

An Analysis of The Vitamin Content Within the Seeds of Quinoa (*Chenopodium Quinoa Willd.*)

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Abstract: In this present study, the quantitative vitamin composition within the seeds of quinoa (*Chenopodium quinoa Willd.*) was comprehensively investigated employing modern analytical methodologies, whilst simultaneously elucidating its profound significance in the realm of traditional medicine. Throughout the course of the research, the specific concentrations of water-soluble vitamins present in the quinoa seeds were rigorously analysed, allowing for a detailed evaluation of their biological importance and potential health benefits for the human body. Furthermore, the findings established that the biologically active compounds inherent in quinoa significantly enhance metabolic processes within the organism, bolster the immune system, and exhibit substantial antioxidant properties that contribute to overall physiological well-being.

Keywords: Quinoa, Vitamins, Biologically active compounds, High-performance liquid chromatography, Traditional medicine, Antioxidants.

Introduction: Quinoa (*Chenopodium quinoa Willd.*) is a cereal crop that has been extensively cultivated within the Andean mountain region for thousands of years. The quinoa plant belongs to the *Chenopodium* genus within the *Amaranthaceae* family and is characterised by a deeply penetrating root system. Depending on the prevailing soil and climatic conditions, its height typically ranges from approximately 0.6 to 3 metres, and it is physiologically classified as an annual crop [1]. In the year 2020, global quinoa production reached an estimated 175,280 tonnes, with the average yield constituting 0.93 tonnes per hectare. Its biochemical composition is exceptionally rich in essential amino acids, vitamins, and minerals, thereby playing a fundamentally important role in the provision and maintenance of contemporary global food security. The total protein content within quinoa seeds fluctuates between 12% and 23%, strictly contingent upon the specific botanical variety [2].

Over the course of recent decades, both the agricultural cultivation and dietary consumption of this plant have been increasing at an accelerated pace on a global scale. The quinoa plant distinguishes itself

through its remarkable agronomical resilience to extreme environmental factors, exhibiting high tolerance to saline soils, prolonged drought, low temperatures, and challenging high-altitude mountainous conditions. It is precisely due to these robust adaptive characteristics, comprehensively coupled with its extraordinarily rich nutritional and biologically active composition, that it is increasingly recognised and championed as one of the definitive “cereal crops of the 21st century” [3].

Quinoa grain is exceptionally abundant in proteins possessing high biological value, essential lipids, dietary fibres, vital vitamins, and mineral substances. Most notably, it is distinctly characterised by an optimal balance of the essential amino acids that are strictly requisite for the healthy functioning of the human body. Furthermore, the biochemical matrix of quinoa encompasses a broad and diverse spectrum of phytochemical compounds, which prominently includes saponins, phytosterols, phytoecdysteroids, phenolic compounds, and complex polysaccharides, alongside an array of bioactive proteins and peptides [4].

Relying comprehensively upon the systematic analysis of existing scientific literature, we have established the primary objective of this current research. The fundamental aim is the precise quantitative determination of water-soluble vitamins present within the extract of quinoa seeds. This analytical investigation was rigorously conducted employing the method of High-Performance Liquid Chromatography (HPLC) at the scientific laboratory of the "Scientific Research Centre for the Chemistry of Commodities and Traditional Medicine," structurally affiliated with Andijan State University.

Experimental Section

Determination of vitamin content in quinoa seed extract using the HPLC method.

Reagents and equipment used. Vitamin B12 was obtained from "Rhyburg Pharmaceuticals" (Germany), Vitamin C from "Carl Roth GmbH" (Germany), Vitamin B9 from "DSM Nutritional Products GmbH" (Germany), and Vitamins B1, B2, B3, B6, and PP from "BLDPharm" (China). HPLC-grade water and acetonitrile, alongside chemically pure grade acetic acid and sodium hydroxide reagents, were utilised.

The determination of the quantity of water-soluble vitamins within the plant was carried out on an LC-40 Nexera Lite high-performance liquid chromatograph manufactured by the Shimadzu Corporation, Japan [5].

Preparation of standard solutions. Solutions (100 mg/l) of vitamins C (CAS 50-81-7), B1 (CAS 59-43-8), B6 (CAS 58-56-0), B3 (CAS 59-67-6), B12 (CAS 68-19-9), and PP (CAS 98-92-0) were prepared by dissolving 5 mg of each respective vitamin in 50 ml of a 0.1 N HCl solution. Standard solutions of vitamins B2 (CAS 83-88-5) and B9 (CAS 59-30-3) were prepared by dissolving 5 mg of these vitamins in 50 ml of a 0.025% sodium hydroxide solution. Subsequently, 200 µl of the initial solutions of vitamins B1, B6, B3, B12, and PP were taken

and mixed to prepare a solution with a concentration of 14.286 mg/l for each vitamin. In this manner, standard solutions with concentrations of 7.143, 3.571, and 1.786 mg/l were prepared. Standard solutions of Vitamin C with concentrations of 286, 143, 71.5, and 57.2 mg/l were also prepared. Pure water was used for the 0 mg/l concentration to construct the calibration curve.

Preparation of the sample extract. For the extraction of water-soluble vitamins, 1 g of the tested sample was weighed and placed into a 50 ml conical flask, to which 25 ml of a 0.1 N HCl solution was added. The mixture was extracted in a GT SONIC-D3 (China) brand ultrasonic bath at a temperature of 60°C for 20 minutes. The mixture was then cooled, filtered, and brought to a volume of 25 ml with water in a volumetric flask. A 1.5 ml aliquot of the extract was filtered through a 0.22 µm syringe filter, transferred into a vial, and utilised for analysis.

Chromatographic conditions.

Determination of vitamins. The standard solutions and the sample extract were analysed using an LC-40 Nexera Lite high-performance liquid chromatograph comprising an LC-40D pump, an SIL-40 autosampler, and an SPD-M40 photodiode array (PDA) detector, employing LabSolutions ver. 6.92 software. A Shim-pack GIST C18 (150 × 4.6 mm; 5 µm, Shimadzu, Japan) reversed-phase column and a gradient mobile phase (Table 1) consisting of acetonitrile (A) and a 0.25% aqueous solution of acetic acid (B) were applied. The injection volume was set at 10 µl, the flow rate at 0.6 ml/min, and the column thermostat temperature at 40°C. The analytical signal (peak area) for each vitamin was recorded at three wavelengths: 265, 291, and 550 nm (Figures 1-3). A 15-minute gradient was used for the determination of Vitamin C (Table 2), and the analytical signal was measured at a wavelength of 265 nm.

Table 1. Mobile phase gradient programme for the determination of vitamins.

Time, minutes	Acetonitrile (A), %	0.5% acetic acid (B), %
0	0	100
3	0	100
14	20	80
17	50	50
18	0	100
25	Completion	

Table 2. Mobile phase gradient programme for the determination of Vitamin C..

Time, minutes	Acetonitrile (A), %	0.5% acetic acid (B), %
0	0	100
2	0	100
6	50	50

6,01	0	100
15	Completion	

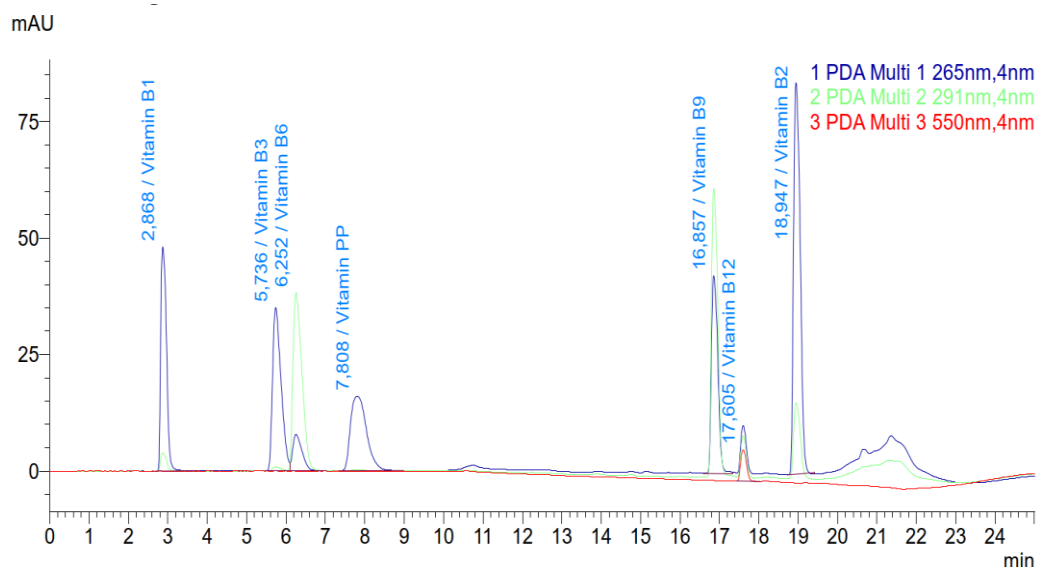


Figure 1. Chromatogram of a standard solution of vitamins.

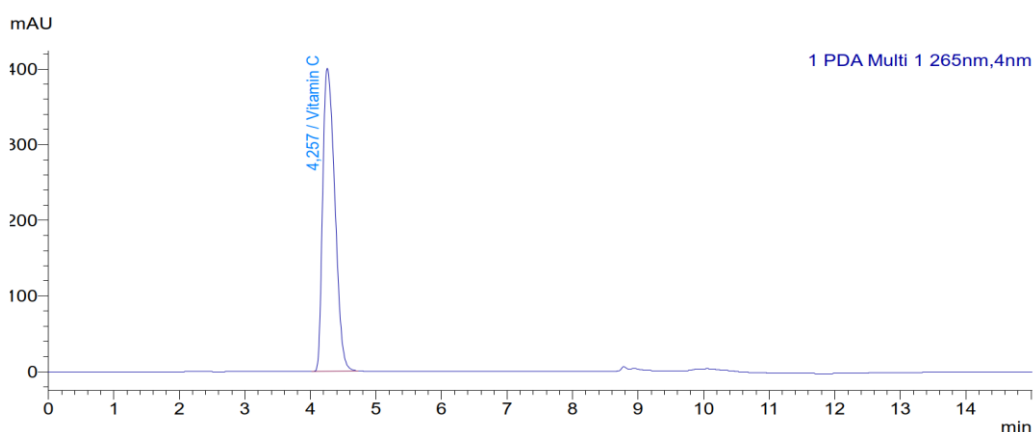


Figure 2. Chromatogram of a standard solution of vitamin C

RESULTS AND DISCUSSION

Numerous scientific studies have been conducted regarding the determination of vitamins and biologically active substances in the seeds of quinoa (*Chenopodium quinoa* Willd.) utilizing high-performance liquid chromatography (HPLC). In research carried out by foreign scientists, the presence and quantities of water- and fat-soluble vitamins within quinoa seeds have been analyzed based on various chromatographic methods. In studies conducted by scientists Kristel Hälvin, Ildar Nisamedtinov, and Toomas Paalme, B-group vitamins in quinoa seeds were identified. The research results noted the presence of significant amounts of vitamins B1, B2, B3, B5, and B6 in quinoa [6].

In the scientific work conducted by Sanja Popovic and colleagues, the quantity of tocopherols, specifically

vitamin E, in quinoa seeds was determined using normal-phase HPLC. The results of the study demonstrated that the antioxidant properties of quinoa are remarkably high [7].

In the research conducted by our team, a chromatogram of the quinoa seed extract was obtained. Based on these results, the amounts of vitamins present in a 100 g sample were calculated using the following formula and are presented in Table 3.

$$X = \frac{C_{vit} \cdot V_{extract}}{m_{sample}} \cdot 100 \text{ g}$$

Where:

- X — the amount of vitamins in 100 grams of the sample, mg;

- C_{vit} — the concentration of the vitamin in the extract determined by the HPLC method, mg/l;
- $V_{extract}$ — the volume of the sample extract, l;
- m_{sample} — the mass of the sample weighed out for the preparation of the extract.

The results of determining the amount of water-soluble

vitamins in quinoa seeds are presented in Table 4, and their respective chromatograms are shown in Figures 3 and 4. As can be observed from the data in the table, the total amount of water-soluble vitamins determined in the quinoa seeds constituted 2.839 mg/100 g. Among the detected vitamins, the amount of Vitamin C was the highest, accounting for 28.8% of the total vitamin content.

Table 3. Amount and retention times of vitamins in the extract.

Vitamin	Retention time, sec	Concentration, mg/l	Amount in 100 g sample, mg
Vitamin B ₁	2.736	0.201	0.503
Vitamin B ₃	5.645	0.120	0.300
Vitamin PP	7.412	0.088	0.220
Vitamin B ₉	16.927	0.024	0.060
Vitamin B ₂	18.894	0.301	0.753
Vitamin B ₆	6.488	0.074	0.185
Vitamin B ₁₂	Not detected	0.000	0.000
Vitamin C	4.211	0.327	0.818

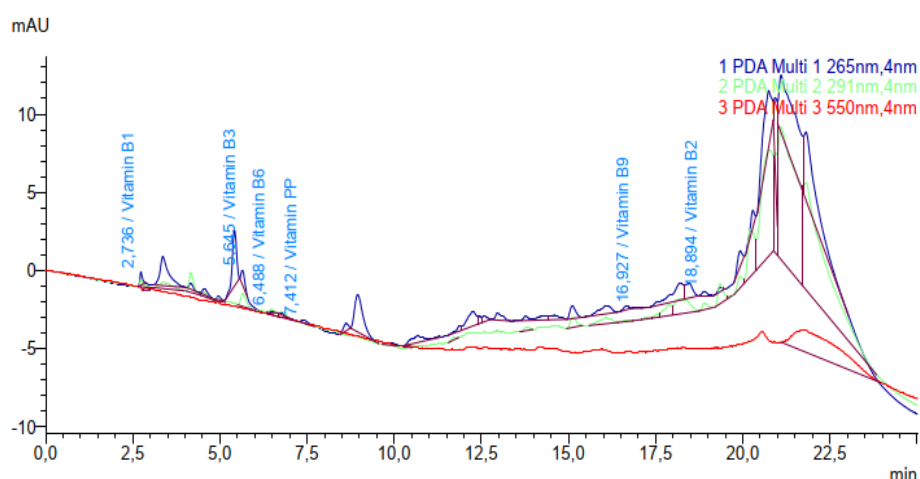


Figure 3. Chromatogram for the determination of vitamins in the sample extract.

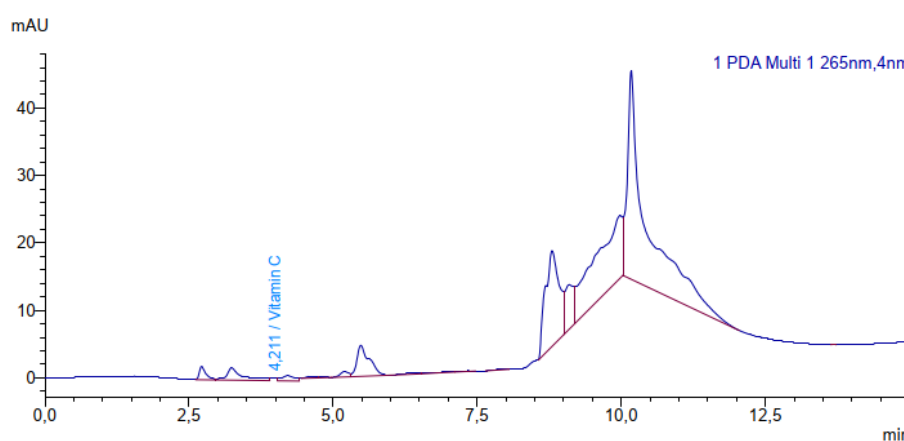


Figure 4. Chromatogram for the determination of Vitamin C in the quinoa extract.

According to the obtained results, the presence of a range of biologically active vitamins was observed

within the analysed sample. Based on these findings, the highest concentration was recorded for Vitamin C,

which amounted to 0.818 mg per 100 g of the sample. Vitamin C possesses potent antioxidant properties, playing a significant biological role in bolstering the body's immune system, mitigating oxidative stress, and

safeguarding cells from the deleterious effects of free radicals. This result conclusively demonstrates the presence of antioxidant activity within the investigated plant.

Table 4 Amount and percentage of vitamins within the extract

Vitamin	Amount (mg)	Percentage (%)
Vitamin C	0.818	28.8 %
Vitamin B ₂	0.753	26.5 %
Vitamin B ₁	0.503	17.7 %
Vitamin B ₃	0.300	10.6 %
Vitamin PP	0.220	7.7 %
Vitamin B ₆	0.185	6.5 %
Vitamin B ₉	0.060	2.1 %
Vitamin B ₁₂	Not detected	0 %

CONCLUSION

Over the course of the conducted research, the quantity of water-soluble vitamins within the seeds of quinoa (*Chenopodium quinoa* Willd.) was determined utilizing the method of high-performance liquid chromatography (HPLC). The research results demonstrated that quinoa is a plant exceptionally rich in biologically active substances.

According to the findings, the presence of various quantities of water-soluble vitamins was identified within the studied sample. Upon analyzing the percentage ratios of the vitamin contents, it was observed that Vitamin C accounted for the largest proportion in the sample. Its measured amount was 0.818 mg, which constituted 28.8% of the total vitamin composition. This specific finding further underscores that the antioxidant properties of the investigated plant are highly significant. Vitamin C plays a crucial biological role in strengthening the immune system within the body, regulating oxidation-reduction (redox) processes, and effectively mitigating the adverse effects of free radicals.

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