Elemental composition of *Apium graveolens* L. seeds as an indicator of the nutritional value of competitive organic products

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Abstract. The elemental composition of *Apium graveolens* L. seeds of root (Cupid and Root gribovsky) and leaf varieties (Samurai and Tender) was determined using x-ray fluorescence analysis. In quantitative terms, the macronutrients are dominated by Ca (1.59-2.24% dry matter) and K (0.8-1.28%), as well as Na, P, S, Mg, and microelements – iron, zinc and manganese. It is shown that there is a wide variability of indicators for macro-and microelements. Significant varietal differences in accumulation were noted for sodium, silicon, chlorine, strontium (variability of more than 70%), as well as aluminum, iron, titanium, nickel, copper, and bromine. Varieties Cupid is characterized by increased accumulation of iron, silicon, sulfur, potassium, titanium, zinc, zirconium; varieties Samurai – sodium, phosphorus, sulphur, chlorine, calcium; varieties Tender – potassium, manganese, copper, bromine, and barium; Root gribovsky – manganese and bromine. A high level of variation in the elemental composition of celery seeds of root and leaf varieties makes it possible to select plants that differ in an increased content of deficient macro-and microelements.

1. Introduction

Celery (*Apium* L.), most often used as a spice-aromatic plant, belongs to the Celery family (Apiaceae). This genus consists of about 20 species distributed worldwide [1]. Plants are biennial and perennial, rarely annual, growing up to one meter in swampy areas of subtropical and temperate regions. Plants are grown worldwide for their green leaves, root crops, petioles, and seeds (fruits) [2,3]. *Apium graveolens* L. is the most common in the culture, known as common celery. There are three varieties of common celery: petiolar - var. *dulce* (Mill.) Pers., root- var. *rapaceum* (Mill.) DC. And leaf - var. *secalinum* Alef. [4,5].

Celery seed is valuable by essential oil (~ 3% of dry weight) with a characteristic aroma [6] and a high accumulation of limonene, coumarins, furanocumarins (bergapten), fatty acids [3]. The essential oil contains about 60% of limonene, 20-30% of phthalides, and up to 13% of β-selinene as the main phytocomponents [3,7].

*Apium* plant seeds have a moisture content of 5% -11% and usually contain the following components: protein (0.8%), fixed oil (5.8–14.2%), essential oil (1.5–3.0%), total ash content (6.9% -11.0%), acid-insoluble ash (0.5-4.0%). Leaves and petioles usually contain moisture (80.3–93.5%), fibers (1.4% -1.2%), fat (0.6% -0.1%), protein (up to 0.8%), mineral substances (2.1%-0.9%), iron...
(0.06%-0.05%), calcium (0.23%-0.3%), phosphorus (0.14%-0.4%), vitamin C (62.6 mg/100 mg) and vitamin A (5800-7500 IV) [8].

Despite a fairly large amount of research on the biochemistry of celery, the elemental composition of the seeds of this plant has not been studied enough. Therefore, the aim of the research is to study the quantitative content of macro-and microelements in *Apium graveolens* seeds.

2. Materials and methods

The seeds of celery of the root varieties Root Gribovsky, Cupid and leaf varieties Samurai and Tender were taken as the research object.

Determination of the content of chemical elements in plant samples was performed by x-ray fluorescence analysis (RFA) at the Institute of Geochemistry SB RAS (Irkutsk) on an x-ray spectrometer S8 Tiger, Bruker (Germany). The procedure for preparing plant samples for RFA: grinding in an agate mortar; taking the sample - 0.5 g; pressing the emitter tablet from the sample plant on a substrate of boric acid.

3. Results

Vegetable growing in Russia is developing dynamically. The optimal level of consumption, at which we can talk about the protective activity of vegetables against diseases of the century, scientists consider 700-900 g per person per day [9,10]. The content of macro-and microelements is one of the important characteristics of the nutritional and pharmacological value of vegetable crops [11]. Our research has shown that celery is an accumulator of a number of important macronutrients, especially Ca (1.59-2.24% of dry matter) and K (0.8-1.28%), as well as Na, P, S, Mg (table). The accumulation of silicon, aluminum, and iron in celery seeds is estimated to be no more than tenths of a percent.

Our results indicate the high nutritional value of celery seeds as a source of Ca, K and other macronutrients for humans.

Celery seeds are accumulators of microelements such as manganese, zinc, copper, etc. Microelements often act as cofactors in enzyme systems and are involved in redox reactions, in addition to having several other vital functions in plants. Most importantly, microelements are involved in the main physiological processes of photosynthesis and respiration [12,13], and their lack can interfere with these vital physiological processes, thereby limiting crop growth. However, the microelement composition of seeds is influenced by the relationship: synergy or antagonism of elements in the soil-plant system.

**Table 1.** Elemental composition of common celery seeds.

| Elemental composition, % | Cupid  | Samurai | Gribovsky | Tender | Range of variation, % |
|--------------------------|--------|---------|-----------|--------|----------------------|
| **Macronutrients, % on dry matter**                      |        |         |           |        |                      |
| Na                       | 0.076  | 0.307   | 0.102     | 0.099  | 75.2                 |
| Mg                       | 0.343  | 0.358   | 0.257     | 0.333  | 28.2                 |
| Al                       | 0.025  | 0.011   | 0.018     | 0.011  | 56.0                 |
| Si                       | 0.162  | 0.096   | 0.057     | 0.040  | 75.3                 |
| P                        | 0.49   | 0.59    | 0.35      | 0.45   | 40.7                 |
| S                        | 0.54   | 0.53    | 0.32      | 0.49   | 40.7                 |
| Cl                       | 0.24   | 0.43    | 0.11      | 0.19   | 74.4                 |
| K                        | 1.25   | 1.05    | 0.80      | 1.28   | 37.5                 |
| Ca                       | 1.87   | 2.24    | 1.59      | 1.91   | 29.0                 |
| **Microelements, ppm** |        |         |           |        |                      |
| Fe                       | 0.0309 | 0.0126  | 0.0123    | 0.0114 | 63.1                 |
| Ti                       | 18     | 6       | 9         | 6      | 66.7                 |
Cr  |  2.5 |  < 2 |  2.2 |  < 2 |  20.0  
Mn  |  35  |  29  |  48  |  47  |  39.6  
Ni  |  2   |  1   |  2   |  3   |  66.7  
Cu  |  7   |  8   |  16  |  12  |  56.3  
Zn  |  63  |  54  |  56  |  53  |  15.9  
Br  |  < 3 |  3   |  6   |  8   |  62.5  
Rb  |  5   |  6   |  4   |  3   |  50.0  
Sr  |  124 |  62  |  33  |  42  |  73.4  
Zr  |  2.2 |  1.1 |  < 1 |  < 1 |  54.5  
Ba  |  < 5 |  < 5 |  6   |  9   |  44.4  
Pb  |  < 3 |  < 3 |  < 3 |  < 3 |   0   

Varietal differences in the accumulation of particular macro- and microelements in celery seeds are observed:
- The Cupid variety is characterized by an increased accumulation of iron, silicon, sulfur, potassium, titanium, zinc, and zirconium;
- Samurai – sodium, phosphorus, sulfur, chlorine, calcium;
- Tender - potassium, manganese, copper, bromine, barium;
- Root gribovsky – manganese, and bromine.

The greatest varietal differences in the accumulation of elements were found in sodium, aluminum, silicon, iron, and chlorine. The accumulation of sodium, nickel, copper, bromine, rubidium, strontium, and zirconium varies significantly depending on the varieties. The content of lead, zinc, and chromium is fairly stable in varieties.

Previously, we studied the elemental composition of seeds of 5 varieties of different types of cabbage crops. It is shown that there is a wide variability of indicators for the macronutrients silicon, aluminum and the microelement titanium [14]. It is shown on seeds of 6 onion varieties that a wide variability of indicators is also observed for the macronutrients silicon, aluminum and the microelement titanium [15]. Mainly for the majority of macro-and microelements in onion seeds and various types of cabbage crops, the values of their concentrations are in a narrow range.

4. Summary

The data presented in this paper allow expanding our understanding of the quantitative content of macro- and microelements in celery seeds. As for mineral substances of celery seed, their qualitative composition consists of macronutrients (sodium, potassium, magnesium, calcium, sulfur, phosphorus, etc.) and microelements (copper, zinc, iron, manganese, etc.). The analysis of the mineral components of the plant seeds showed that in a number of macronutrients in quantititive terms calcium and potassium is dominated, and some microelements – zinc.

There are significant varietal differences in the accumulation of macro-and microelements, especially for sodium, silicon, chlorine, aluminum, iron, and copper.

The results of elemental analysis allow concluding that celery seeds are a storage organ for such macroelements as K and microelements. However, the level of macro - microelements in mature seeds and the variability of the macro-microelement composition of seeds are mainly determined by the genotypic features of the culture, the age of plants and environmental factors. It is considered that in higher plants, the elemental composition of reproductive organs is more constant than that of vegetative ones. A high level of variation in the elemental composition of celery seeds of two varieties makes it possible to select plants that differ in an increased content of deficient macro-and microelements.
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