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INFLUENCE OF DIFFERENT TYPES AND MIXTURES OF COMPOSTS ON QUALITY OF TOMATOES FRUITS (*SOLANUM LYCOPERSICUM L.*)

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Abstract

A greenhouse experiment was conducted with different types of composts in order to investigate the effect of composts on fruit quality characteristics of tomato (*Lycopersicum esculentum* L.) commercial F1 Hybrid (cv. Danubius). The tomato fruit quality was estimated by assessing some quality parameters as: dry matter, titratable acidity, ascorbic acid, antioxidants and lycopene.

The experiments were carried out in a research greenhouse of Plant physiology department - Faculty of horticulture and forestry from Timisoara. We used three mature composts prepared from: dry wheat straw, chicken manure, grass lawn, sawdust, green leaves and cow manure, in different ratios, composted during eight months in boxes (B) and plastic bags (S). Fruits were analysed for: dry matter content (%), antioxidant activity by Ferric Reducing Ability of Plasma - FRAP (µM Trolox/g fresh matter), ascorbic acid (mg/100g fresh matter), acidity (%), lycopene (µg/g.f.w.).

Dry matter presented values between 4.62% and 8.74%, with an amplitude of variation of 4.12%, due to a variability among variants of 22.36%. The titratable acidity showed a variation amplitude of 2.5 associated with a medium variability between combinations of 16.03%, with limits ranging from 3.20 and 5.70. At the combinations of different variations and substrates, the antioxidant activity showed values between 42.90 and 84.49 µM Trolox/g. Lycopene content showed an amplitude of variation of 346.91 µg/g, combined with a very high variability between combinations of 49.98%, with limits ranging from 42.35 and 389.26 µg/g.

Between the most of the assessed characteristics, there are linear relationships that allow an accurate estimation of the mutual influence, according to analysis of variance and covariance. Correlation study indicates the existence of positive and statistically assured influences between fruit acidity and FRAP, respectively lycopene.

Key words: *Tomatoes, Titratable acidity, Vitamin C, Antioxidants, Lycopene.*

1. Introduction

Tomatoes (*Solanum lycopersicum* L.) are the most consumed vegetables on the Earth, both as fresh or in processed form. Although organic tomato cultivation recently appeared in Romania, this trend took strong increase. Many consumers believe that greenhouse vegetables grown in the soil are superior in organoleptic quality and have higher vitamin and mineral content than those grown in other media Johansson *et al*., [1].

However, some authors have reported that: dry matter, sugar, soluble solids, vitamins and carotenoids, acidity and taste of tomatoes have better grades when they grew in culture systems when using compost compared to soil or hydroponic system, Gruda [2]. Tomatoes are rich source of lycopene, ascorbic acid and other different antioxidants. Rein *et al*., [3] consider that daily consumption of 15 mg of lycopene showed reduced C-reactive protein, a marker reported as key influence of cardiovascular disease. Another important antioxidant compound present in tomatoes is ascorbic acid. Although its content is moderate, its contribution to diet is meaningful, because of high consumption. For the beneficial health effects are responsible the interactions between different synergistic phytonutrients in tomatoes, and for this reason tomatoes has been conferred with the status of "functional food", Binoy *et al.*, [4].

Because all of this we consider that it is important to investigate the effect of organic fertilizer such as the compost, in the growth of tomato and its quality.

2. Materials and Methods

2.1 Materials

In the experiment for obtaining tomato plants we used three types of mature compost prepared from: dry wheat straw, chicken manure, grass lawn, sawdust, green leaves and cow manure, in different proportion which have been composted during 8 months. Finally we obtained three main variants of compost from boxes (B1, B2, B3) and another three from black plastic bags (S1, S2, S3). From Table 1 we can see that B3, S3 samples of compost have the lowest ratio C/N (about 30), while B2, S2 have a value of four fold bigger, while B1, S1 have an intermediate value of C/N ratio.

Table 1. Compost organic matter mixtures

Compost variant	Organic matter	Amount kg	C/N ratio
B1/S1	Wheat straw	22.5	36
	Chicken manure	30	
	Grass lawn	30	
B2/S2	Sawdust	15	120
	Wheat Straw	57	
	Chicken manure	15	
B3/S3	Green leaves	30	30
	Fresh chicken manure	30	
	Caw manure	30	

The tomato seedlings (hybrid F1 Danubius) were planted in pots (20 L capacity) filled with a mix of compost coming from boxes and plastic bags, in different proportions. The control was filled 100% with soil from field. The experiment was performed in greenhouse condition during the season from March to August 2013. Every variant was carried out in triplicate. Tomato plants were grown in ecological system, without any addition of chemical fertilizer or pesticide treatments. Tomato fruits were harvested from each variant at the red-ripe stage. A sample of at least 2 kg from each tomato plant was harvested from each combination treatment. After washing and freezing at -20 ^{0}C, tomatoes were chopped and stirred in a blender (Singer SPM 400), in order to perform physical-chemical analysis related to quality assessment. For every combination of compost we prepared an average sample of tomato fruit.

2.2 Methods

2.2.1 Determination of dry matter content

16 aluminum vials with a diameter of 50 mm and a height of 30 mm were half-filled with the samples, and then were placed in a thermo regulated oven for 24 hours at a temperature of 105 ^{0}C; initial and final weight of samples was determined and the difference between these values was related to 100, which effectively represents the percentage of moisture in the tissue.

2.2.2 Determination of total antioxidant capacity (Ferric reducing ability of plasma - FRAP)

Antioxidant activity was determined by FRAP method on the basis of TPTZ (2,4,6-tri-2-pyridyl-s-triazin) ligand and color changes of TPTZ-Fe^{+3} complex when iron was reduced from $^{+3}$ to $^{+2}$ state of oxidation under the influence of hydro soluble antioxidant (Benzie and Strain [5]). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was used as standard antioxidant, and results were calculated as µM Trolox/g fresh weight.

2.2.3 Ascorbic acid determination

For the titrimetric determination of ascorbic acid (vitamin C), 10 g of sample were weighed to which 20 mL of oxalic acid was added. The resulting mixture was filtered through Whatman paper filter, and 1.5 mL filtrate was put in a 25 mL Erlenmeyer flask, and afterwards 10 mL of oxalic acid and 1 mL 1N hydrochloric acid were added. Each sample was titrated with indophenol (2,6-dicloridofenol redox indicator) until a distinct pink color persisted at least 5 seconds. Results were expressed as mg ascorbic acid/100 g fresh weight.

2.2.4 Acidity determination

In order to determine the acidity, 10 g were weighed from each sample. They were placed in a 50 mL Erlenmeyer flask, 10 mL of distilled water was added, and obtained composition was agitated 30 minutes for homogenization. Then 1 mL phenolphthalein (0.2%) was added to each sample and titrated with the 0.1 N sodium hydroxide solution until the appearance of violet color. Citric acid was used as standard, and titratable acidity was calculated in %.

2.2.5 Determination of lycopene

10 g of sample were weighed, and it was placed in a 50 mL Erlenmeyer flask, to which were added 10 mL of hexane/methanol/acetone (2 : 1 : 1) mixture containing Butylated Hydroxy Toluene (BHT) as antioxidant. The samples were stirred for 1 hour. Absorbance of the solution containing lycopene extraction was analyzed at 503 nm in a spectrophotometer (UV-VIS Specord 205, Analytik Jena). Lycopene was used as external standard and final results were expressed in µg Lycopene/g fresh weight (Barrett *et al.*, [6], Sadler *et al.*, [7]).

2.2.6 Statistical analysis

Obtained data were statistically analyzed by ANOVA test. To make possible the display in a single graph of the performance of each genotype for each of the five traits, was used the basic principle of the biplot technique developed by Gabriel [8], and GGE biplot method developed by Yan *et al.,* [9].

3. Results and Discussions

Exploring combinations of different variants and substrates, we found that dry matter content reveals values between 4.62% at combination B2-B3 100% and 8.74% at combination B1-S3 25%, with an amplitude of variation of 4.12%, due to a variability among variants of 22.36%. Approximately 62.5% of the combinations achieved dry matter content values between 5 and 8%, while the remaining combinations were distributed symmetrically, respectively three values of less than 5 and more than 8 (Table 2).

Compared to the control, 68.75% of the compost combinations achieved lower values of dry weight content in range 1.3 to 12.8%, without statistically relevant deviations. The highest increases were recorded statistically at combinations: B1-S3 25% (3.44***), B2-S3 75% (3.12***) and B1-B1 75% (3.05***). These three combinations allowed obtaining a significantly higher dry matter content compared to other combinations.

Concerning tomatoes acidity (Table 3) we noticed an amplitude of variation of 2.5 associated to a medium variability between combinations of 16.03%, with limits ranging from 3.20 to variant B1 on substrate B1 75% and 5.70 at combination B3-S2 75%. Among these culture conditions, 56% of the combinations showed values of fruit acidity between 3 and 4, while 31% had acidity between 4 and 5, and 13% reveals the acidity values over 5.

Compared to the control, the combinations B3-S2 75%, B3-S1 75%, B3-B1 25% and respectively B1-B3 25%, had a significant influence on the acidity causing an increase of 0.8 - 2 units in fruits. In the case of two combinations (B2-S3 75%, B1-B1 75%) fruit acidity presented lower values, without statistically significant differences.

The content of vitamin C in the tomatoes fruits showed values between 5 and 20 mg/100g, while only one combination has achieved a value above 20 mg/100 g in combination B1S3 25% (Table 4). In the case of these 16 combinations of variants and substrates, vitamin C content reveals values between 5.65 mg/100g at B2-B3 50%, 20.74 mg/100 g at B1-S3 25%, with a variation amplitude of 15.09 mg/100g. In the context of a medium amplitude and variability of 13.32%, it is noted that in the case of combination B1-S3 25% the plants accumulated in fruits significant higher amounts of vitamin C in comparison with other combinations, and the differences are statistically assured.

Compared to the control, plants grown on variant B1 in association with substrate S3, 25% showed a significantly distinct increase of vitamin C by 50%, while under the influence of given conditions by combinations of variant B1 and substrates B1 75% and B3 25% with B2-B3 50%, the amount of vitamin C in fruits has been significantly reduced.

Table 2. Dry matter content of tomato cultivated on different compost variants

No	Variants	Substrate	Dry Weight (%)	Compared to control	
				Relative value (%)	Difference significance
1	Control	Soil from field	5.30[b]	100	-
2	B3	S2 75%	5.56[b]	104.91	0.26
3	B3	S1 50%	5.56[b]	104.91	0.26
4	B3	S1 75%	6.34[b]	119.62	1.04
5	B3	B1 25%	5.41[b]	102.08	0.11
6	B3	B2 25%	5.23[b]	98.68	-0.07
7	B2	S3 50%	5.34[b]	100.75	0.04
8	B2	B1 100%	5.37[b]	101.32	0.07
9	B2	B3 50%	4.73[b]	89.25	-0.57
10	B2	B3 100%	4.62[b]	87.17	-0.68
11	B2	S3 75%	8.42[a]	158.87	3.12***
12	B1	B1 75%	8.35[a]	157.55	3.05***
13	B1	B1 50%	5.39[b]	101.7	0.09
14	B1	S3 25%	8.74[a]	164.91	3.44***
15	B1	S1 25%	5.00[b]	94.34	-0.3
16	B1	B3 25%	5.80[b]	109.43	0.5

a; b - Differences between the variants marked with different letters are considered significant at P = 0.05.
**Indicate significant differences at P = 0.01; ***Indicate significant differences at P = 0.001.

Table 3. Titratable acidity of tomato cultivated on different compost variants

No	Variant	Substrate	Titratable Acidity %	Compared to control	
				Relative value (%)	Difference/ significance
1	Control	Soil from field	3.70^{c,d}	100	-
2	B3	S2 75%	5.70^{a}	154.05	2.00***
3	B3	S1 50%	3.70^{c,d}	100	0
4	B3	S1 75%	5.55^{a}	150	1.85***
5	B3	B1 25%	4.55^{b}	122.97	0.85*
6	B3	B2 25%	4.00^{b,c}	108.11	0.3
7	B2	S3 50%	4.10^{b,c}	110.81	0.4
8	B2	B1 100%	4.30^{b,c}	116.22	0.6
9	B2	B3 50%	3.95^{b,c,d}	106.76	0.25
10	B2	B3 100%	4.05^{b,c}	109.46	0.35
11	B2	S3 75%	3.65^{c,d}	98.65	-0.05
12	B1	B1 75%	3.20^{d}	86.49	-0.5
13	B1	B1 50%	4.00^{b,c}	108.11	0.3
14	B1	S3 25%	3.70^{c,d}	100	0
15	B1	S1 25%	3.80^{b,c,d}	102.7	0.1
16	B1	B3 25%	4.50^{b,c}	121.62	0.80*

a; b; c; d - differences between the variants marked with different letters are considered significant at P = 0.05;
*Indicate significant differences at P = 0.05; *** indicate significant differences at P = 0,001.

Table 4. Ascorbic acid (Vitamin C) content of tomato cultivated on different compost variants

No	Variant	Substrate	Ascorbic acid	Compared to control	
			(mg/100 g)	Relative value (%)	Difference/ significance
1	Control	Soil from field	13.83^{b,c,d}	100	-
2	B3	S2 75%	16.34^{a,b}	118.15	2.51
3	B3	S1 50%	16.97^{a,b}	122.7	3.14
4	B3	S1 75%	17.60^{a,b}	127.26	3.77
5	B3	B1 25%	13.20^{b,c,d}	95.44	-0.63
6	B3	B2 25%	11.31^{c,d,e}	81.78	-2.52
7	B2	S3 50%	10.06^{d,e}	72.74	-3.77
8	B2	B1 100%	16.34^{a,b}	118.15	2.51
9	B2	B3 50%	5.65^{f}	40.85	-81,8^{00}
10	B2	B3 100%	15.71^{b,c}	113.59	1.88
11	B2	S3 75%	10.06^{d,e,f}	72.74	-3.77
12	B1	B1 75%	8.17^{e,f}	59.07	-5,66^{0}
13	B1	B1 50%	16.34^{a,b}	118.15	2.51
14	B1	S3 25%	20.74^{a}	149.96	6.91**
15	B1	S1 25%	13.83^{b,c,d}	100	0
16	B1	B3 25%	6.91^{f}	49.96	-69,2^{00}

a; b; c; d; e; f - Differences between the variants marked with different letters are considered significant at P = 0.05;
^{0}Indicate significant differences at P = 0.05; ^{00} Indicate significant differences at P = 0.01;
**Indicate significant differences at P = 0.01.

The levels of dry matter, acidity and vitamin C in the organic tomatoes grown in compost were in agreement with another research study for organic tomatoes grown in soil and compost Thyboa *et al.*, [10], and with the levels reported for conventional tomatoes grown in soil and on rock-wool slab (Lippert [11]; Petersen *et al.*, [12]).

Concerning the antioxidant activity (FRAP) in tomatoes fruit at the combinations of compost, values varied between 42.90µM Trolox/g at combination B2-B3 50%, and 84.49 µM Trolox/g at combination B3-S1 75%, (Table 5). This show a variation amplitude of 41.59 µM Trolox/g, from a variability between variants of 21.83%. Under the aspect of this characteristic, a symmetrical distribution is observed among these 16 combinations, thus six of them have achieved an antioxidant activity between 50 and 60 µM Trolox/g, five combinations are above 60 and five combinations are less than 50 µM Trolox/g.

Compared to the control, about 44% of the variants - substrates combinations presented higher antioxidant activity in fruits, but only for four combinations differences were statistically significant. The largest relative increases were achieved by combinations: B3-S1 75% (45.02%), B2-B3 100% (33.93%), B3-S2 75% (33.93%), and B1-S3 25% (27.96%). The first two of the above-mentioned combinations, are allowing the possibility of a significantly higher antioxidant activity among combination compared with 11. Tomatoes from variants B2-B3 50% and B1-B1 75%, showed a significantly lower antioxidant activity compared to seven of the combinations.

As well as in other studies, antioxidant activity was found that can vary significantly due to different nutritive level of growth substrates (Anissa and Hdider [13]). Considering that we used the same genotypes of tomatoes, the variability appeared is due only to the accessibility of nutrients offered by combinations of compost (Binoy *et al.*, [4]).

Assessment of the lycopene content recorded a very high variability (see Table 6). Amplitude of variation of 346.91 µg/g, representing 49.98%, with limits ranging from 42.35 µg/g for variant B1 - B1 75% and 389.26 µg/g at combination B3-S2 75% it can observed. From the total variants, 56% of these showed a quantity of lycopene between 100 - 200 µg/g, while 25% have values higher than 200 µg/g, and 19% have a less lycopene amount accumulated below 100 µg/g. Compared to the control, 80% of combinations showed lower values of fruit lycopene content, in 40% of cases the differences were statistically significant. The combination B3-S1 75% determined a significant increase of lycopene content, of about 55%.

Table 5. Antioxidants activity (FRAP) of tomato fruits cultivated on different compost variants

No	Variant	Substrate	FRAP	Compared to control	
			µM Trolox/g	Relative value (%)	Difference/ significance
1	C	Soil from field	58.26[d, e, f]	100	Martor
2	B3	S2 75%	76.37[a, b]	131.08	18.11*
3	B3	S1 50%	48.65[e, f]	83.5	-9.61
4	B3	S1 75%	84.49[a]	145.02	26.23**
5	B3	B1 25%	55.96[e, f]	96.05	-2.3
6	B3	B2 25%	57.79[d, e, f]	99.19	-0.47
7	B2	S3 50%	49.25[e, f]	84.53	-9.01
8	B2	B1 100%	72.40[a, b, c, d]	124.27	14.14
9	B2	B3 50%	42.90[f]	73.64	-15.36
10	B2	B3 100%	78.03[a]	133.93	19.77*
11	B2	S3 75%	51.06[e, f]	87.64	-7.2
12	B1	B1 75%	43.20[f]	74.15	-15.06
13	B1	B1 50%	60.92[c, d, e]	104.57	2.66
14	B1	S3 25%	74.55[a, b, c]	127.96	16.29*
15	B1	S1 25%	61.96[b, c, d, e]	106.35	3.7
16	B1	B3 25%	49.20[e, f]	84.45	-9.06

a; b; c; d; e; f - Differences between the variants marked with different letters are considered significant at P = 0.05.
[0]Indicate significant differences at P = 0.05.
*Indicate significant differences at P = 0.05; ** Indicate significant differences at P = 0.01.

These results are similar to Barrett *et al.*, [14], and Caris-Veyrat *et al.*, [15], who found higher levels of lycopene in three varieties of organic tomatoes on a fresh weight basis.

Between the most of the assessed characteristics, there are linear relationships that allow an accurate estimation of the mutual influence, according to analysis of variance and covariance showed in Table 7. The dry matter content manifested nonlinear influence to the other characteristics, being difficult to predict meaning and measure of these influences.

Correlation studies indicate the existence of positive and statistically assured influences between fruit acidity and FRAP, respectively lycopene with positive statistical significances. Also, there is a significant and very close relationship between the content of vitamin C and FRAP.

Table 6. Lycopene content of tomato cultivated on different compost variants

No	Variant	Substrate	Lycopene (μg /g)	Compared to control	
				Relative value (%)	Difference/ significance
1	C	Soil from field	251.65b, c	100	Control
2	B3	S2 75%	171.14c, d, e, f	68.01	-80.51
3	B3	S1 50%	256.20b, c	101.81	4.55
4	B3	S1 75%	389.26a	154.68	137.61*
5	B3	B1 25%	194.14b, c, d, e	77.15	-57.51
6	B3	B2 25%	147.84d, e, f, g	58.75	-103,81^{0}
7	B2	S3 50%	160.08cdef	63.61	-91.57
8	B2	B1 100%	176.04bcdef	69.95	-75.61
9	B2	B3 50%	90.21fg	35.85	-161,44^{00}
10	B2	B3 100%	176.34bcdef	70.07	-75.31
11	B2	S3 75%	185.74bcdef	73.81	-65.91
12	B1	B1 75%	42.35g	16.83	-209,30^{000}
13	B1	B1 50%	47.03g	18.69	-204,62^{000}
14	B1	S3 25%	131.52efg	52.26	-120,13^{0}
15	B1	S1 25%	120.80efg	48	-130,85^{0}
16	B1	B3 25%	276.62b	109.92	24.97

a; b; c; d; e; f; g - differences between the variants marked with different letters are considered significant at P = 0,05;
^{0}Indicate significant differences at P = 0,05; ^{00} indicate significant differences at P = 0,01; ^{000} Indicate significant differences at P = 0,001.
*Indicate significant differences at P = 0,05. *** Indicate significant differences at P = 0,001.

Table 7. Covariance and correlation coefficient values between quality traits in tomato cultivated on different variants and compost substrates

Parameter	1.	2.	3.	4.	5.
1. Acidity	r = 1,000 S^2 = 0,44	r = 0,265 S^2_{XY} = 0,75	r = 0,590* S^2_{XY} = 5,17	r = 0,531* S^2_{XY} = 31,09	r = -0,285 S^2_{XY} = -0,25
2. Vitamin C		r = 1,000 S^2 =18,14	r = 0,785*** S^2_{XY} = 44,02	r = 0,224 S^2_{XY} = 83,90	r = 0,068 S^2_{XY} = 0,38
3. FRAP (antioxidant activity)			r = 1,000 S^2 = 173,42	r = 0,341 S^2_{XY} = 395,48	r = -0,053 S^2_{XY} = -0,92
4. Lycopene				r = 1,000 S^2 = 7742,28	r = -0,104 S^2_{XY} = -12,15
5. Dry weight					r = 1,000 S^2 = 1,77

*Indicate significant differences at P = 0.05.
*** Indicate significant differences at P = 0,001. $r_{5\%}$ = 0,497; $r_{1\%}$ = 0,623; $r_{0,1\%}$ = 0,742.

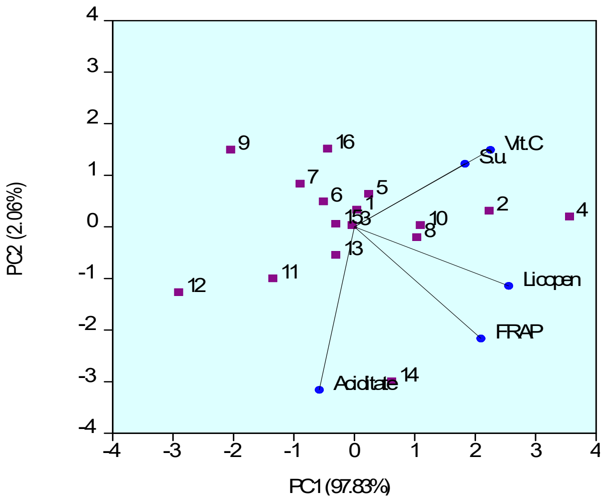

Figure 1. Biplot of first two principal components for the analyzed mineral traits in tomato cultivated on different variants and compost substrate (1; 2; 3…14; 15; 16 - variants studied)

For different variants of compost mixtures multivariate data analysis (Figure 1) based on the first two principal components, expresses 99.89% of the variability of the five quality indicators assessed for tomato fruits quality. The biggest differences among quality indicators were recorded for lycopene and vitamin C, while for acidity differences were lowest. According to projection vectors each combination of different characteristic, it is found that at combination B3-S1 75% and B3-S2 75%, the high dry matter content and vitamin C are associated with higher lycopene content and antioxidant activity (FRAP), due to a lower average fruit acidity.

The combination B1-S3 25%, high acidity fruit is characterized by high levels of lycopene and (FRAP), between low dry matter and vitamin C.

In the case of compost combination B1-B3 25% the high values of vitamin C and dry matter content in tomatoes fruits are associated with a low content of lycopene and FRAP, and high acidity of the fruits respectively. For the combinations, B1-S1 25% and B3-S1 50%, the values of these five characteristics are close to the average.

4. Conclusions

- Although limited biological variability (sampling from one year) is taken into account in this study, results give a general idea of some quality parameters in organically grown tomatoes under different combinations of compost.

- Combinations B3-S2 75%, B3-S1 75%, B3-B1 25% and respectively B1-B3 25%, had a significant influence on the acidity causing an increase of 0.8 - 2 units in fruit compared to the control. Also, 68.75% of the compost combinations variants have achieved the lowest values of dry weight content relates to control.

- Plants grown on variant B1 in association with substrate S3 25% showed a significantly distinct increase by 50% of vitamin C, compared to the control.

- Plants grown on B3 - S1 75%, B3-S2 75%, variants and respectively B2 - B3 100% achieved the highest antioxidant activity, represents a valuable combination not only for improving the status of dietary antioxidants in our diet but also for increasing of nutritional value.

- Compared to the average experience, only under the variant B3 - S1 75%, there was a significant increase of lycopene, to 213.20 μg/g.

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