18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Iodine biofortification of cabbage plants cultivating in hydroponic system

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Abstract Iodine is an essential trace element in the human diet being involved in the synthesis of thyroid hormones. Iodine deficiency affects ca. 2.2 billion people worldwide, therefore it is an important challenge to find a plant-based source of iodine, which would provide the recommended dietary allowance.

In this work iodine biofortification of cabbage was studied cultivating plants in hydroponic system containing iodine in concentration of 0.01-1.0 mg/L as potassium iodide or potassium iodate. During the experiment plant physiological properties, biomass production, concentration changes of iodine- as well selected essential elements were investigated. In addition, chemical form of the accumulated iodine in root samples was also determined.

Results showed that iodine addition had no effect on the photosynthetic efficiency and chlorophyll content. Biomass production was stimulated by the iodide treatment in all dosages, while applying iodate this phenomenon was observed only in low concentrations, above 0.5 mg /L the yield was reduced. Increasing iodine concentrations in the nutrient solutions resulted in higher iodine content in all plant parts, the presence of iodide caused 2-7 times higher accumulation compared with the iodate treatment and it was established that in cabbage roots reductive reactions are dominant, iodate was converted to iodide.

Keywords: iodine, biofortification, cabbage, nutrients

1. Introduction

Iodine (I) is an important essential element for the human health being involved in the synthesis of thyroxine and triiodothyronine hormones. The recommended daily intake for a normal adult person is 150 µg. (WHO 2004; Zimmermann and Boelaert, 2015; Andersson and Braegger, 2022; Hatch-McChesney and Lieberman, 2022). The most often applied method preventing iodine deficiency disorders (IDDs) is salt iodization, however, for instance during cooking the iodine content of this product can be loss, and excessive salt consumption can lead to different cardiovascular diseases, therefore other strategies should be considered e.g. iodine biofortification of vegetables applying different agronomic technologies (fertilizer, irrigation, hydroponic systems) (Medrano-Macías et al., 2016; Gonzali et al., 2017). In this work iodine uptake and translocation were investigated in cabbage plants growing in hydroponic culture. During the experiment plant physiological properties (chlorophyll content, photosynthetic efficiency) biomass production, concentration changes of iodine- as well selected essential elements were investigated.

2. Materials and methods

2.1 Plant growing

Cabbage seeds were germinated on filter paper moistened with deionized water in Petri dish under diffuse sunlight at room temperature for 7 days. Seedlings were selected and rolled up in a sponge strip which was then placed into a round shaped polystyrene plate (d=13 cm) with a hole in the middle (d=35 mm). The plates were then inserted into a pot filled up with 200 mL modified Hoagland nutrient solution (Table 1). Iodine was added to the nutrient solution as iodide (I^-) or iodate (IO_3^-) chemical forms in concentration of 0.01-1.0 mg I/L

Table 1. Composition of modified Hoagland solution

Macronutrient	Conc. (mM)	Micronutrient	Conc. (µM)
KNO_3	1.25	Fe(III)-citrate-hydrate	25.0
$Ca(NO_3)_2$	1.25	$MnCl_2 \cdot 4H_2O$	4.5
$MgSO_4$	0.50	$ZnSO_4 \cdot 7H_2O$	0.19
KH_2PO_4	0.25	$Na_2MoO_4 \cdot 2H_2O$	0.12
		$CuSO_4 \cdot 5H_2O$	0.08
		H_3BO_3	11.6

2.2 Sample preparation and elemental analyses

After the harvest plant tissues (root, stem, leaf) were separated, the different parts were dried in a laboratory oven at 40°C for 48 hours, then dry masses were determined. Samples were solubilized in the presence of 7 cm^3 concentrated nitric acid and 3 cm^3 hydrogen-peroxide applying a microwave assisted digestion system. Elemental concentration of the mineralized plant parts were determined using an inductively coupled plasma mass spectrometer.

3. Results

Iodide or iodate addition had no impact on the photosynthetic efficiency or chlorophyll content of cabbage plants. Due to the iodide addition the dry mass values of edible plants stimulated, in case of iodate similar phenomena was observed, however only in lower concentration, above 0.5 mg/L dosage the values remained practically unchanged compared with the control plants. Increasing iodine dosage in the Hoagland nutrient solutions resulted in higher iodine concentrations in all plant tissues compared with the untreated plants, and it can be generally established that the highest iodine concentrations were determined in the roots and lowest in the edible parts. Depending on the plant tissues the presence of iodide in the nutrient solution resulted in 2-7 times higher accumulation, compared with the iodate treatment, applying 1.0 mg/L iodine dosages the maximum iodine concentrations in the leaf tissues were 29.2 mg/kg (iodide) and 12.2 mg/kg (iodate), respectively (Figure 1). Type of the iodine treatment had different impact on the essential element transport, applying iodide in the nutrient solution the concentration of all elements was decreased, while adding 1.0 mg/L iodate the transport was stimulated compared with the control plants.

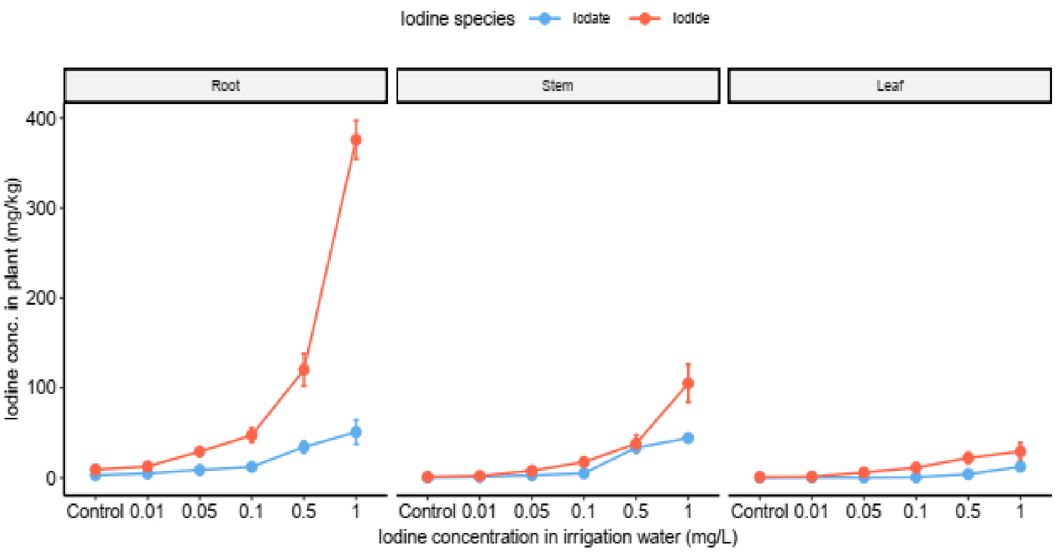

Figure 1. Iodine concentration in plant parts of cabbages cultivated in nutrient solutions containing iodide or iodate species

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