according to the quinoa part and also that their amount and composition of free sugar will vary between cultivation condition.

3.3. Organic acids

Acetic acid was the most abundant organic acid in leaves and stem of quinoa, with their higher levels determined in leaves (428.40 mg%) (Table 3). Malic acid, oxalic acid, formic acid, and succinic acid were not detected in leaves and stem, and citric acid was detected but that is very small amount with 3.57 mg% and 6.41 mg%, respectively. Briefly, citric acid content of stem was exhibited a significant higher level than that of leaves ($p<0.001$).

Table 3. Organic acid content in leaves and stem of *Chenopodium quinoa*

Components (mg% fresh weight)	Leaves	Stem	t-value
Malic acid	ND[1)]	ND	-
Citric acid	3.57±0.01[2)]	6.41±0.07	-65.762[***3)]
Oxalic acid	ND	ND	-
Acetic acid	428.40±16.39	107.76±2.19	33.590[**]
Formic acid	ND	ND	-
Succinic acid	ND	ND	-

[1)]ND, not detected.
[2)]Results are presented as mean±SD (n=3).
[3)]Significantly different between leaves and stem by the two independent sample t-test ([**]$p<0.01$, [***]$p<0.001$).

In the metabolic pathway of animals and plants mitochondria, organic acids such as citric acid, oxalic acid, and acetic acid play a central role. For example, citric acid and oxalic acid are involved in diverse metabolic pathway including detoxification of metal substances and resistance for anaerobic stress, and acetic acid of plant participates in the tricarboxylic acid cycle, one of the energy metabolisms (Mucha et al., 2005; Yang et al., 2014). In addition, the level of organic acid in plant also can be varied according to cultivars as well as between individual part, and the growth condition such as soil, climate. Moreover, the previous study reported that the accumulation of organic acids is increased by environmental stress (Lopez-Bucio et al., 2000). Therefore, it is expected that the level of organic acid contained in quinoa had been varied by various factors. Sensory characteristics including flavor, color, and texture are affected by organic acids, and tissue and biological stability also closely related in organic acids (Chung et al., 2000). For this reason, organic acids are being widely used as additives in the vegetable or fruit beverages, drinks, and smoothie (Pereira et al., 2013). Therefore, it is

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likely that leaves and stem of quinoa can be effectively applied in a variety of food filed, even though the level of organic acids are low.

3.4. Minerals

Table 4 presents the mineral content of quinoa according to its different two parts. All elements except for copper were identified in quinoa, and the major minerals were calcium, potassium, magnesium, and sodium. Particular, potassium was verified as having the highest level in leaves and stem of quinoa; its content in two parts was determined as 750.65 mg% and 869.15 mg%, respectively. Potassium content of quinoa stem higher than that of quinoa leaves and this was exhibited a significant difference ($p<0.001$). However, calcium, iron, magnesium, sodium, zinc, and selenium were showed the significant higher in leaves than stem ($p<0.001$). Notably, calcium and magnesium contents of leaves were roughly six times than those of stem. The content of zinc and selenium in leaves and stem was trace as the 0.89 mg%, 0.09 mg% (leaves), 0.23 mg%, 0.05 mg% (stem). These results similar with results of other studies that among minerals contained in quinoa, amaranth, spinach, moringa leaves, *Chenopodium album* sprouts, and Stinging nettle sprouts potassium was highest (Edelman and Colt, 2016; Pathan et al., 2019; Pradhan et al., 2015). In addition, the potassium content results of quinoa according to tissue is consistent with what reported by Park et al. (2011). Park et al. (2011) demonstrated that potassium content in stem of *Cucumis sativus* L. higher than leaves. Park et al. (1993) reported that the mineral content in leaf and stalk of *Brassica juncea* is similar or the mineral content in leaf exhibited higher than those of stem, among others calcium and magnesium content exhibited the big difference. It was very similar to our results. The minerals absorbed from plant roots are transported to the stems or leaves, or some mineral is stored in the roots (Nam et al., 2018). Accordingly, the mineral contents in plant are known to vary differ according to the various tissue. In addition, the mineral contents can be affected by the growth season, harvest season, soil conditions, and the quantity or variety of fertilizer (Mitchell, 1936). Therefore, it is considered that distribution of minerals in quinoa tissues may completely different on various factors.

Table 4. Mineral content in leaves and stem of *Chenopodium quinoa*

Minerals (mg% fresh weight)	Leaves	Stem	t-value
Ca	254.90±9.60[1)]	39.74±1.07	38.581[***2)]
Cu	ND[3)]	ND	-
Fe	2.23±0.03	0.21±0.01	128.484[***]
K	750.65±1.65	869.15±3.25	-56.312[***]
Mg	156.75±1.45	26.22±0.33	152.149[***]
Na	37.52±0.04	26.21±0.08	224.150[***]
Zn	0.89±0.02	0.23±0.00	71.753[***]
Se	0.09±0.00	0.05±0.00	12.599[***]

[1)]Results are presented as mean±SD (n=3).
[2)]Significantly different between leaves and stem by the two independent sample t-test ([***]$p<0.001$).
[3)]ND, not detected.

3.5. Fatty acids

Most fatty acids were not identified in leaves and stem of quinoa, and only palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2, n-6), and linolenic acid (C18:3, n-3) (Table 5). All fatty acids were exhibited as significant higher levels in leaves than in stem ($p<0.001$), and the content difference of fatty acid ranges from between 2.5 times and 6.8 times. Especially, linolenic acid (C18:3, n-3) contained as highest level was detected only in leaves (176.09 mg%) but no

Table 5. Fatty acids component in leaves and stem of *Chenopodium quinoa*

Fatty acids (mg% fresh weight)	Leaves	Stem	t-value
C6:0	ND[1)]	ND	-
C8:0	ND	ND	-
C10:0	ND	ND	-
C12:0	ND	ND	-
C13:0	ND	ND	-
C14:0	ND	ND	-
C15:0	ND	ND	-
C16:0	80.16±0.90[2)]	22.44±0.43	100.420[***3)]
C16:1	ND	ND	-
C17:0	ND	ND	-
C18:0	5.69±0.18	2.24±0.02	33.226[***]
C18:1	52.12±1.38	8.36±0.03	55.019[***]
C18:2, n-6	48.60±1.57	7.16±0.67	42.062[***]
C20:0	ND	ND	-
C18:3, n-3	176.09±3.56	ND	85.691[***]
C20:1	ND	ND	-
C22:0	ND	ND	-
C20:3, n-3	ND	ND	-
C22:1, n-9	ND	ND	-
C20:4, n-6	ND	ND	-
C24:0	ND	ND	-
C24:1	ND	ND	-
Total SFA[4)]	85.85±0.72	24.68±0.45	124.941[***]
Total UFA[5)]	276.81±6.51	15.52±0.71	69.153[***]
Total UFA/total SFA	3.22±0.05	0.63±0.02	86.899[***]

[1)]ND, not detected.
[2)]Results are presented as mean±SD (n=3).
[3)]Significantly different between leaves and stem by the two independent sample t-test ([***]p<0.001).
[4)]SFA, saturated fatty acid.
[5)]UFA, unsaturated fatty acid.

identified in stem. For leaves, the unsaturated fatty acid (UFA) content was higher than the saturated fatty acid (SFA) content; its content of UFA and SFA was determined as 276.81 mg% and 85.85 mg%, respectively. However, the UFA and SFA in stem was showed 15.52 mg% and 24.68 mg%, it was verified a result opposite to result in leaves. Briefly, SFA content in stem was roughly 1.5 times high than UFA content. According to Choi and Lim (2014), depending upon the extracts, but most extracts from *Euphorbia Supina* of a therophyte contained high n-3 fatty acid. Also, another study revealed that there was linolenic acid (C18:3, n-3) of high content in leaves of plant (Pascual-Villalobos and Lopez, 2010). Chung et al. (1996) demonstrated that leaves of pine sprouts contained higher SFA than UFA and stem of pine sprouts showed higher UFA than SFA. Briefly, these results opposite to our results. However, they reported that SFA and UFA contents of pine needles was different according to sampling times. Therefore, we are expected to be the fatty acid content and composition of plant showed completely different by environment, climate, condition, etc. as well as sampling times. Most of the fatty acids in plant are contained in the seed of the plant, and the leaves and stem contain very small amounts, so related studies are insignificant. However, Petrov et al. (2016) reported that the plant contained high fatty acid will have a crucial role in the regulation of resistance to low-temperature stress in the tissue of Yakut horses. Consequently, the fatty acids of plant are considered that to be important as food for animals as well as have sitological value.

3.6. Vitamins

Vitamin C (ascorbic acid) and E (tocopherol) was the major vitamin in leaves of quinoa and all vitamin except for vitamin B_{12} (cyanocobalamin) were identified in leaves (Table 6). Quinoa leaves contained the highest level of vitamin E (2.25 mg/100 g), and vitamin C was next highest (2.02

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Table 6. Vitamin content in leaves and stem of *Chenopodium quinoa*

Vitamins	Leaves	Stem	t-value
β-Carotene (μg/100 g fresh weight)	44.14.13±281.52[1)]	42.94±2.22	26.893[***2)]
B_1 (thiamin) (μg/100 g fresh weight)	293.35±2.69	43.25±4.00	89.771[***]
B_2 (riboflavin) (μg/100 g fresh weight)	256.54±2.24	50.03±0.47	156.462[***]
B_3 (niacin) (μg/100 g fresh weight)	2.72±0.88	Tr[3)]	5.332[*]
B_5 (pantothenic acid) (μg/100 g fresh weight)	21.90±0.89	6.44±0.30	28.495[***]
B_6 (pyridoxine) (μg/100 g fresh weight)	21.64±0.31	3.22±0.05	100.497[***]
B_{12} (cyanocobalamin) (μg/100 g fresh weight)	ND[4)]	ND	-
C (ascorbic acid) (mg/100 g fresh weight)	2.02±0.07	ND	53.229[***]
E (tocopherol) (mg/100 g fresh weight)	2.25±0.76	0.04±0.01	4.996[**]

[1)]Results are presented as mean±SD (n=3).
[2)]Significantly different between leaves and stem by the two independent sample t-test ([*]p<0.05, [**]p<0.01, [***]p<0.001).
[3)]Tr, trace.
[4)]ND, not detected.

mg/100 g). In addition, many vitamin B_1 (thiamine) and vitamin B_2 (riboflavin) were detected in leaves with 293.35 μg/100 g and 256.54 μg/100 g, respectively. For stem of quinoa, β-carotene, vitamin B_1, vitamin B_2, and vitamin E were the major vitamin. It has only a small amount of vitamin B_5 (pantothenic acid) and vitamin B_6 (pyridoxine) with 6.44 μg/100 g and 3.22 μg/100 g, respectively, and also the content of vitamin B_3 (niacin) was minute amounts. Vitamin B_{12} and vitamin C were not detected in stem. Overall, quinoa leaves were contained higher level of vitamin than quinoa stem, and its difference was significant ($p<0.05$). In particular, the content difference of vitamin B_1, vitamin B_2, and vitamin B_6 ranged from 5.1 times to 6.8 times. Vitamin A and E are known to be a biological compound with anticancer, antioxidant, anti-hypertension, and anti-inflammation properties and crucial role in the tissue of human. In addition, vitamin B_1 and B_2 content in plant has a potential to improve nutrition for human health (EI Sohaimy et al., 2015). Especially, vitamin B_1 have the resistance to bacterial, viral, and fungal infections in vegetable crop (Ahn et al., 2005). Thus, the quinoa leaves rich in vitamin A, E, and B_1 are expected to be a useful for human and have excellent resistance to various plant diseases.

4. Conclusions

This study was investigated for the nutritional content of young leaves and stems of quinoa grown in Korea. Specifically, the leaves of quinoa were exhibited to contain an abundance of various nutrients required in the human. Analysis showed that it contained much acetic acid participated in the tricarboxylic acid cycle and quinoa is high in calcium and potassium and many kinds of minerals. In addition, they are impregnated the linolenic acid, one of omega-3 fatty acids. Moreover, it demonstrated that quinoa leaves contained many kinds of vitamin such as vitamin B_1, B_2, C, and E. These findings showed that quinoa is worth it, and will be laying the groundwork to expanding supply and demand generation of quinoa. Further, this study is an excellent source for developing of

salads and various processed products using quinoa leaves, is offer the application prospect to various food industry fields.

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Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Jang HL. Data curation: Jang HL. Formal analysis: Jang HL. Methodology: Nam JS. Validation: Nam JS. Writing - original draft: Nam JS. Writing - review & editing: Jang HL.

Ethics approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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