


Effect of 1-MCP treatment on tomato photosynthetic chlorophyll activity during storage

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ABSTRACT

Ethylene has key roles in triggering and speeding up ripening processes, which in tomatoes take the form of various qualitative changes. Tomatoes, just like all climacteric fruits, need a continuous ethylene exposure to accelerate ripening. Therefore, it is possible to use ripening regulators preventing ethylene binding. According to some studies, chlorophyll fluorescence measurements can be used at least as efficiently as tristimulus colorimetry classifying tomatoes based on maturity. Measurements were carried out by treating fresh tomatoes with 1-MCP (1-methylcyclopropene) at six different stages of ripening and studying the changes in chlorophyll content related quality characteristics (e.g. surface colour, chlorophyll fluorescence) during postharvest storage (two-week refrigerated storage at 15 °C followed by a two-week shelf life). According to our results, chlorophyll content and photosynthetic activity of the treated samples decreased much less than those of untreated ones. Additionally, anti-ripening treatment proved to be more effective on tomatoes at an earlier stage of ripening.

KEYWORDS

postharvest, 1-MCP, chlorophyll fluorescence, anti-ripening, SmartFresh™

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INTRODUCTION

Table tomato has a great importance in the whole world. The demand for fresh tomatoes and various processed tomato-based preparations is growing steadily. One important reason is that they are useful foodstuffs due to their high mineral content, antioxidant and health-protective properties. Shelf life of table tomatoes ranges from a few days to a few weeks, depending on the cultivar and storage temperature. Regulation, initiation or delay of fruit ripening usually depends on factors affecting ethylene production or action. 1-Methylcyclopropene (1-MCP) is an ethylene blocker that has been widely used to retard post-harvest ripening in a wide range of fruits (Watkins, 2006; Sisler and Serek, 2003). When bound to ethylene receptors, 1-MCP acts as an effective ethylene antagonist and its effects can be sustained over a long period of time (Sisler et al., 2003). It can therefore slow down the maturation process and the senescing of the fruit (Sisler and Serek, 1997). Nguyen and co-workers studied the effects of 1-MCP treatment on apricots and found that the treatment significantly delayed apricot ripening regardless of treatment temperature (Nguyen et al., 2016). A previous trial investigated the influence of 1-MCP treatment on Bosc Kobak pears. Under the proper conditions and maturity, the treatment could block ethylene production for 2–4 months and in turn, ripen this pear cultivar (Hitka et al., 2014). Mir and co-workers studied the effects of single, repeated and continuous 1-MCP treatments on tomatoes at different stages of maturity. They found that a single treatment delayed colour development in mature green tomatoes by about 6 days, while repeated treatments after 10 days delayed colour development by a further 8–10 days. Continuous treatment inhibited colour development throughout the application, but did not completely eliminate firmness loss (Mir et al., 2004).

New non-destructive measurement methods allow us to obtain accurate information on the post-harvest quality and its changes. Chlorophyll fluorescence analysis can be used to determine the postharvest quality related maturity and changes in photosynthetically active chlorophyll content (Urbano Bron et al., 2004; Herppich et al., 2012) and the DA value (I_{AD} , absorbance difference index) measured by the DA-meter[®] can also be used to monitor all of these (Costa et al., 2011; Nyasordzi et al., 2013; Hale et al., 2013; Spadoni et al., 2016). The experience of several researchers and research groups (Fatchurrahman et al., 2020; Hitka, 2011; Zsom, 2007) shows that the photosynthetic activity of horticultural crops containing chlorophyll, i.e. freshness/ripeness, quality properties, shelf life can be determined non-destructively, quickly, easily and relatively cheaply by chlorophyll fluorescence spectroscopy. It is a widely used measurement possibility in postharvest studies, because it can detect the effects of non-invasive pathogens, cell damage caused by external stress factors and signs of ageing before the onset of visible symptoms (Gorbe et al., 2012). Zsom-Muha and co-workers studied Golden Delicious apples at different stages of ripening using different non-destructive methods. They concluded that the different ripeness stages can be well distinguished by chlorophyll fluorescence method and DA-index[®] (Zsom-Muha et al., 2017).

The aim of this study was to investigate the applicability of chlorophyll fluorescence spectroscopy in case of tomato (*Lycopersicum esculentum* var. *cerasiforme*) for monitoring the maturity (in terms of commercial value). Additionally, the effect of 1-MCP treatment, which has been successfully applied to several horticultural crops such as apple (Hitka et al., 2006) on Pitenza F₁ table tomato postharvest ripening was investigated.



MATERIALS AND METHODS

In this study, tomatoes of the Pitenza F₁ variety from a farm in Budapest, Hungary were tested. Tomatoes were harvested on the day of 1-MCP treatment. After delivery to the laboratory, harvested tomatoes were classified by colour into 6 different maturity groups (Fig. 1) based on the internationally accepted CTIFL colour scale. The OECD's Guide to Objective Tests to Determine Quality Of Fruit And Vegetables, Dry And Dried Produce describes the procedure for determining colour visually using a colour scale (OECD, 2018).

Forty samples were selected per maturity stage, half of which were treated with the anti-ripening treatment, except for the fully mature (mature red) absolute control group F, which was not treated at all. The physiological plant development regulator used for the treatment was Smartfresh™ ProTabs (Authorisation No: 04.2/1181-3/2017), with an active ingredient of 2% 1-methylcyclopropene (CAS registration number 3100-04-7). Tomatoes of different stages of ripeness placed on a paper tray were placed in an airtight plastic box ($V = 0.5 \text{ m}^3$). For the samples to be treated, Smartfresh™ ProTabs tablets were added in the amounts recommended by the producer, resulting in the release of gaseous 1-MCP. The concentration of 1-MCP in air was 625 ppb. Treatment was applied at 15 °C for 12 h. After treatment, samples were stored at 15 °C for 2 weeks and then placed at 20 °C to simulate countertop (shelf-life) storage.

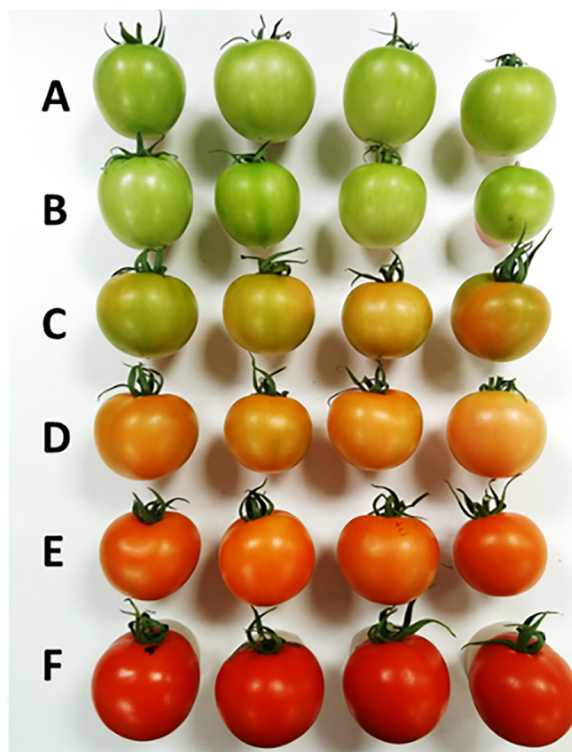


Fig. 1. Our 6 different ripeness group



The reduction of chlorophyll activity by post-ripening during storage was monitored using a PSI Open FluorCam FC 800-O/2020 (Photon Systems Instruments, Czech Republic) controlled by FluorCam7 (version 1.2.5.18) imaging chlorophyll fluorometer. The PSI Open FluorCam system provides chlorophyll fluorescence data not only for a specific area, but also for the entire selected sample surface. Colour change during tomato ripening is closely linked to the degradation of chlorophyll, the green pigment responsible for photosynthetic activity. F_m (maximum dark fluorescence signal), F_0 (dark or minimum fluorescence signal) and F_v (variable fluorescence, $F_m - F_0$) parameters were measured in the case of dark adapted (half an hour before the measurements) tomato samples.

In addition, the ripening and senescence of tomatoes was monitored using a FRM01-F type Vis/NIR DA-meter[®] (Sinteleia s.r.l., Italy) controlled by Sinteleia DA-meter[®] ver. 3.4, which is also based on the measurement of chlorophyll content. It is a Vis/NIR spectroscopic instrument, based on the principle of measuring the difference in absorbance between two different wavelengths. One of the measured wavelengths is the absorption peak of chlorophyll-a (670 and 720 nm) and the other is the reference wavelength during maturation to ensure minimum absorption. Chlorophyll content is determined by the DA-index[®] (I_{AD}), which has a value between 0 and 5 and is calculated as follows:

$$I_{AD} = A_{670} - A_{720}$$

where A_{670} and A_{720} were the A values at the 670 and 720 nm wavelengths. The I_{AD} and the DA-meter[®] were patented by the [University of Bologna \(2005\)](#).

The data obtained from the measurements were processed using the MS-Excel program. For evaluation, SPSS for Windows ver. 14 statistical software was used. Statistical analyses were performed at the 95% confidence level ($\alpha = 0.05$). Results are presented as mean in figures, with bars indicating the confidence interval (95% CI) for the mean.

RESULTS

Based on the F_0 and F_m values of the treated mature green (A) and breaker (B) tomatoes ([Figs 2 and 3](#)), it can be concluded that the combined effect of treatment and cooling slowed down the ripening process significantly, with post-ripening starting to a significant extent practically only after the tomatoes were placed at 20 °C. For turning (C), pink (D) and light red (E) tomatoes, there is also a significant difference in the F_0 value ([Fig. 2](#)) between treated and untreated samples on 7d, but these groups are almost completely mature by the end of week 2.

While the F_0 value is the minimum fluorescence emitted during the dark-adapted phase, the F_m value is the fluorescence produced by a short pulse of strong actinic light. The more chlorophyll a crop contains, the higher this value will be. [Figure 3](#) shows a much clearer distinction between the mature green (A) and the breaker (B) groups of tomatoes and the other groups. There is also a significant difference between treated and untreated samples for groups A and B.

F_v value is the difference between F_m and F_0 . The F_v/F_m ratio is an indicator of the efficacy and soundness of the Photosystem II. It has a maximum value of around 0.8, but decreases as the crop matures and gets older. Our results show ([Fig. 4](#)) that there is a significant difference between treated and untreated samples for all groups from 7d onwards, clearly demonstrating



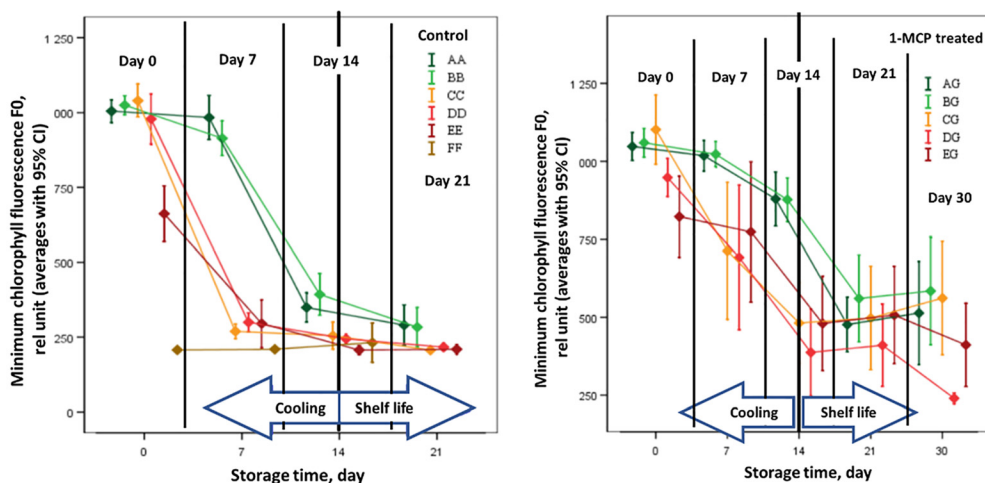


Fig. 2. Change of minimum chlorophyll fluorescence (F_0) of tomato samples (untreated on the left and 1-MCP treated on the right) measured with the PSI Open FluorCam

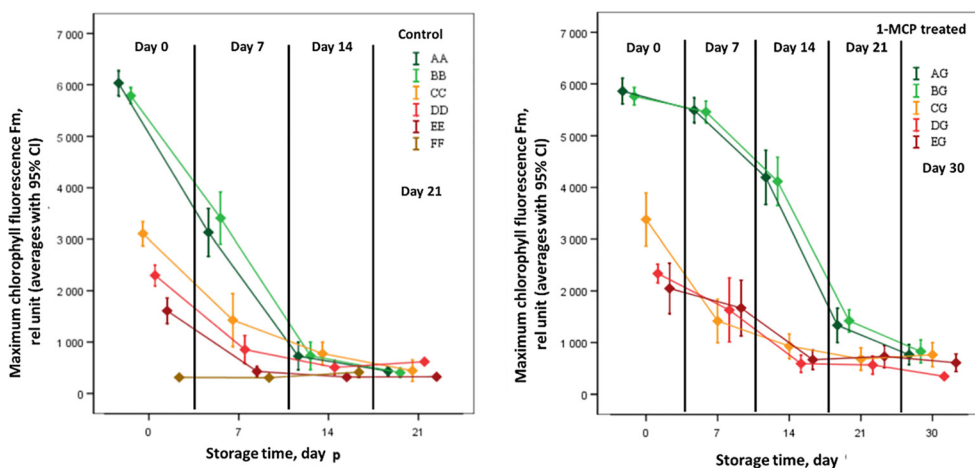


Fig. 3. Change of maximum chlorophyll fluorescence (F_m) of tomato samples (untreated on the left and 1-MCP treated on the right) measured with the PSI Open FluorCam

the efficacy of 1-MCP treatment. Additionally, it was observed that the values started to decrease intensively after the move to room temperature.

The DA-index[®] for all samples (Fig. 5) was very similar to the F_m results obtained with the PSI Open FluorCam. In this case, the treatment was most effective also for the mature green (A) and breaker (B) tomatoes, while the control group values decreased steadily and approached 0 on about 14d, whereas the values of the treated tomatoes changed only slightly during cold storage, but after moving to ambient temperature of 20 °C, there was also an intense decrease.



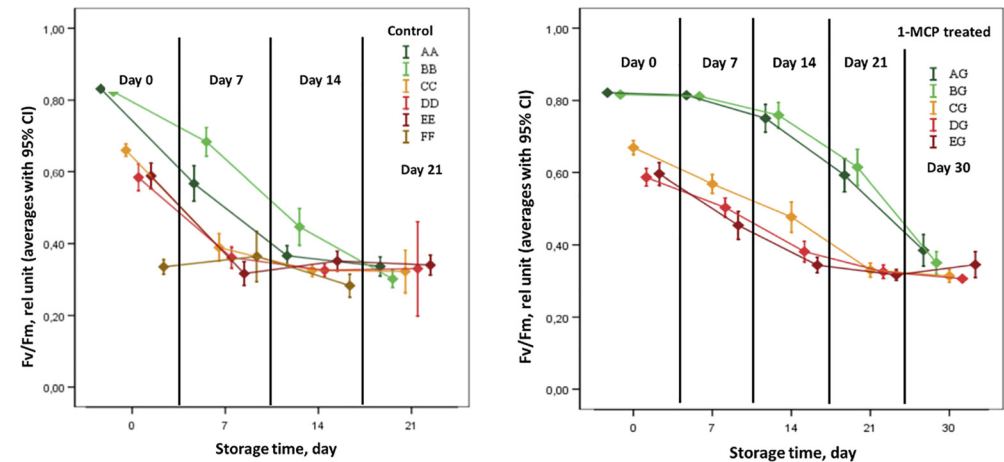


Fig. 4. Change of the F_v/F_m value of tomato (untreated on the left and 1-MCP treated on the right) samples

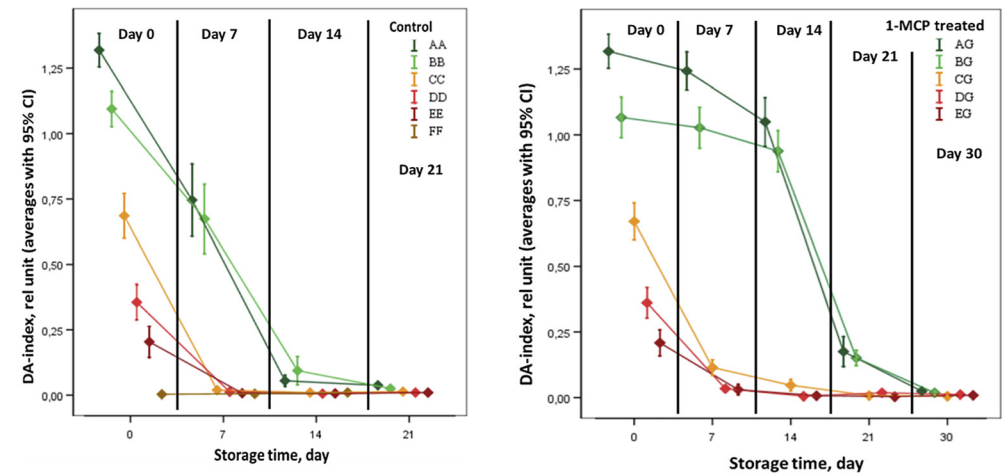


Fig. 5. Change of DA-index[®] of tomato samples (untreated on the left and 1-MCP treated on the right) measured by the Sinteleia FRM01-F type Vis/NIR DA-meter[®] during storage

For the other three groups (C, D, E), there was no significant difference between treated and untreated samples, and on 7d these groups approached the value of 0 measured for the fully mature (F) group.

DISCUSSION

In agreement with the findings of Kasampalis et al. (2020), the chlorophyll fluorescence spectroscopy measurement method has been shown to be suitable for monitoring the ripening of



tomatoes. While Ramzan et al. (2022) investigated the effect of 1-MCP on green-ripe tomatoes, Taye et al. (2019) tested the treatment on pink and red tomatoes. In both studies, the ripening of tomatoes was significantly slowed down after treatment. Based on our results obtained, it was concluded that 1-MCP anti-ripening treatment had a positive effect on all stages of tomato ripening, but only on significantly slowing down the ripening process in the mature green (A) and breaker (B) tomatoes, while prolonging the shelf life of the other three groups (C, D, E). While the treated samples could be tested for 30 days, the control samples were spoiled after 21 days. The results also showed that the treated tomatoes were fully able to ripen after treatment and that the effectiveness of the treatment highly depended on storage temperature. Even a small amount of cooling can significantly extend shelf life. Our results obtained with the DA-meter[®] also supported the above findings, making this instrument suitable for monitoring the mature process related colour change.

CONCLUSIONS

Based on our results obtained, the Vis/NIR DA-meter[®] and the chlorophyll fluorescence imaging fluorometer we used proved to be suitable for monitoring chlorophyll changes associated with tomato postharvest ripening. In evaluating the results, we found that 1-MCP treatment had a positive effect on tomato at all stages of ripening, but the earlier the stage, the more effective the treatment.

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