CHANGES OF NUTRIENT VALUES IN HIDROPHONIC TOMATO GROWING SYSTEM

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Abstract. *As consumer demands change, beside early availability of fruits and vegetables, high content value becomes more and more expected. Health-enhancing impacts of tomato are, among others, attributed to lycopene, thus varieties containing higher amount of lycopene are sought-after in production. In 2017 we have examined the content values of Aruba F1 vine tomato grown in the greenhouse of St István University Galambos educational facility. We used the data of plant monitoring (leaf area etc.). The climate computer controlling the greenhouse made it possible to record and assess different sets of data such as outer and inner temperature, insolation, CO_2 level etc. The overall conclusion is that, beside the variety, environmental conditions dominantly influence the amount of lycopene even in case of soilless cultivation. Although these environmental factors can, in certain extent, be adjusted in greenhouses, plants react in a sensitive way to changes occurring in light conditions, temperature and CO_2 level.*

Keywords: *hydroponics, tomato, temperature, insolation, artificial regulation of carbon dioxide, content value, lycopene*

INTRODUCTION

Plants produce the compounds of their bodies from carbon dioxide received from the environment and using energy. Therefore, almost every plant reacts to the increase of the CO_2 content by more intensive photosynthesis and biomass-production. Outdoor plants obtain the necessary amount of carbon dioxide from the atmosphere that has a CO_2 concentration of approximately 300 ppm (0.03 vol%). In tightly sealed greenhouses the required amount of carbon dioxide can be provided by ventilation. However, the issue of CO_2 fertilisation has been emerged in the 1950s in connection with vegetable forcing. This practice has become an integral part of forcing in numerous countries during the past 20 to 25 years. In our experiment we tried to learn how the growing conditions of vegetable forcing, CO_2 content in particular, influence content value.

Literature review

Examinations on tomato are emphasised in the past few years as this vegetable is connected to healthy eating. It is mainly due to its lycopene content providing red colour to the fruits. Tomato contains more lycopene (60 to 64% of its total carotenoid content) than any other cultivated plants. Some researches concluded that lycopene helps preventing several types of tumor diseases (LUGASI ET AL, 2004) as well as delaying the early ageing of the skin thanks to its antioxidant characteristics.

Lycopene content of tomato fundamentally depends on (HELYES ET AL, 2002) the variety (industrial tomatoes have significantly higher amount of it) and the environmental factors, particularly light and temperature conditions during the burgeoning and ripening stages. Maturity at the time of picking and the date of the harvest also play a role in setting the amount of lycopene.

According to DEÁK ET AL. (2012) the key for the biosynthesis of carotenoids is presumably the low temperature. It reflects to the researches of ISHIDA (1999) who conducted experiments on cherry tomato kept in greenhouse and concluded that lycopene content was three times higher at 16 °C than at over 25 °C. Examinations of HELYES L. (2007) also justified this theory. Low temperature favours lycopene synthesis, although it has an adverse effect on producing vitamin C. Average lycopene content of berries exposed to direct radiation is approximately 20% higher compared to those not receiving such treatment. In outdoor production where support systems are used those tomatoes receiving more direct insolation at higher temperature showed a 35% decrease as regards of their lycopene content.

Ventilation is a kind of compromise between the access to carbon dioxide and temperature in greenhouses without artificial CO_2 dosing systems. STANGHELLINI and fellow researchers (2009) came to the conclusion that, considering the close connection between temperature and production, the best and most profitable choice for producers is to use the least possible ventilation (taking the limitations of air moisture and temperature regulation into account) and apply bottled CO_2 for reaching at least the outside concentration. In this case the CO_2 does not leave the system, so this level ensures that all the carbon dioxide be assimilated.

JARQUÍN-ENRÍQUEZ ET AL. *(2013)* studied the effects of light on the colour development of tomato and on the accumulation of lycopene. They used two greenhouses with different covers (double layer polyethylene K50 Clear + K50 IR / AC and flat glass with 4 mm thick 15% CaCO3 coating) and made experiments in several production phases. They found that the amount of light the tomato berries received after the ripening had started is of key importance, since it is able to increase the biosynthesis of lycopene. More of this compound has been accumulated in the fruits receiving larger amount of light exposure. These tomatoes had better colourisation and visual quality. It has to be considered whether to use the techniques of whitening, washing and shading in order to regulate temperature in greenhouses if the aim is to increase the colour intensity and the accumulation of lycopene in tomatoes.

Impacts of increased carbon dioxide level on yield have been examined by several experts under various atmospheric concentration level and other unfavourable producing conditions (e.g. plants infected by pathogens or stressed and salty soil etc.). Research results show considerable standard deviation, nevertheless they generally prove the favourable influence of higher carbon dioxide level. Among others ZISKA ET AL. (2001) grew tomato at 500 ppm of night-time atmospheric CO_2 concentration. Total biomass production was 10% higher than in case of those tomatoes (control group) cultivated at 370 ppm CO_2 concentration.

As a response to increasing amount of consumer complaints ZHANG ET AL. (2014) examined the factors influencing the content value of tomato grown under greenhouse conditions. This plant is very often tended in greenhouses in China so as to ensure early harvest and satisfy consumer demands. However, examinations show that the quality factors, such as colour and taste as well as the average content of ascorbic acid and carotenoids are generally poor. To react to these widespread complaints Zhang et al. carried out a greenhouse experiment in which the 800 to 900 ppm CO_2 concentration has been the only variable factor compared to the value of 100 to 250 ppm daytime concentration of the control greenhouses. This simple change made in the growing conditions resulted a greenhouse effect and led to the considerable increase regarding the concentration of health-preserving compounds – including lycopene, beta-carotene and ascorbic acid. The heightened level of carbon dioxide also improved the taste of tomatoes that is due to the amount of sugars, titratable acidity and the sugar/acid ratio. It was also stated that the raised CO_2 level helped all other organoleptic attributes, such as colour, tightness, aromas and other features of the tomato berries.

MATERIAL AND METHODS

The crops involved in the experiment can be found in Szarvas, in the Galambos educational facility of St. István University. A greenhouse built in 2016 with almost 2,000 m^2 gross and 1,800 m^2 net area and 6 m height was used for the research. The greenhouse has two symmetric and separable area where it is possible to set different climatic conditions. The system for providing CO_2 has also been installed. It consists of 12 connected bottles, so-called bündels, that have electronic switch valves through which the level of CO_2 can be regulated inside the greenhouse. Perforated KPE pipes with the diameter of 20 mm ensure the even distribution of carbon dioxide all along the rows.

The tomatoes have been planted in 16 February 2017. The selected Aruba F1 variety has become one of the most popular vine tomatoes cultivated in Hungary during the past years. Its main positive features are the spectacular sepals, deep red colour and longevity. This latter characteristic is outstandingly important for commercial supermarket chains.

Seedlings were grown in 10 by 15 cm rockwool cubes in Szentes. They were transferred to the greenhouse when reaching six-leaves stage. Each rockwool cube has two plants to grow. These tomatoes were planted in once used coco peat growing medium maintaining the density of 3.8 plants/m^2.

A climate computer operates in the greenhouse making it possible to constantly record the measured data. Thus, inside radiation, temperature and air moisture at the top of the plants in both blocks of the greenhouse as well as CO_2 concentration at 2 m height have been observed and recorded in 15 minute intervals during the entire production period. CO_2 has been released into the greenhouse on an occasional basis in 2017.

During the experiment, from week 27 on the following data were continuously recorded: a) weekly growth, b) leaf length, c) number of leaves, d) leaf width, e) leaf area, f) stem diameter, g) vine distance, h) flowering vines, i) fruit setting vines and j) yield. These parameters were examined in both climate blocks involving 12 plants in four rows regarding each block.

Content value of tomatoes (lycopene, 13-cis-lycopene, beta-carotene, lycoxanthin-lutein, phytoene, phytofluene and total carotenoids) has been examined in the laboratory

of St. István University Regional University Knowledge Centre. Samples were picked three times during the production period at the following dates:
1. 11 May (week 19)
2. 3 August (week 31)
3. 29. September (week 39)

RESULTS AND DISCUSSIONS

Ripening cycle of tomato is approximately 60 days from flowering to reaching full ripened state of berries, so we examined a 60-day-long period before harvesting. Insolation and CO_2 concentration within the greenhouse as well as outside and inside temperatures were recorded (Table 1).

Table 1.

Measured radiation, CO_2 concentration and outside and inside temperature in the greenhouse, 2017

Date of harvest	**total insolation (J/cm2)**[1]	**average outside air temperature (C°)**[2]	**inside temperature (C°)**[2]		**CO_2 concentration (ppm)**[2]	
			Block1	**Block2**	**Block1**	**Block2**
11 May 2017 (week 19)	58509	9.3	17.2	17.0	440.0	480.7
3 August 2017 (week 31)	91452	19.4	19.4	19.4	456.8	483.6
29 September 2017 (week 39)	67976	18.2	18.5	18.7	454.1	494.8

1 Total amount of 60 days preceding harvest.
2 Average of 60 days preceding harvest.

By comparing data from May and September it can be seen that, beside almost the same amount of total insolation, the average daily temperature was significantly lower in May. The difference is nearly twofold: the mean temperature was approx. 9 °C higher in September. In spite of this difference the greenhouse provided constant and balanced temperature for the plants. The alteration between the lowest and highest value was only 1.4 °C. While inside temperature data were very similar regarding the two separate parts (Block1 and Block2), CO_2 concentration was 5 to 9% higher in case of Block2 (where carbon dioxide was administered on an occasional basis). The level of CO_2 was 60 to 120 ppm higher than the atmospheric concentration (approx. 380 ppm).
The advantage of producing plants at a balanced temperature can clearly be demonstrated by the yields (pieces). This indicator maintains a relatively balanced value until the topping of the plants (weeks 45 and 46).

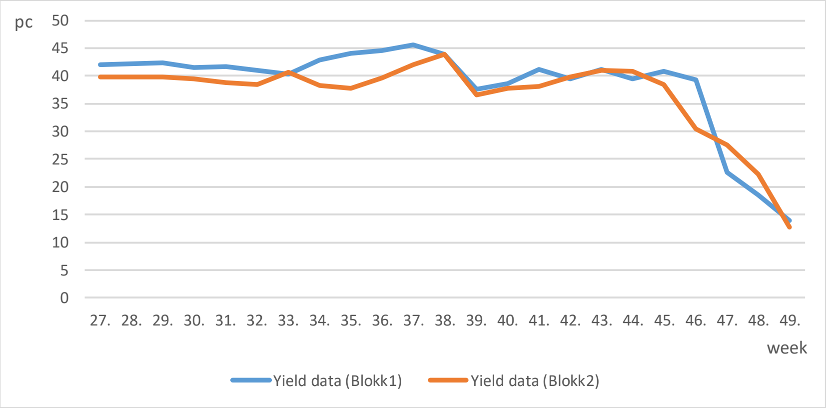

Figure 1 Weekly yield data in the two climate blocks, 2017

One of the outstanding qualities of Aruba F1 tomato is its deep red colourisation. Sample picked at the first ripening of the plants (week 19) showed high total carotenoid values – including high lycopene content. The second sample harvested at the beginning of August (week 31) proved to have much higher content value. However, the last sample received nearly two months later represented significantly lower content value, falling well short of the numbers seen in case of the May sample.

As for the first and second samples berries from Block2 (where the concentration of CO_2 was higher) had 22 to 25% higher content value than tomatoes coming from Block1. This difference could not be observed during the examination of the samples harvested in September.

Table 2

Nutrient contents of the examined Aruba F1 tomatoes

Date of harvest	total carotenoids (µg/g raw material)		lycopene (µg/g raw material)	
	Block1	**Block2**	**Block1**	**Block2**
11 May 2017 (week 19)	613.11	757.82	439.51	548.74
3 August 2017 (week 31)	814.29	993.38	661.00	820.89
29 September 2017 (week 39)	484.11	491.88	380.75	376.73

Regarding the period preceding the first two samplings the size of leaf area has not changed notably due to the balanced growing. However, in the 60-day-long period (weeks 31 to 39) before the third sampling (week 39), i.e. in the phase of growing and ripening berries the leaf area decreased considerably, by approximately 30% (based on the highest and lowest recorded values). During the same period we noticed the fall of weekly mean temperature from 23.8 °C in week 31 to 14.5 and 14.6 °C in week 39 (the difference is 39%). No significant differences could be observed between the two climate blocks of the greenhouse in this aspect.

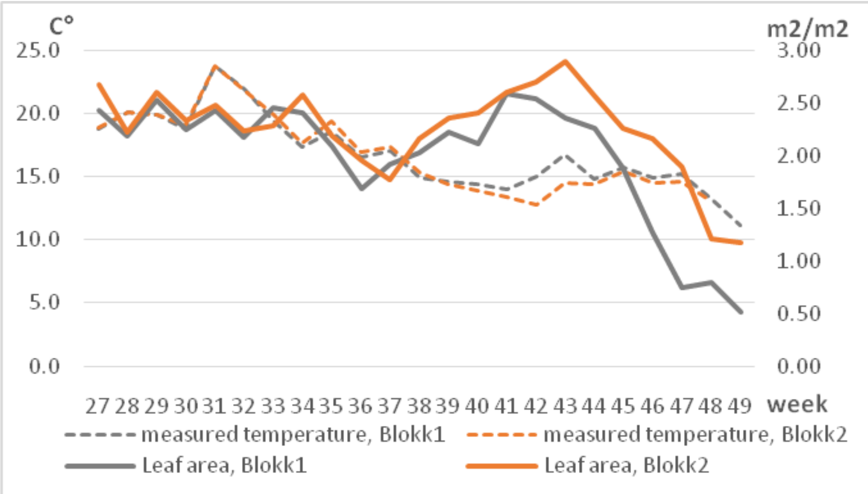

Figure 2 Changes of leaf area and measured temperature in the two climate blocks, 2017

CONCLUSIONS

One of the outstanding characteristics of Aruba F1 tomato is its deep red colour. Based on the measurements it is due to its high content value – especially to lycopene. However, content values showed considerable fluctuations during the examined growing period of 2017. The difference between the highest and lowest recorded values was approximately 50%. Remarkable distinction was also observed between the highest peak in August and the lowest value in September. It can only partly be explained by the decreasing temperature and insolation, since samples from May had higher content values despite the same amount of total insolation and lower weekly mean temperatures. By examining the 60-day-long ripening period it can be concluded that the considerable (-39%) decrease of temperature implied the reduction of leaf area (-30%). Therefore, it can be presumed that these two changes together led to the notable alteration of content values.

Dissimilar content value (regarding lycopene) measured in the two climate blocks (May: +23.6%; August: +23.0%; September: +1.6%) cannot be explained by the fluctuations of total insolation and inside mean temperature, since these parameters were generally the same regarding both blocks. Only the level of carbon dioxide showed considerable difference during the examined period (May: +9.2%; August: +5.9%; September: +9.0%).

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