





Изучение силатрансодержащего препарата на улучшение потребительских свойств салата (*Lactuca sativa* var. Дубачек МС), выращенного в фитотроне ИСР 0.1 методом гидропоники

Али Джамиль Осман	¹	ali.mcisa@gmail.com	 0000-0002-8309-1854
Людмила Г. Елисеева	¹	eliseeva-reu@mail.ru	 0000-0003-2715-9989
Валерий Н. Зеленков	^{2,3}	zelenkov-raen@mail.ru	 0000-0001-5481-2723
Вячеслав В. Латушкин	⁴	slavalat@ya.ru	 0000-0003-1406-8965

¹ Российский экономический университет им. Г.В. Плеханова, Стремянный пер., 36, Москва, 115093, Россия

² Всероссийский научно-исследовательский институт овощеводства – филиал «Федеральный научный центр овощеводства», Московская область, Раменский район, д. Веряя, стр.500 дер, Веряя, Московская обл., 140153, Россия





³ Всероссийский научно-исследовательский Институт Лекарственных и Ароматических Растений, ул. Грина 7, стр.1, Москва, 117216, Россия.

⁴ Институт Стратегий Развития – Автономная некоммерческая организация, д. 11 переулоч Столешников, Москва, 125009, Россия.

Аннотация. В статье представлены результаты экспериментального исследования возможности улучшения потребительских свойств салата (*Lactuca sativa* var. Dubachuk MC), выращенного в условиях замкнутой системы в фитотроне ИСР-0.1, путем применения листовой обработки «1-Этоксисилатраном» – новым препаратом на основе кремния, принадлежащим группе силатранов. В результате проведенных исследований было установлено, что применение препарата в концентрации $5 \cdot 10^{-4}$ мл/л при обработке ES1 не приводит к изменению качественных свойств продукции, однако наблюдается увеличение эффективности действия препарата при использовании более высоких концентраций. Компоненты с наилучшим выходом были получены в результате внекорневой обработки ES3 и ES4 с концентрациями $5 \cdot 10^{-3}$ и 10^{-2} мл/л соответственно. Применение внекорневой обработки в вегетативной фазе привело к комплексному эффекту активации физиологических процессов салата, стимуляции фотосинтетической активности и накоплению фотосинтетических пигментов путем регистрации увеличения хлорофилла на 22,7% и содержания каротиноидов в свежих листьях – на 18,6%. Накопление нитратов в ES4 составило 792,3 мг/100 г, что в 2,7 раза выше, чем в контроле. Также было зафиксировано увеличение содержания сухого вещества на 12,2%, суммарного количества антиоксидантов, увеличение содержания аскорбиновой кислоты на 40% по сравнению с контролем. При этом в более высоких концентрациях наблюдалось лишь незначительное увеличение общего содержания фенола. Влияние на метаболическую активность приводит к повышению производительности вследствие увеличения массы продукции. Интерес представляют дальнейшие исследования в направлении изучения влияния 1-Этоксисилатрана на другие листовые овощи и продление срока их хранения.

Ключевые слова: фитотрон, 1-этоксисилатран, кремнийорганический, салат, пищевая ценность

The study of a silatrane-containing preparation on improving the consumer properties of lettuce (*Lactuca sativa* var. Dubachek MC), grown hydroponically in phytotron-ISR 0.1

Ali J. Othman	¹	ali.mcisa@gmail.com	 0000-0002-8309-1854
Ludmila G. Eliseeva	¹	eliseeva-reu@mail.ru	 0000-0003-2715-9989
Valeriy N. Zelenkov	^{2,3}	zelenkov-raen@mail.ru	 0000-0001-5481-2723
Vyacheslav V. Latushkin	⁴	slavalat@ya.ru	 0000-0003-1406-8965

¹ Russian Economic University. G. V. Plekhanova, Stremyanny avenue, 36, Moscow, 115093, Russia Federation)

² All-Russian Research Institute of Vegetable - branch "Federal Scientific Center of Vegetable, Moscow region, Ramensky district, d. Vereya, p. 500 der, Vereya, Moscow region, 140153, Russia

³ All-Russian Research Institute of Medicinal and Aromatic Plants, 7 Grina str., p. 1, Moscow, 117216, Russia.

⁴ Institute for Development Strategies is an Autonomous Non-profit Organization, 11 Stoleshnikov lane, Moscow, 125009, Russia.

Abstract. This paper presents the results of experimental study on the possibility of improving consumer properties of lettuce (*Lactuca sativa* – var. Dubachuk MC) grown under the conditions of closed system in ISR-0.1 phytotron by applying foliar treatment of different concentrations of 1-ethoxysilatan - a new silicon based preparation belonging to Silatrans group. The trial demonstrated no effect of the preparation when applied in a concentration of $5 \cdot 10^{-4}$ ml/l in ES1 treatment. However, the effectiveness starts upon using higher concentrations. The best yield components were obtained as a result of foliar treatments of ES3 and ES4 with concentrations of $5 \cdot 10^{-3}$ and 10^{-2} ml/l respectively. Applying foliar treatment in vegetative phase resulted in complex effect of activation of physiological processes in plants, stimulating the photosynthetic activity and accumulation of photosynthetic pigments by recording a 22.7% increase in chlorophyll-a and 18.6% in carotenoids content in fresh leaves. Nitrate accumulation recorded 792.3 mg/100g in ES4 which is 2.7 times higher than the control. Also, an increase in dry matter content by 12.2%, pigments by 16.3%, total antioxidants capacity, a 40% increase in ascorbic acid content were recorded. While only slight increase in total phenolic content was observed in higher concentrations. These overall considerable influences in metabolic activities lead to a better productivity in case of production mass. Further studies should be concerning the effect of 1-ethoxysilatan on other leafy vegetables and prolonging the storage of them.

Keywords: phytotron, 1-ethoxysilatan, organosilicon, Lettuce, nutritional value, Antioxidants, Total phenolic content.

Для цитирования

Осман А.Д., Елисеева Л.Г., Зеленков В.Н., Латушкин В.В. Изучение силатрансодержащего препарата на улучшение потребительских свойств салата (*Lactuca sativa* var. Дубачек МС), выращенного в фитотроне ИСР 0.1 методом гидропонии // Вестник ВГУИТ. 2020. Т. 82. № 1. С. 96–102. doi:10.20914/2310-1202-2020-1-96-102

For citation

Othman A.J., Eliseeva L.G., Zelenkov V.N., Latushkin V.V. The study of a silatrane-containing preparation on improving the consumer properties of lettuce (*Lactuca sativa* var. Dubachek MC), grown hydroponically in phytotron-ISR 0.1. *Vestnik VGUIT* [Proceedings of VSUET]. 2020. vol. 82. no. 1. pp. 96–102. (in Russian). doi:10.20914/2310-1202-2020-1-96-102

This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License

Introduction

Lettuce (*Lactuca sativa*), an annual plant, belongs to the family Asteraceae and is of an important leafy vegetable primarily consumed fresh or in salad mixtures with other kinds of fresh vegetables. Nowadays, it become an ever more popular product in the Russian markets and can be seen predominantly as fresh lettuce in pots which is consumed in significantly increasing amounts due to their perception as being “healthier and Alive” food. Its beneficial effects are believed to be due to vitamins and phytochemicals such as ascorbic acid, carotenoids, polyphenols and fibers that may protect key biological constituents such as lipoproteins, membranes, and DNA [1]. In fact, recent studies have shown the health effects of lettuce in preventing cardiovascular diseases in rats and humans [2, 3]. In recent decades, silicon was shown to be effective on decreasing the harmful effect of a variety of stresses on plant growth and development. Besides the whole spectra of biotic stressors, like pathogens or microorganisms. Si was shown to ameliorate the negative effect of the whole spectra of abiotic stresses, including heavy metals, salinity, and water imbalance in plants [4, 5].

While silicon is not essential for the growth of higher plants, we do know that its availability influences many aspects of the biology of plants that naturally have moderate to high levels of the element [4, 6]. Examples are restriction of grazing and parasitism, increased light interception, and alleviation of the effects of deficiency or excess of nutrient and other solutes [4, 6, 7]. Thus, although silicon is not essential for higher plants it very significantly improves fitness in nature and increases agricultural productivity.

During the following years investigations in the field of organosilicon compounds were concentrated on the development of new methods of synthesis of Silatrans and on the study of their biological effect on animals. Silatrans are a new class of biologically active compounds having a broad spectrum of action and application in therapy, agriculture, fur-farming, poultry breeding, plant growing, cultivation of useful insects and microorganisms [8]. Previously studied organosilicon preparations from Silatrans family like 4-chlorophenoxyacetie acid and its silatranyl methyl ester and Heteroauxin silatranyl methyl ester stimulate the growth of the cultures of Tobacco (*Nicotiana rustica*) and soya tissues effectively.

The influence of silatranes on the growth and development of flax (*Linum usitatissimum*) was investigated using aqueous solutions

of 1-(chloromethyl)-3,7,10-trimethylsilatrane 97). The treatment was carried out I 0–15 days after the beginning of growth in the period of intensive formation of fibre in stalks [8, 9]. The studied preparation of our experiment 1-ethoxysilatrane (ES) itself has been prepared by the reaction of trichloroethoxysilane with the tetrapodal ligand tris(2-hydroxy-3,5-dimethylbenzyl) amine [8].

Photosynthetic Pigments are the substances with very different chemical structure; they are present in the form of porphyrin pigments (chlorophyll a, b), carotenoids, anthocyanins and flavones [9, 10, 11]. Total leaf pigment includes chlorophyll-a, chlorophyll-b and carotenoids that are necessary for photosynthesis process. The content of foliar pigments varies depending on species. Carotenoids are lipid-soluble pigments and their health benefits include prevention of certain cancers, cardiovascular and eye diseases as well as enhanced immune system [12]. Variation in leaf pigments and its relation can be due to internal factors and environmental conditions. On study reported that chlorophyll and carotenoids content varied with microclimatic conditions in *Adiantum* species [13].

Antioxidants provide adaptation of plants to adverse environmental factors, participate in the utilization of active forms of oxygen. Antioxidants of non-enzymatic nature include phenolic substances, bioflavonoids, carotenoids, chlorophyll and many others. They participate in various protective mechanisms, thanks to the conjugated double bonds of the reactive oxygen species (ROS) and inhibit the development of radical oxidation processes [14].

Although lettuce is not the richest source of a number of nutrients, including Ascorbic acid [15], its advantage is that it can be eaten raw, with its nutritive value preserved, as much of it would be lost by cooking. Ascorbic acid is known to increase the organism's resistance to viruses and bacterial infections including allergies. Apart from this, it has marked antioxidant characteristics and is one of major antioxidant agents [16, 17] in removing free radicals along with vitamins E and A, and the minerals selenium and zinc. Consumption of antioxidants in food via natural sources is good for the prevention of cardiovascular diseases, especially arteriosclerosis [18]. In addition, antioxidant compounds are susceptible to variation among varieties, growing practices, processing and storage conditions on the biologically active compounds [19, 20].

The aim of this study is to test the foliar effect of organosilicon compound 1-ethoxysilatrane from Silatran family on growth parameters and biochemical components and product quality of

oakleaf lettuce and choose the optimal concentration that best improves its content, quality and consequently consumer acceptance.

Materials and methods

lettuce oakleaf (*Lactuca sativa* var. Dubachek MC) was cultivated in phytotron ISR-0.1 conditions. The experiment was carried out in G.V. Plekhanova. Moscow in 10th January 2019. On a Cultivation media substrate based of mineral wool, three seeds were sown in each growing hole. After 14 days from germination, a foliar treatment by spraying solution containing 1-ethoxysilatrane (ES) was carried out using 4 different concentrations: ES1; ES2; ES3; ES4, $5 \cdot 10^{-4}$, 10^{-3} , $5 \cdot 10^{-3}$, 10^{-2} mL.L⁻¹ respectively. For control plants, we sprayed water (Table 1).

Chlorophylls and Carotenoids Accurately weighted 0.5g of fresh plant leaf sample was taken and homogenized with 10 ml of different extractant solvent. Homogenized sample mixture was centrifuge for 10,000 rpm for 15min at 40 °C. The supernatant was separated and 0.5ml of it is mixed with 4.5ml of ethanol 96%. The solution mixture was analyzed for Chlorophyll-a, Chlorophyll-b and total carotenoids content in spectrophotometer (shimadzu uv 2401pc uv vis, Japan). The method and equations used for calculating the concentration of pigments are those of Lichtenthaler and Wellburn [21, 22].

Ascorbic acid determination The content of the free form of vitamin C (Ascorbic acid) was determined by capillary electrophoresis system (Капель 105M – Russian Federation) under positive high voltage polarity (internal diameter of the capillary 50/60 µm, total length 75 cm) was used [4] Buffer: 10 mM sodium tetraborate, 40 mM, (pH 9.2), Sample injection 450 mbar.s⁻¹, Voltage: +20 kV, Detection 254 nm or 200 nm, at 23 °C.

Analysis were done up to the method suggested by [23] with some modification. A 5g of fresh sample was diluted to 100cm³ and well shaken for 10 minutes in the dark then it was filtered and placed in Eppendorf tube and centrifuged under 15000 rpm twice to avoid any impurities. The supernatant was replaced into the device for analysis.

Total antioxidant activity The total amount of antioxidants in lettuce samples was determined using a coulometric analyzer MVI-01-44538054-07 "EXPERT-006".

Bromine was generated at a constant current of 50 mA from a 0.2 M aqueous solution of KBr in a 0.1 M solution of H₂ SO₄ with the determination of the end of titration by a voltmetric indication with two polarized electrodes made of an inert metal. Then 40 cm³ of the buffer solution was poured into a Becher, the electrodes were lowered, and the generator circuit was switched on. Then an aliquot of the test sample was added to the cell (1 g of macerated lettuce). The end point of titration was fixed when the initial value of the indicator potential was reached. During the reaction time, all substances with antioxidant properties reacted with an excess of bromine. After the mixing time was completed, the device automatically filtered the bromine outflow,

which was numerically equal to the number of antioxidant substances introduced in the aliquot. At the same time, the device showed the total content of antioxidants in milligrams in aliquot. Results are expressed in mg/g of fresh lettuce [24].

Total phenols content Total phenolic content was determined using the Folin-Ciocalteu method. A fresh sample with weight of 0.05g was grounded with 1.5 cm³ 96% ethanol, extraction of phenol compounds was carried out for 45 minutes at 45 °C with periodic stirring (every 15 minutes) and subsequent centrifugation for 2 minutes at rotation speed of 16,000 rpm, from obtained extract samples are taken, with volume of 0.075 cm³, adding to them at 0.075 cm³ Folin-Ciocalteu reagent diluted 5-fold is mixed, after 3 min 0.15 cm³ 20% solution of sodium carbonate and 1.2 cm³ distilled water, closed with a cover, stirred and left at room temperature, and after 1 hour, the optical density of the formed tungsten blue is measured at wavelength 725 nm, the length of the optical path is 1 cm. Total content of PC is expressed in mg-equivalent gallic acid per g fresh raw material weight [25].

Statistical analysis Data analysis was done using the IBM SPSS software (version 20.0) and mean separation was done by Tukey's test at 5% level of significance.

Results and discussion

The quality of these products depends on external and internal parameters. The external quality is essentially represented by leaf color which is strongly dependent on leaf pigments such as chlorophyll, carotenoids. Leaf color represents the visual appearance of the product and has direct effect on attractiveness for consumers. Internal quality is determined by antioxidant components or other active compounds that give a beneficial effect to human health [26]. The most important of them are represented by ascorbic acid, carotenoids and total polyphenols. Moreover, ascorbic acid is considered to be the most handling – and processing-sensitive vitamin and is often used to indicate the harshness of a process [27]. In the process of growing the studied variants of lettuce treated with solution containing different concentration of ES also conducted regular analysis of the dynamics of growth for the vegetative part. For 36 days from sowing the seeds we measured the height of plants, mean values can be seen in (figure 1). It was found that the differences between the treatments appeared since the early stages of growth and development and remained until the harvest. The maximum growth rate was observed in plants treated with ES of both concentrations 10^{-2} and $5 \cdot 10^{-3}$ ml/l. Significant difference in weight and size of plants recorded. Further decrease in the concentration of the preparation led to a less plant development but slightly better than control.

At the end of vegetative growth, shoots mass was determined. Better yields were recorded for treatments number 3, 4 and 5 with concentrations of ES of 19,2; of 21.6 and 27.3% respectively (table 1).

Marketable quality of lettuce is determined mainly by plant size, which depends on fresh weight. remarkable difference of fresh weight at harvesting time can be noticed among all treatments. It was recorded that oakleaf lettuce plants gave highest total fresh weight (42.91g) in ES4 which was similar to ES3 (40.87 g plant⁻¹) and the lowest total fresh weight (30.12 and 30.49g plant⁻¹) was found in ES1 and control respectively. Highest fresh weight of leaf was found (29,15 g plant⁻¹) in ES4 and the lowest leaf fresh weight (22,59 g plant⁻¹) found in ES1.

Table 1.

The effect of different concentrations of ES on the productivity of lettuce plants

Treatment	Conc. of ES (ml/L)	Weight, g/Bush	Increase compared to control, %
(Control)	-	17,3	-
ES1	5.10 ⁻⁴	17,0	-1,37
ES2	10 ⁻³	20,6	+19,2
ES3	5.10 ⁻³	21,0	+21,6
ES4	10 ⁻²	26,0	+27,3

Table 1.

The effect of ES on growth parameters of total, leaf, stem and roots fresh weight (FW) on oakleaf lettuce treatments

Treatment	Fresh weight (FW) per plant at harvesting time (g).			
	Total	Leaf	Stem	Root
Control	30,49 ^d	23,47 ^d	2,92 ^c	3,84 ^b
ES1*	30,12 ^d	22,59 ^e	3,19 ^b	3,89 ^b
ES2*	33,11 ^c	25,79 ^c	3,37 ^b	4,17 ^{ab}
ES3*	40,87 ^b	27,26 ^b	3,44 ^b	4,87 ^a
ES4*	42,91 ^a	29,15 ^a	4,80 ^a	5,04 ^a

*ES1 = 5.10⁻⁴, ES2 = 10⁻³, ES3 = 5.10⁻³, ES4 = 10⁻² ml/L of 1-ethoxysilatan preparation.

Means in the same column indicated by the same letter are not significantly different ($P > 0.5$).

Fresh weight of stem found highest (4.80 g plant⁻¹) in ES4 and the lowest fresh weight of stem (2.92 g plant⁻¹) found in control plants. In case of root, highest fresh weight (5.04 g plant⁻¹) found in ES4 and lowest fresh weight (3.84 and 3.87 g plant⁻¹) found in control and ES1 respectively. Clearly, we can notice the increase in total fresh weight, leaves, stems and roots weight after a foliar application of ES of concentrations above

10⁻³ ml/L where we can start to notice the improvement of physical properties of oakleaf lettuce plants at harvesting time.

The highest dry matter at harvesting time (8,21%) were found in ES4 and the lowest dry weights (7,39 and 7.40%) found in control and ES1 respectively. Meanwhile, at the harvesting time, we noticed that total dry matter is increasing in correspondence to the increase of ES concentration. These might be due to the activation of metabolic processes of lettuce plants after foliar treatment with organosilicon preparation, which led to an accumulation of plants dry matter content as shown in (table 3.).

Table 2.

Percentage of Dry weight (dry matter) and accumulated Nitrates in mg/100g under different concentrations of ES

Treatment	Dry weight (DW), (%)	Nitrates mg/100g
Control	7,39 ^b	283.01 ^d
ES1	7,40 ^b	273,3 ^d
ES2	7,84 ^{ab}	442 ^c
ES3	8,10 ^a	709,67 ^b
ES4	8,21 ^a	792,33 ^a

Means in the same column indicated by the same letter are not significantly different ($P > 0.05$).

Taking into account the important role of antioxidants for the plant itself and for providing healthy nutrition, we determined the effect of the studied organosilicon preparation on the total content of antioxidants (table 4) and the most important compounds which determine the antioxidant activity of lettuce leaf, including chlorophyll content, carotenoids and Ascorbic acid. The maximum value of total antioxidant capacity (TAC) reached 17.42 mg/g in treatment ES4, which is 1.75 times higher than their level in the control – 9,95 mg/g (table 2). It is important to notice the impact of treatments on the accumulation of the residuals for non-metabolized nitrates in lettuce leaves. As shown in (table 2), the residual nitrate content does not exceed the permissible level (2000 mg/kg). However, a clear correlation observed between the increase in the concentrations of ES and the content of residual nitrate accumulated in shoots. The reason behind that is due to activation of physiological activity and the increased demand of plants for nitrogen. Considering the content of nitrates did not exceed 50% of the ADI. This is reflecting one of the important indicators for lettuce products safety for human consumption.

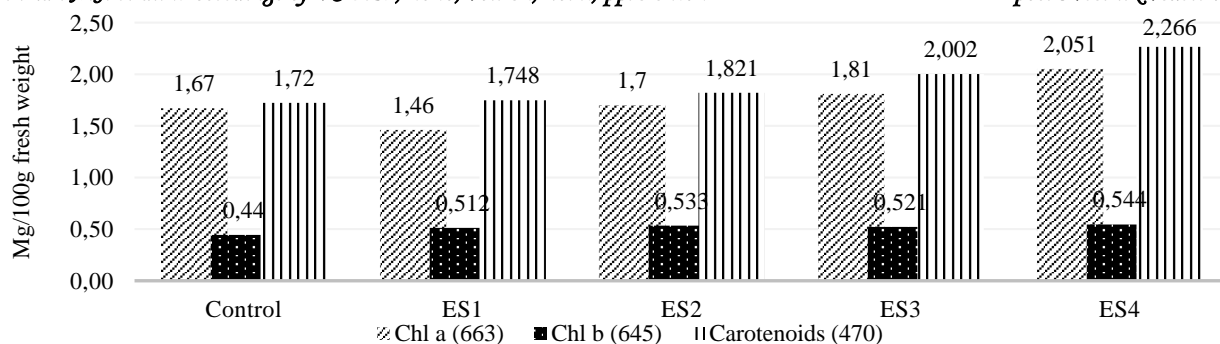


Figure 1. Accumulation of chlorophyll (a and b) carotenoids pigments in treated cultivars comparing to control, $\mu\text{g}\cdot\text{ml}^{-1}$ fresh weight

In all the studied treatments the content of chlorophyll a exceeded the content of chlorophyll b (Fig.5), which indicates the normal course of the processes of photosynthesis in the treated leaves. A significant increase in the activity of photosynthetic processes can be noted in treatments ES2, ES3, and ES4. At the same time, the maximum content of chlorophyll a recorded in treatment ES4 comparing to control. While to significant difference in accumulation of chlorophyll b in all treatments. A considerably high content in carotenoids found 2.02, 2.051 $\mu\text{g}\cdot\text{ml}^{-1}$ FW in treatments ES3 and ES4 comparing to 1.67 and 1.46 $\mu\text{g}\cdot\text{ml}^{-1}$ FW in control and ES1 respectively. Carotenoids are also involved in photosynthesis, growth and other

physiological functions of the plants. Increase in carotenoid content is an adaptive reaction of plants. Foliar treatment with ES causes adaptive enhancing and organization of the photosynthetic apparatus and leads to an increase in the content of photosynthetic optical pigments. the tendency to increase the content of Ascorbic acid caused by the intensification of the processes of photosynthesis. ES increased Ascorbic acid content from 6,52 to 13,17 mg/100 (table 4). Clearly, we can notice that the beginning of the effect of ES preparation by applying a foliar treatment on the content of ascorbic acid starts in concentrations of $0,5\cdot 10^{-2}$ and higher. Whereas no obvious effect on lower concentrations comparing to control.

Table 3. Content of Total phenolic content (TPC), Ascorbic acid and Total antioxidant capacity (TAC) under different concentrations of 1-ethoxysilatran

Treatment	Total antioxidant capacity (TAC) mg/g	Total phenols content (mg GAE)/g FW	Ascorbic acid mg/100g
Control	9,154 ^c	0.131 ^b	3.72 ^c
ES1	14,823 ^b	0.129 ^b	4.84 ^b
ES2	15,807 ^b	0.169 ^{ab}	5.01 ^{ab}
ES3	17,423 ^a	0.172 ^a	5.16 ^a
ES4	17,154 ^a	0.177 ^a	5.72 ^a

Means in the same column indicated by the same letter are not significantly different ($P > 0.05$). TPC values were expressed as gallic acid equivalents (GAE) mg/g fresh weight

Total phenolic content (TPC) increased only in treatment ES2 with concentration of ES of $5\cdot 10^{-3}$ mL⁻¹ (table 4) but did not increase significantly with higher concentrations. While ES1

treatment recorded no changes on (TPC) content, Alike treatment ES4 which recorded 35% increase in total phenolic content comparing to control treatment.

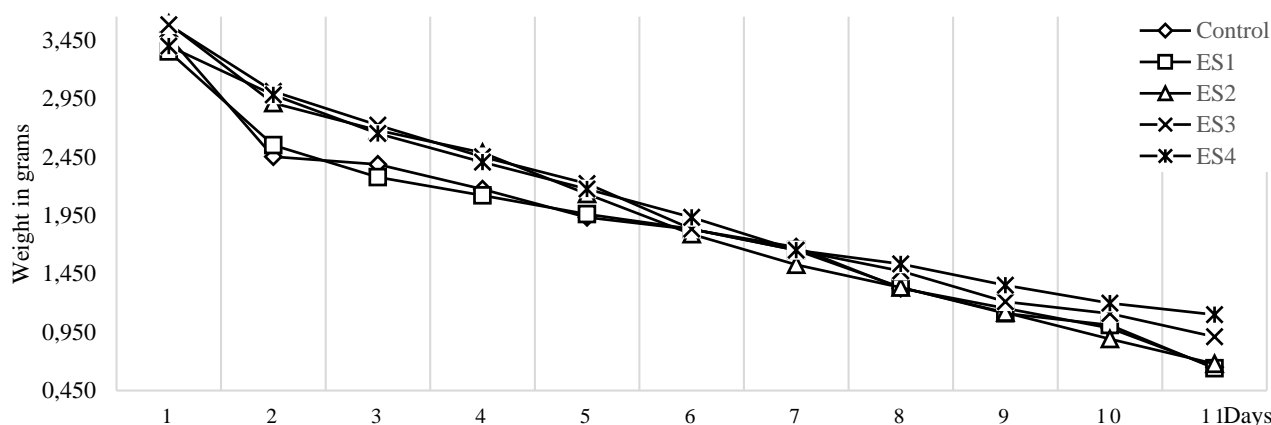


Figure 2. The effect of different concentrations of 1-ethoxysilatran treatment wight loss of lettuce leaves stored in desiccators

An important criterion for the physiological state and indicator of consumer properties of lettuce is the water-holding capacity of the leaves. This indicator affects the appearance of the lettuce, leaf turgor and causes weight loss in the turnover process. Weight of cut oakleaf lettuce was recorded at the beginning, during 11 days of the storage period in desiccators at room temperature. The influences of tested ES on weight loss of leaf lettuce are presented in fig. 1. The fresh weight of all samples markedly decreased during storage at room temperature. But the reduction rates were most severe in control, ES1 and ES2 samples and decreased proportionally with the increase in concentration of ES. The average values according to the results of all treatments after 11 days of storage amounted to 19.12, 18.91, 25.41 and 32.34% in treatments ES1, ES2, ES3 and ES4 respectively. In the control treatment, weight loss recorded 18.69% of the original fresh weight before cut. Changes in color were the most noticeable in both ES1 and control treatments which turned into yellowish-white to light green comparing to other treatments which maintained more light green color during the process of storage. The weight loss during storage period in desiccators is due to loss of water by continual transpiration of lettuce leaves. Probably, the organosilicon compound ES affects the structure of colloidal particles of the shoots and increases their water-holding ability. These results are of great practical importance and can be successfully used to develop technology for the post-harvest storage of lettuce and probably leafy vegetables in the retail environment for restaurants and farms. Our results correlate well with data obtained by other researchers studying the effect of Silatran group on Tobacco (*Nicotiana rustica*) and Soybean (*Glycine max*) [28]. The influence of organosilicon preparations from Silatran group on the permeability of membranes, changing

in enzyme activity, inducing of cell division, reducing the activity of water in the cell, increasing the productivity and quality of plants, accelerating maturation and increasing persistence.

Conclusion


Analyzing the obtained results, we can conclude that the complex influence of the organosilicon compound of Silatran group – 1-ethoxysilatran (ES) on the activation of physiological processes in lettuce plants in the process of growing effectively increased its biochemical activities. In concentrations of $5 \cdot 10^{-4}$ ml/l in ES1 treatment, no changes in results occurred. In higher concentration of 10^{-3} ml/l we can notice a slight increase. In concentration of 10^{-2} ml/l, preparation significantly influenced the metabolic activity of lettuce leaves have comparison to control, recording the best biochemical increase. In ES3 and ES4 variants within $5 \cdot 10^{-3}$ to 10^{-2} ml/l, no significant changes in the metabolic activity of lettuce leaves have occurred in comparison to ES2 which means that further increase in the concentration of ES is likely to be less effective. As a result, growth processes were activated, an increase in plant productivity, an improvement in appearance and turgidity also has been noticed. Consequently, foliar treatment with 1-ethoxysilatran on oakleaf lettuce (*Lactuca sativa* – var. Dubachuk MC) under the conditions of closed system in ISR-0.1 phytotron resulted in complex effect of activation of physiological processes and gives positive effects. influencing growth and productivity of the culture, increasing the dry matter content by 12.16%, accumulating photosynthetic pigments by 16.26%, as well as 1.7 times increase in the total anti-oxidant capacity including total polyphenols and ascorbic acid, improving the quality and nutritional value of lettuce and decreased the loss of weight (dehydration) during storage.


References


- 1 Szeto Y.T., Kwok T.C., Benzie I.F. Effects of a long-term vegetarian diet on biomarkers of antioxidant status and cardiovascular disease risk. *Nutrition*. 2004. pp. 863–866.
- 2 Nicolle C., Cardinault N., Gueux E., Jaffrelo L. et al. Health effect of vegetable-based diet: Lettuce consumption improves cholesterol metabolism and antioxidant status in the rat. *Clinical Nutrition*. 2004. pp. 605–614.
- 3 Serafini M., Bugianesi R., Salucci M., Azzini E. et al. Effect of acute ingestion of fresh and stored lettuce (*Lactuca sativa*) on plasma total antioxidant capacity and antioxidant levels in human subjects. *British Journal of Nutrition*. 2002. pp. 615–623.
- 4 Epstein E. Silicon. *Annual review of plant biology*. 1999. no. 50 (1). pp. 641–664.
- 5 Adrees M., Ali S., Rizwan M., Zia-ur-Rehman M. et al. Mechanisms of silicon-mediated alleviation of heavy metal toxicity in plants: a review. *Ecotoxicology and Environmental Safety*. 2015. pp. 186–197.
- 6 Datnoff L.E., Snyder G.H., Korndörfer G.H. et al. Silicon in agriculture. *Studies in plant science*. 2001.
- 7 Britez R.M., Watanabe T., Jansen S., Reissmann C.B. et al. The relationship between aluminium and silicon accumulation in leaves of *Faramea marginata* (Rubiaceae). *New Phytologist*. 2002. pp. 437–444.
- 8 Voronkov M.G. Biological activity of silatranes. In *Bioactive Organo-Silicon Compounds*. Springer, 1979. pp. 77–135.
- 9 Britton G. The biochemistry of natural pigments. Cambridge University Press, 1983.
- 10 Brown S.B., Houghton J.D., Hendry G.A.F. Chlorophyll breakdown. Boca Raton, CRC Press, 1991. pp. 465–489.
- 11 Costache M.A., Campeanu G., Neata G. Studies concerning the extraction of chlorophyll and total carotenoids from vegetables. *Romanian Biotechnolo Letters*. 2012. vol. 17. no. 5. pp. 7702–7708.
- 12 Kopsell D.A., Kopsell D.E. Accumulation and bioavailability of dietary carotenoids in vegetable crops. *Trends in Plant Science*. 2006. pp. 499–507.
- 13 Shaikh S.D., Dongare M. Analysis of photosynthesis pigments in *Adiantum lunulatum* Burm. At different localities of Sindhudurg District (Maharashtra). *Indian Fern*. 2008. pp. 83–86.


- 14 Agarwal A., Saleh R.A., Bedaiwy M.A. Role of reactive oxygen species in the pathophysiology of human reproduction. Fertility and sterility. 2003. pp. 829–843.
- 15 Albrecht J.A. Ascorbic acid content and retention in lettuce. Journal of food. 1933. no. 16. pp. 311–316.
- 16 Padayatty S.J., Katz A., Wang Y., Eck P. et al. Vitamin C as an antioxidant: evaluation of its role in disease prevention. Journal of the American college of Nutrition. 2003. pp. 18–35.
- 17 Bielski B.H., Richter H.W., Chan P.C. Some properties of the ascorbate free radical. Annals of the New York Academy of Sciences. 1975. no. 258(1). pp. 231–237.
- 18 Hu F.B. Dietary pattern analysis: a new direction in nutritional epidemiology. Current opinion in lipidology. pp. 3–9.
- 19 Baur S., Klaiber R.G., Koblo A., Carle R. Effect of different washing procedures on phenolic metabolism of shredded, packaged iceberg lettuce during storage. Journal of Agricultural and Food Chemistry. 2004. pp. 7017–7025.
- 20 DuPont M.S., Mondin Z., Williamson G., Price K.R. Effect of variety, processing, and storage on the flavonoid glycoside content and composition of lettuce and endive. Journal of agricultural and food chemistry. 2000. pp. 3957–3964.
- 21 Lichtenthaler H.K. Chlorophylls and carotenoids: pigments of photosynthetic membranes. Method Enzymo. 1987. pp. 350–382.
- 22 Lichtenthaler H.K., Wellburn A.R. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochem. Soc. Trans. 1983. no. 11. pp. 591–592.
- 23 Komarova N.V., Kamentsev Y.S. A practical guide to the use of capillary electrophoresis systems" DROP 105, "" Products of processing fruits and vegetables. Methods for determining vitamin C. St. Petersburg, Veda LLC, 2006. 171 p. (in Russian).
- 24 Lapin A.A., Gorbunova E.V., Zelenkov V.N., Gerasimov M.K. Determination of antioxidant activity of wines by coulometric method. Scientific and methodological guide. Moscow, Russian Academy of natural Sciences RAEN, 2009. pp. 64.
- 25 Zagorskina N.V., Nechaeva T.L., Lapshin P.V. A method for determining the total content of phenolic compounds in plant objects. Patent RF, no. 2700787, 2019.
- 26 Lobo V., Patil A., Phatak A., Chandra N. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy reviews. 2010. pp. 118.
- 27 Spinardi A., Cocetta G., Baldassarre V., Ferrante A. et al. Quality changes during storage of spinach and lettuce baby leaf. In VI International Postharvest Symposium. 2009. vol. 877. pp. 571–576.
- 28 Voronkov M.G., Baryshok V.P. Silatrans in medicine and agriculture. Publish house Russian academy of science. 2005. pp. 284–292.

Сведения об авторах

Али Джамиль Осман аспирант, кафедра товароведения и товарной экспертизы / лаборатория экспертизы товаров растительного происхождения, Российский экономический университет имени Г.В. Плеханова, Стремянный пер., 36, Москва, 115093, Россия, ali.mcisa@gmail.com
 <https://orcid.org/0000-0002-8309-1854>

Людмила Г. Елисеева д.т.н., профессор, кафедра товароведения и товарной экспертизы / лаборатория экспертизы товаров растительного происхождения, Российский экономический университет имени Г.В. Плеханова, Стремянный пер., 36, Москва, 115093, eliseeva-reu@mail.ru
 <https://orcid.org/0000-0003-2715-9989>

Валерий Н. Зеленков ст. науч. сотрудник, Всероссийский научно-исследовательский институт овощеводства – филиал «Федеральный научный центр овощеводства», Московская область, Раменский район, д. Верея, стр.500 дер, Верея, Московская обл., 140153, Россия, zelenkov-raen@mail.ru
 <https://orcid.org/0000-0001-5481-2723>

Вячеслав В. Латускин к.с/х.н., специалист по сельскому хозяйству, Институт Стратегий Развития - Автономная некоммерческая организация, д. 11 переулок Столешников, Москва, 125009, Россия, slavalat@ya.ru
 <https://orcid.org/0000-0003-1406-8965>


Вклад авторов


Али Джамиль Осман написал рукопись, корректировал её до подачи в редакцию и несет ответственность за плагиат
Людмила Г. Елисеева предложила методику проведения эксперимента и организовала производственные испытания
Валерий Н. Зеленков Вячеслав В. Латускин консультация в ходе исследования


Конфликт интересов


Авторы заявляют об отсутствии конфликта интересов.

Information about authors

Ali J. Othman graduate student, commodity science and commodity expertise department / laboratory of plant products expertise, Plekhanov Russian University of Economics, 36 Stremyanny avenue, Moscow, 115093, Russia, ali.mcisa@gmail.com
 <https://orcid.org/0000-0002-8309-1854>

Ludmila G. Eliseeva Dr. Sci. (Engin.), professor., commodity science and commodity expertise department / laboratory of plant products expertise, Plekhanov Russian University of Economics, 36 Stremyanny avenue, Moscow, 115093, Russia, eliseeva-reu@mail.ru
 <https://orcid.org/0000-0003-2715-9989>

Valeriy N. Zelenkov senior researcher, All-Russian Research Institute of Vegetable - branch "Federal Scientific Center of Vegetable, Moscow region, Ramensky district, d. Vereya, p. 500 der, Vereya, Moscow region, 140153, Russia., zelenkov-raen@mail.ru
 <https://orcid.org/0000-0001-5481-2723>

Vyacheslav V. Latushkin Cand. Sci. (Agric.), agricultural specialist, Institute for Strategic Development - Autonomous Non-profit Organization., 11 Stoleshnikov avenue, Moscow, 125009, Russia), slavalat@ya.ru
 <https://orcid.org/0000-0003-1406-8965>

Contribution

Ali J. Othman wrote the manuscript, correct it before filing in editing and is responsible for plagiarism
Ludmila G. Eliseeva proposed a scheme of the experiment and organized production trials
Valeriy N. Zelenkov Vyacheslav V. Latushkin consultation during the study

Conflict of interest

The authors declare no conflict of interest.

Поступила 05/02/2020	После редакции 17/02/2020	Принята в печать 28/02/2020
Received 05/02/2020	Accepted in revised 17/02/2020	Accepted 28/02/2020