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THE INFLUENCE OF SOME TECHNOLOGICAL FACTORS ON THE FUNCTIONAL FOOD CHARACTERISTICS OF CARROTS IN THE HILLY AREA OF TRANSYLVANIA

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ABSTRACT. The global warming and aridization process in Romania presents zonal risk situations that can strongly affect the production potential and quality of carrot crops. An experiment was designed which follows the effect of technological factors on the quantity and quality of production for three varieties of carrots *(Royal Chantenay, Atomic Red* and *Purple Haze* F_1), under organic cultivation conditions. 18 carrot samples were analyzed to evaluate the antioxidant capacity and total of mineral elements. For the antioxidant capacity a photochemiluminescence methods was used and the Photochem instrument from AnalytikJena togheter the ACL kit and for the total content of mineral elements was used the ICP-MS Elan Drc II Perkin-Elmer. By irrigating the carrot culture, the antioxidant capacity increases by 17.6% compared to the control sample (non-irrigated). Through chemical fertilization and zeolite fertilization of carrot culture, the antioxidant capacity increases by 3.2% and 18.8%, respectively, compared to the control sample (basic fertilization). By irrigating the carrot culture, the total content of mineral elements increases by 14.1% compared to the control sample (non-irrigated). Through chemical fertilization and fertilization with zeolite of carrot culture, the total content of minerals elements increases by 5.5% and 18.9% respectively with the control sample (basic fertilization).

Keywords: *carrots, zeolites, functional foods, fertilization, irrigation, organic farming*

INTRODUCTION

Carrot (*Daucus Carota L.*) is a vegetable and medicinal plant, the most important crop in the Apiaceae family [1]. Carrot root is widely used due to its richness in carotenoids, anthocyanins, dietary fiber, vitamins and other

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nutrients. Carrot extracts, which serve as sources of antioxidants, have important functions in preventing many diseases [4].

Obtaining superior quantitative and qualitative carrot harvests involves using water and fertilizers rationally if it exploits irrigated land as correctly as possible [2].

Natural zeolites are part of a family of natural minerals, of volcanic origin, with three main properties that are of great interest for agricultural purposes: high cation exchange capacity; high water retention capacity in free channels; high adsorption capacity, which make them particularly attractive for use as fertilizers [3,5]. The exploitation and use of zeolites abroad is constantly growing. In the United States, Japan, South Korea, and Western European countries, 300,000 tons of zeolites were used in 1995 [6]. Great successes in the use of natural zeolites in various fields are obtained in Japan, Hungary, Bulgaria. There are more than 60 zeolite deposits in Russia with total projected reserves of clinoptilolite, mordenite and phillipsite of 3.5 billion tons. The trend is for zeolitic volcanic tuffs to become export materials for producing countries. Out of 45 countries that possess deposits of natural zeolites, only in 16 of them have they been exploited, respectively: USA (20 mining operations), Japan (10 mining operations), Russia (4 mining operations), South Korea, China and Yugoslavia, 2 mining operations [7]. In Romania, important deposits of clinoptilolytic tuffs are located in the Transylvanian Depression and in the adjacent basins such as Silvania and Maramureş. Taking into account the extension, thickness and content in zeolites, the most important volcanic tuff deposits in Romania are described as "Tuf de Dej" in the Transylvanian Depression, "Tuf de Slănic" in the Tarcău Unit and the Subcarpathian Depression, "Tuf de Perşani” in the Transylvanian Depression. The volcanic tuff deposits in our country are easily accessible, with possibilities of quarry exploitation. Of the 40 known zeolitic minerals, only six have large reserves and properties needed for practical use [8,14].

The promotion and sustainable use of natural resources is an opportunity to address issues related to food security, quality of life and the environment [9].

To successfully promote this type of agriculture, agricultural producers should meet several requirements and conditions, the most important of which are crop rotation, fertilization, weed and pest control as well as reducing energy consumption [10,13].

The transition of agricultural producers to sustainable agriculture has become a topic of great interest in most countries of the world. In Romania, in order to apply sustainable agriculture, it is necessary to establish certain goals and respect some principles and methods, such as increasing the quality of life in rural areas by increasing incomes from agricultural activities, expanding more public services and utilities, diversifying certain non-agricultural activities. For now, Romania's agriculture is in a difficult situation, due to poor equipment and machinery, the unstable situation in rural infrastructure, low application of natural fertilizers, but also due to small irrigated areas and soil degradation. In this way, the major problem of agriculture in the future is not to produce more, but to produce sustainably [11,12].

The aim of this study was to identify ecological technological solutions to improve the functional food characteristics of three varieties of carrots: *Royal Chantenay, Atomic Red* and *Purple Haze F_1* by synergistic use of irrigation and fertilization with natural zeolites. By protecting the environment and within the limits of economic efficiency, the aim was to identify methods to increase the production and quality of carrot cultivation.

RESULTS AND DISCUSSION

The influence of irrigation, fertilization and carrot variety on the antioxidants capacity of carrots

The quality of production of carrots was analyzed in terms of the content of antioxidants - molecules that protect the body from the effects of free radicals. The samples were taken from all experimental variants, on all 3 repetitions, choosing plants from the center and extremities of the experimental plots, diagonally, for each of the three years of experience. The antioxidants content was calculated as the average of the three years of experimentation (2016-2018) and is expressed in ascorbic acid equivalent.

As can be seen in Tables 1, irrigation, chemical fertilization as well as zeolite fertilization had a very significant effect on the antioxidants content of plants.

Table 1. The influence of irrigation, fertilization and carrot variety on the antioxidants capacity of carrots, 2016- 2018

Experimental condition	Antioxidant capacity (µg/mgTrolox)	Relative production (%)	Difference (µg/mg Trolox)	Significance
Not irrigated	235.26	100.0	0.00	Control sample
Irrigated	276.75	117.6	41.50	[a] ***
Basic Fertilization	238.53	100.0	0.00	Control sample
Chemical fertilization	246.07	103.2	7.54	***
Fertilization with zeolite	283.41	118.8	44.88	***
Royal Chantenay	24.22	100.0	0.00	Control sample
Atomic Red	25.19	104.0	0.98	[b] *
Purple Haze F_1	718.60	2967.4	694.38	***

[a] *** - very significant effect; [b] * - significant positive effect

The analysis of the results in Table 1 shows that for the carrot culture carried out under irrigation conditions, the antioxidant content increases by 17.6% compared to the control sample (non-irrigated). Through chemical fertilization and zeolite fertilization of carrot culture, the antioxidant capacity increases by 3.2% and 18.8%, respectively, compared to the control sample (basic fertilization). *Purple Haze F_1* show a very significant effect in antioxidant capacity compared with *Royal Chantenay* and *Atomic Red.*

The analysis of the results from Table 2 on the influence of the interactions between factors A x B x C, irrigation regime x fertilization x carrot variety at the carrot harvest, in the environmental conditions from Aiton - Cluj, between 2016 and 2018, indicated that the irrigation regime and fertilizers applied during the period of plant growth had a significant

Table 2. The effect of the interaction of the three technological factors on the carrot antioxidant content, 2016-2018

Experimental condition	Antioxidant capacity (µg/mgTrolox)	Relative production (%)	Difference (µg/mg Trolox)	Significance
$^{a}a_1 \times {}^{b}b_1 \times {}^{c}c_1$	19.37	100.0	0.00	Control sample
$^{d}a_2 \times b_1 \times c_1$	21.60	111.5	2.23	^{i}-
$a_1 \times b_1 \times {}^{e}c_2$	19.80	100.0	0.00	Control sample
$a_2 \times b_1 \times c_2$	22.40	113.1	2.60	-
$a_1 \times b_1 \times {}^{f}c_3$	622.10	100.0	0.00	Control sample
$a_2 \times b_1 \times c_3$	725.90	116.7	103	^{j}***
$a_1 \times {}^{g}b_2 \times c_1$	22.43	100.0	0.00	Control sample
$a_2 \times b_2 \times c_1$	25.50	113.7	3.07	^{k}*
$a_1 \times b_2 \times c_2$	24.30	100.0	0.00	Control sample
$a_2 \times b_2 \times c_2$	26,60	109.5	2.30	-
$a_1 \times b_2 \times c_3$	632.60	100.0	0.00	Control sample
$a_2 \times b_2 \times c_3$	745.00	117.8	112.0	***
$a_1 \times {}^{h}b_3 \times c_1$	27.23	100.0	0.00	Control sample
$a_2 \times b_3 \times c_1$	29.17	107.1	1.93	-
$a_1 \times b_3 \times c_2$	26.83	100.0	0.00	Control sample
$a_2 \times b_3 \times c_2$	31.23	116.4	4.40	**
$a_1 \times b_3 \times c_3$	722.63	100.0	0.00	Control sample
$a_2 \times b_3 \times c_3$	863.37	119.5	140.3	***

$^{a}a_1$- not irrigated; $^{b}b_1$-basic fertilization; $^{c}c_1$- *Royal Chantenay*; $^{d}a_2$-irrigated; $^{e}c_2$-*Atomic Red*; $^{f}c_3$-*Purple Haze F_1*; $^{g}b_2$-chemical fertilization; $^{h}b_3$-fertilization with zeolite; ^{i} - statistically positive; ^{j} ***-very significant effect; k*- significant positive effect.

influence on the content of antioxidants recorded in the experimental fields of the crop, which involves the recommendation for the application of irrigation and fertilization to obtain a quality production.

The influence of irrigation, fertilization and carrot variety on the total content of minerals element

The quality of production was analyzed in terms of the total content of minerals element of carrots which are biologically active substances, non-caloric, but which ensure the normal function of all cells and tissues of the body.

As can be seen in the Table 3, irrigation as well as all fertilization options had a very significant effect on the mineral content of plants. Through chemical fertilization and fertilization with zeolite of carrot culture, the total content of minerals elements increases by 5.5% and 18.9% respectively with the control sample (basic fertilization). *Atomic Red* and *Purple Haze* F_1 had a very significant negative effect in total content of minerals element compared with *Royal Chantenay.*

Table 3. The influence of irrigation, fertilization and carrot variety on the total content of minerals element, 2016- 2018

Experimental condition	Total content of minerals element (mg/kg)	Relative production (%)	Difference (mg/kg)	Significance
Not irrigated	8711.55	100.0	0.00	Control sample
Irrigated	9937.04	114.1	1225.49	[a]***
Basic fertilization	8623.63	100.0	0.00	Control sample
Chemical fertilization	9069.54	105.5	472.91	***
Fertilization with zeolite	10252.71	118.9	1629.07	***
Royal Chantenay	10377.57	100.0	0.00	Control sample
Atomic Red	9321.27	8.,8	-1056.30	[b]000
Purple Haze F_1	8274.05	79.7	-2103.52	000

[a] ***- very significant effect; [b]000- very significant negative effect

The analysis of the results in Table 4 indicates that the irrigation regime and fertilizers applied during the plant growth period had a very significant influence on the total mineral content recorded in the experimental fields of the crop.

Table 4. The effect of the interaction of the three technological factors on the total content of minerals element, 2016-2018

Experimental condition	Total content of minerals element (mg/kg)	Relative production (%)	Difference (mg/kg)	Significance
[a]a_1 x [b]b_1 x [c]c_1	8878.23	100.0	0.00	Control sample
[d]a_2 x b_1 x c_1	10058.77	113.3	1180.53	[i]***
a_1 x b_1 x [e]c_2	8103.03	100.0	0.00	Control sample
a_2 x b_1 x c_2	9181.97	113.3	1078.93	***

Experimental condition	Total content of minerals element (mg/kg)	Relative production (%)	Difference (mg/kg)	Significance
$a_1 \times b_1 \times {}^{f}c_3$	7245.10	100.0	0.00	Control sample
$a_2 \times b_1 \times c_3$	8274.70	114.2	1029.60	***
$a_1 \times {}^{g}b_2 \times c_1$	9516.90	100.0	0.00	Control sample
$a_2 \times b_2 \times c_1$	10847.40	114.0	1330.50	***
$a_1 \times b_2 \times c_2$	8512.30	100.0	0.00	Control sample
$a_2 \times b_2 \times c_2$	9541.97	112.1	1029.67	***
$a_1 \times b_2 \times c_3$	7578.67	100.0	0.00	Control sample
$a_2 \times b_2 \times c_3$	8582.03	113.2	1003.37	***
$a_1 \times {}^{h}b_3 \times c_1$	10673.70	100.0	0.00	Control sample
$a_2 \times b_3 \times c_1$	12290.40	115.1	1616.70	***
$a_1 \times b_3 \times c_2$	9587.03	100.0	0.00	Control sample
$a_2 \times b_3 \times c_2$	11001.430	114.8	1414.27	***
$a_1 \times b_3 \times c_3$	8308.97	100.0	0.00	Control sample
$a_2 \times b_3 \times c_3$	9654.83	116.2	1345.87	***

[a]a_1- not irrigated; [b]b_1-basic fertilization; [c]c_1- Royal Chantenay; [d]a_2-irrigated; [e]c_2-Atomic Red; [f]c_3-Purple Haze F1; [g]b_2-chemical fertilization; [h]b_3-fertilization with zeolite; i - very significant effect.

Determination of heavy metal content in carrot samples

The effect of the interaction of the three technological factors on the content of heavy metals (mg / kg) in carrots (Table 5) is different.

The content of heavy metals: Pb, Cd, Cu, Zn, As, Hg was studied in the carrot samples from the experimental field Aiton, Cluj County, specifying the level of dangerous concentration in relation to the maximum allowed concentrations of heavy metals in food products, according to Order no. 640 of September 19, 2001 published in the OFFICIAL MONITOR no. 173 of March 13, 2002, on the safety and quality conditions for fresh vegetables and fruits intended for human consumption [15].

With, Cd, Zn are more concentrated in plants of the *Royal Chantenay* variety, the irrigated-chemically fertilized system.

Pb, As are more concentrated in plants of the *Purple Haze F$_1$* variety, the irrigated-basic fertilization system.

Table 5. Heavy metal content of carrot samples

Experimental condition	Pb	Cd	Cu	Zn	As	Hg
$a_1 \times b_1 \times c_1$	0.08	0.22	10.10	34.50	0.05	<0.05
$a_2 \times b_1 \times c_1$	0.1	0.21	9.80	32.7	0.05	<0.05
$a_1 \times b_1 \times c_2$	<0.05	<0.05	5.72	11.44	0.07	<0.05
$a_2 \times b_1 \times c_2$	<0.05	<0.05	5.43	12.11	0.06	<0.05
$a_1 \times b_1 \times c_3$	0.26	<0.05	9.29	22.13	0.12	<0.05
$a_2 \times b_1 \times c_3$	0.45	0.11	7.80	23.21	0.26	<0.05

Experimental condition	Pb	Cd	Cu	Zn	As	Hg
$a_1 x b_2 x c_1$	0.12	0.29	11.20	48.1	0.06	<0.05
$a_2 x b_2 x c_1$	0.12	0.31	10.27	47.30	0.05	<0.05
$a_1 x b_2 x c_2$	<0.05	<0.05	4.85	10.10	0.06	<0.05
$a_2 x b_2 x c_2$	0.21	0.21	6.23	33.20	0.05	<0.05
$a_1 x b_2 x c_3$	0.24	0.12	8.10	21.45	0.04	<0.05
$a_2 x b_2 x c_3$	0.32	<0.05	4.50	19.83	0.10	<0.05
$a_1 x b_3 x c_1$	0.09	0.11	6.78	35.76	0.06	<0.05
$a_2 x b_3 x c_1$	0.10	0.09	5.44	32.19	0.07	<0.05
$a_1 x b_3 x c_2$	0.19	0.16	5.80	28.45	0.05	<0.05
$a_2 x b_3 x c_2$	0.20	0.17	6.05	27.54	0.04	<0.05
$a_1 x b_3 x c_3$	0.28	0.07	4.32	22.34	0.06	<0.05
$a_2 x b_3 x c_3$	0.10	0.04	3.21	15.33	0.03	<0.05
CMA	0.5	0.2	-	-	-	0.03

CONCLUSIONS

The analysis of the results for the period 2016-2018 shows that for the carrot culture carried out under irrigation conditions, the antioxidant capacity increases by 17.6% compared to the control sample (non-irrigated).

Through chemical fertilization and zeolite fertilization of carrot culture, the antioxidant capacity increases by 3.2% and 18.8%, respectively, compared to the control sample (basic fertilization).

Purple Haze F_1 show a very significant effect in antioxidant capacity compared with *Royal Chantenay* and *Atomic Red.*

Throughout the research period, irrigation as well as all fertilization options had a very significant effect on total content of minerals elements of the plants.

Through chemical fertilization and fertilization with zeolite of carrot culture, the total content of minerals elements increases by 5.5% and 18.9% respectively with the control sample (basic fertilization).

Atomic Red and *Purple Haze F_1* show a very significant negative effect in minerals element compared with *Royal Chantenay*.

EXPERIMENTAL SECTION

The experiments were performed in the hilly area of Transylvania, Aiton locality (46 ° 31 'and 46 ° 31' northern latitude; 23 ° 40 'and 23 ° 48' east longitude) containing 3 repetitions, 18 variants, 54 experimental plots. The comparative cultures were ordered in a multifactorial system, completely randomized, with subdivided plots.

The experimental factors studied were: irrigation regime - with two experimental variants (non-irrigated / irrigated), fertilization, with three experimental variants (basic fertilization / chemical fertilization / zeolite fertilization) and carrot variety, with three experimental variants (*Royal Chantenay, Atomic Red and Purple Haze F_1*) (table 6).

The experiments contained a number of 3 repetitions (n = 3), the number of variants analyzed in the experiment was 18 (v = 2 x 3 x 3), the total number of experimental plots was 54 (18 x 3). We opted for a rectangular shape of the test plots (90x60 cm). The comparative cultures were ordered in a multifactorial system, completely randomized, with subdivided plots.

For the statistical analysis of the results, the POLIFACT statistical program was used - analysis of variance for completely randomized multifactorial experiments. As witnesses in the statistical analysis, a_1 (non-irrigated) was used for irrigation, b_1 (basic fertilization) for fertilization, c_1 (*Royal Chantenay*) for the carrot variety.

Table 6. Experimental factors and experimental variants

The factors studied	Experimental variants
Factor A Irrigation regime	a_1 – not irrigated
	a_2 – irrigated
Factor B Fertilization	b_1 – basic fertilization
	b_2 – chemical fertilization
	b_3 – fertilization with zeolite
Factor C Carrot variety	c_1 – *Royal Chantenay*
	c_2 – *Atomic Red*
	c_3– *Purple Haze F_1*

Methods and equipment used to determine the content of heavy metals and minerals

Instrumentation used: • Microwave digester Berghoff MWS-3+ (Eningen, Germania) • ICP-MS ELAN DRC II Perkin-Elmer

Reagents and materials used: • 65% HNO_3 (Merck, Germany); • H_2O_2 30% analytical purity (Merck, Germany); Multi-element stock solution 1000 mg / l (Merck, Darmstadt, Germany); • Ultrapure water, Milli-Q (Millipore, Bedford, MA, USA).

Procedure: Three replicates of 0.5 g of sample (dried at 40 ° C, ground and homogenized) were subjected to microwave digestion with 8 ml of 65% HNO_3 and 3 ml of 30% H_2O_2. After cooling to ambient temperature, the sample was diluted to 25 ml with ultrapure water, then filtered through a 0.45 µm cellulose membrane filter. The control samples were prepared analogously. Concentrations of total content of minerals in mineralized solutions were determined using ICP-MS. To verify the performance of the proposed method, the sensitivity of the method was studied by determining and calculating the detection and quantification limits.

Methods and equipment used to determine total antioxidant capacity.

Instrumentation used • Plastic tubes; • Test tubes with 50 ml for centrifuge; • Photochem Analytics Jena; • Single-channel automatic pipettes (500-5000 µl, 100-1000 µl, 10-100 µl); • Centrifuge D-78532 HETTICH - Germany.

Reagents and materials used: • ACW kit consisting of: dilution solution for water-soluble samples, buffer solution, photosensitizer solution, standard antioxidant solution; • ACL kit consisting of: buffer solution, photosensitizer solution, standard antioxidant solution; • Methanol; • Ultrapure water

Procedure: Carrot samples for *Atomic Red, Purp Haze F_1* and *Royal Chantenay* were analyzed. After homogenization and crushing, the carrot samples were extracted using methanol. The mixture was centrifuged at 3500 RPM for 8 minutes and analyzed using the Photochem instrument from Analytik Jena together with the ACL (Antioxidative Capacity of the Lipid Soluble Compounds) kit. Antioxidant capacity was expressed as Trolox equivalent. The determinations were performed according to the ACL kit.

For the statistical analysis of the results, the POLIFACT statistical program was used - analysis of variance for completely randomized multifactorial experiments.

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