DOI: 10.7251/QOL1601012V **UDC:** 635.64:575.22

Original scientific paper

Influence of Cold Plasma Treatment on Textural and Color Characteristics of Two Tomato Varieties

Milan Vukić, Dragan Vujadinović, Vesna Gojković, Radoslav Grujić
University of East Sarajevo, Faculty of Technology, Zvornik

Abstract: New technologies had been developed to prolong postharves sustainability of horticultural crops. Technologies as hot air treatment or iridation with UV-C spectral emissions are among them. Al of them have positive and negative effects on quality of horticultural crops. Increasingly under research for decontamination of foods is cold plasma technology, especially fresh fruits and vegetables. Possibility of creating cold plasma under atmosferic presures (ACP) offers new preservation tool to reduce microbial infections of vegetable crops. Effects of atmosferic cold plasma on food quality, however, remains under researched.. In this study, tomato is treated with air ACP generated with an dielectric barrier discharge reactor (DBD). Changes in textural and color characteristics of two tomato fruit varieties after cold plasma treatment were analysed by performing TPA test and color measurements. The effect of air ACP on tomato texture and color was insignificant.

Keywords: Cold plasma, Tomato, Texture, Color

Introduction

Fresh tomato (Solanum lycopersicum L.) with yearly global production exceeding 161 million tonnes per year is one of the most importan vegetable crops in human nutrition (FAOSTAT, 2012). By its botanic nature tomato is very perishable fruit coused by rapid ripining which enables microbial infection and development (Pinheiro et al., 2013). In the past raw agricultural produce has frequently been associated with foodborne outbreaks. Refrigerating can delay these unwanted changes, but it is not always possible to perform as tomatoes are susceptible to chilling injury (Luengwilaiet al., 2012). Different chemical have been applied for desinfection of vegetable crops (Tzortzakis, 2010).Chlorinated water being the most common, the use of chlorine is associated fith formation of carcinogenic coumpounds (Bermúdez- Aguirre & Barbosa-Cánovas, 2013). In the last several decades, interest in postharvest treatments increased. (Lurie, 1998).

Three dominant termal methods developed: hot water, vapor heat and hot air. From all of these, hot air treatment is used for fungal and insect control and have adventage of humudity regulation. (Lurie, 1998). Heat produce many physiological changes in fruit and that mean tomato fruit as well. Treatment (38C) lasting for three days inhibit ethylene production, color development and fruit softening (Lurieet al., 1996).

New technologies had been developed to prolong postharves sustainability of tomato (Tzortzakis, 2010; Pinheiro et al., 2013). Among them ultraviolet (UV) radiation is most explored. Spectral emission at 254 nm, termed UV-C radiation reduce germicidal activity (Lui et al., 2012). These spectral emissions are harmful but can induce several benevicial effects on vegetable crops if applied in low levels (phenomenon khnow as hormesis). Exposure to UV-C spectral emissions is considered as an potential suptitute to treatment with chemical fungicides, heat treatment in control of postharves disease (Bravo et al., 2012). Reserch show that treatment with UV-C irradiated tomato samples had slightly delayed ripening (Belović et al., 2014). Disadvantege of UV-C spectral emissions in practical use is shadowing effect. Duo to streigh line propagation, same parts of vegetable can shield other areas of same vegetable. This phenomenon complicate practical aplication and increase microbial infection risk.

One new technology that could be more adventagues dou to absence of shadowing effect is cold plasma. In contrast to the use of UV-C spectral emissions UV-C spectral emissions and plasma reactive species can arise from point sources everywhere from within the plasma to synergistically inactivate microorganisms. Plasma can be generated and maintained under vacum or at atmosferic presures. Cold plasma under atmosferic preasures is more practical for several reasons. Vacum condition can reduce water presence in foodstuff, it can be generated in packed food and different gasses and their mixtures can be applied. Defferent technics of generating atmosferic cold plasma can be used, DC, AC, pulsed DC, RF, MW, or dielectric barrier (DB) or electron and laser beams (Conrads and Schmidt, 2000). Recent research focus mainly on dielectric barrier (DB) generated cold plasma application due vary simple aparatus and possible easy application in practice. It is shown that plasma can inactivate both vegetative and bacterial endospores. In compering different plasma technologies or plasma technologies with heat or UV-C radiation common target of Bacillus atrophaeus (subtilis) is most studied (Philip et al., 2002). Microbiol inactivation is explained by two dominant mechanisms. Generation of UV spectral emissions in the ranges of 10±290 nm, and wavelengths above 200 nm, at a fluence (radiation fieldstrength) of several mW/cm^2, and by plasma reactive species of which oxygen is most effective (Laroussi, 2005). Previus work with ACP showed reductions in total mesophiles and yeasts/moulds, which are primary causes of spoilage (Misra et al., 2014a). The efficient reduction of microorganism with a ACP suggests possible prolongation of shelf life of the treated vegetable crops products. Research also indicates that microbial reductions were solely due to unique chemical species obtained in plasma state (Pankaj et al., 2013). More and more aplications of air ACP on vegetable crops is researched with litle known effect on texture and color of vegetable crops as most research is focused on microbiological safety.Therefore, aim of this study is to examine influence of air (ACP), on textural and color characteristics of two tomato fruit varieties.

Material and methods

Two tomato groups were used in this study. Samples were purchased from the local wholesale fruit market (Zvornik,R.S, BiH). First group was comprised of tomatoes, variety “King”, second group was comprised of chery tomatoes, variety “cerasiforme”. Each group was devided into two batches. One batch was treated with air atmosferic cold plasma for treatment duration of 30s. Second, untreated batch, was used as control.

Plasma treatment

The DBD plasma generator system comprises of two aluminium plate electrodes (outer diameter = 10 mm) over plexiglas (PP) dielectric layers between which is space where tomato sample is placed. The high voltage step-up transformer powered with 12V with pulsed power suplly with voltage output in the range 7.5-15kV. Rigid package made of plexiglas had dimensions of 100 mm x 100 mm x 40mm with 3 mm thickness. The atmosferic air condition at the time of cold plasma treatment was 42% relative humidity (RH) and 25 °C.

Texture measurements

Textural analysis was conducted on three randomly chosen tomatoes from each batch using TA.XT Plus Texture Analyser (Stable Micro Systems, England, UK) before and after tretmans with air atmosferic plasma. Texture profile analysis (TPA) was performed in order to gain characteristics of hardness, springiness, cohesiveness, gumminess, chewiness, and resilience of tomato fruit at the same time. Instrumental settings for TPA test (TPA.PRJ) were taken from the sample projects of the software package (Texture Exponent Software TEE32, version 6,1,4,0, Stable Micro Systems, England, UK). The settings for speed and distance ewere: speed-5mm/s and distance-5 mm.

Color measurements

The color was quantified by CIE L*, a*, b* parameters. Lightness (signified as L*) and color axis (+a* = redness, -a* = greenness), and color axis (+b* = yellowness, -b* = blueness). A spectrophotometer (Konica Minolta CM-5) was used to determine the color of three randomly chosen tomatoes from each batch by detecting the diffused reflected light under standardized observation conditions in SCE mode with changing mask Ø3 mm/Ø6 mm. The color measurement was performed on (along four symmetrical sections) each tomato and average values reported.

Statistical data analysis

Results were expressed as mean values with standard deviation for all replications. Analysis of variance (ANOVA) followed by Tukey multiple-range test for mean comparison at the level of 0,05.

Results and discussion

Texture measurements

Texture Profile Analysis (TPA) was performed to measure different textural properties in order to determine the effect of plasma treatment on the textural characteristics of tomato samples. Results are presented in Table 1. Parametar of adhesiveness could not be measured. However values were still similar with no statistically significant difference ($p \geq 0.05$), indicating that none of samples executed change after air ACP treatment. Higher hardness values obtained for samples of chery tomatoes, variety "cerasiforme"could be explained as an variety feature not caused by air ACP treatment.

Table 1. Textural characteristics of control and plasma treated tomatoes. Values represent means ±sd, n = 3.

Sample	H (g) x 10^3	S	C	G x 10^3	Ch x 10^3	R
"King" Control	10,28±0,71^a	0,76±0,03^c	0,68±0,05^d	7,05±0,82^e	5,42±0,89^f	0,32±0,04^g
Plasma treated	10,43±0,51^a	0,77±0,01^c	0,62±0,05^d	6,52±0,47^e	5,02±0,41^f	0,29±0,03^g
"Cerasiforme" Control	11,28±0,70^a	0,77±0,01^c	0,62±0,006^d	7,01±0,45^e	5,43±0,39^f	0,28±0,004^g
Plasma treated	10,99±0,64^a	0,77±0,01^c	0,62±0,02^d	6,83±0,24^e	5,29±0,21^f	0,29±0,01^g

‡Values within a column followed by the same letter do not differ significantly ($p > 0.05$). (H- Hardness, F- Fracturability, S- Springiness, C- Cohesiveness, G- Gumminess, Ch- Chewiness, R- Resilience).

Springiness values, as an indicator of ability to recover from the initial pressure (Radusin et al., 2013), also did not demonstrated great diversity in both varieties of tomatoes. The springiness values ranged in the same range. Cohesiveness values were higher for variety "King". Control samples of both varieties had significantly lower gumminess, chewiness and resilience that could be attributed to stage of their ripeness. Among all samples, there was no statistically significant difference ($p \geq 0.05$) between control samples and plasma treathed samples. Meaning that the tissue structure of tomatoes produce remains intact by air ACP treatment. Results of Misra et al (2014b) on firmness of plasma treated strawberries are similar with results of this research. There found no statistically significant ($p > 0.05$) difference in firmness among untreated control and (ACP) treated strawberries.

Color measurements

First quality factor judged by tomato product consumers is probably color of tomatoes. Instrumental color measurement of tomato samples are summarized in Table 2.

Table 2. The CIE L*, a*, b* values of control and plasma treated tomato samples. Values represent mean ±sd of measurements made on three tomatoes in quadruplicates along four different sections[§].

Sample	L*	a*	b*
"King" Control	37,77±0,72[a]	26,74±0,68[b]	25,40±1,08[d]
Plasma treated	36,40±2,19[a]	23,75±0,80[c]	23,48±2,12[d]
"Cerasiforme" Control	35,69±0,39[a]	18,83±2,23[b]	23,88±1,64[d]
Plasma treated	37,05±1,71[a]	17,64±1,46[b]	20,79±3,09[d]

[§]Values within a column followed by the same letter do not differ significantly ($p > 0.05$)

Results demostrate that there was no significant difference ($p \geq 0.05$) between the mean L*and b* values of control and plasma treated samples of tomatoes at 95% confidence level. The difference in a* was however, significant between control and plasma treated "King" variety samples. This change, without futher research, must be atributed to the inherent variability in the colour of produce, considering that the L* and b* values were not significantly different from each other. Moreover, no changes in color of the tomatoes were visualy perceivable. Results of this research are in accordance with the research of other authors which experimented with plasma treated strawberries and found no significant changes in color among control and plasma treated samples (Misra et al., 2014a). Bermúdez-Aguirre et al. (2013) and Misra et al. (2014b) have also reported insignificant changes in the colour of tomatoes following cold plasma treatments using aplasma jet array with Argon gas and DBD in-package atmospheric pressure treatment of cherry tomatoes.

Conclusions

Thus, this work demonstrates that air ACP treatment can be performed without inducing significant adversely affecting the colour and texture of tomatoes as predominant physical quality parameters. The DBD system achieved these desired effects with a power input of only 15–20 W, without increasing the temperature of the samples significantly. Results can be summarise as falows, air ACP treatment of tomatoes did not influenced negativly quality of fresh tomatoes. All observed variations in measurement were not statistically significant different ($p \geq 0.05$). Further work is necesery in optimisation of plasma treatment. In adition, physical quality parameters is only good starting point, changes in the chamistry of vegetables need further research. Additionally, in order to assess the long term effects of ACP on food quality, shelf-life studies will be conducted.

Acknowledgements

Authors wish to acknowledge funding from Government of Republic of Srpska. This paper is a result of the research financed by the Ministry of Science and Technology of the Republic of Srpska.

References

Belović, M., Kevrešan, Ž., Pestorić, M., & Mastilović, J. (2015). The influence of hot air treatment and UV irradiation on the quality of two tomato varieties after storage. *Food Packaging and Shelf Life*, *5*, 63-67.

Bermúdez-Aguirre, D., Wemlinger, E., Pedrow, P., Barbosa-Cánovas, G., & Garcia-Perez, M. (2013). Effect of atmospheric pressure cold plasma (APCP) on the inactivation of *Escherichia coli* in fresh produce. *Food Control,* 34(1), 149-157.

Bravo, S., García-Alonso, J., Martín-Pozuelo, G., Gómez, V., Santaella, M., Navarro- González, I., & Periago, M. J. (2012). The influence of post-harvest UV-C hormesis on lycopene, b-carotene, and phenolic content and antioxidant activity of breaker tomatoes. *Food Research International,* 49, 296–302.

Conrads, H., & Schmidt, M. (2000). Plasma generation and plasma sources.*Plasma Sources Science and Technology*, *9*(4), 441.

FAO, 2012. FAOSTAT. Data archives. Production Sheets (accessed March 2016). http://faostat3fao.org/faostat-gateway/go/to/download/Q/QC/E.

Laroussi, M. (2005). Low temperature plasma-based sterilization: overview and state-of-the-art. *Plasma processes and polymers*, *2*(5), 391-400.

Liu, C., Jahangir, M., & Ying, T. (2012). Alleviation of chilling injury in postharvest tomato fruit by preconditioning with ultraviolet irradiation. *Journal of the Science of Food and Agriculture,* 92, 3016–3022.

Luengwilai, K., Beckles, D. M., & Saltveit, M. E. (2012). Chilling-injury of harvested tomato (*Solanum lycopersicum L.*) cv. Micro-Tom fruit is reduced by temperature pre-treatments. *Postharvest Biology and Technology,* 63, 123–128.

Lurie, S. (1998). Postharvest heat treatments. Review. *Postharvest Biology and Technology,* 14, 257–269.

Lurie, S., Handros, A., Fallik, E., & Shapira, R. (1996). Reversible inhibition of tomato fruit gene expression at high temperature – effects on tomato fruit ripening. *Plant Physiology,* 110, 1207–1214.

Misra, N. N., Keener, K. M., Bourke, P., Mosnier, J. P., & Cullen, P. J. (2014a). In-package atmospheric pressure cold plasma treatment of cherry tomatoes. *Journal of bioscience and bioengineering,* 118(2), 177-182.

Misra, N. N., Patil, S., Moiseev, T., Bourke, P., Mosnier, J. P., Keener, K. M., & Cullen, P. J. (2014b). In-package atmospheric pressure cold plasma treatment of strawberries. *Journal of Food Engineering,* 125, 131-138.

Pankaj, S. K., Misra, N. N., & Cullen, P. J. (2013). Kinetics of tomato peroxidase inactivation by atmospheric pressure cold plasma based on dielectric barrier discharge. *Innovative Food Science & Emerging Technologies,* 19, 153-157.

Philip, N., Saoudi, B., Crevier, M. C., Moisan, M., Barbeau, J., & Pelletier, J. (2002). The respective roles of UV photons and oxygen atoms in plasma sterilization at reduced gas pressure: the case of N 2-O 2 mixtures.*, IEEE Transactions on Plasma Science,* 30(4), 1429-1436.

Pinheiro, J., Alegria, C., Abreu, M., Gonçalves, E. M., & Silva, C. L. M. (2013). Kinetics of changes in the physical quality parameters of fresh tomato fruits (Solanum lycopersicum, cv. 'Zinac') during storage. *Journal of Food Engineering,* 114, 338– 345.

Radusin, T., Kevrešan, Ž., Mastilovi _c, J., Novakovi _c, A., & Jani _c-Hajnal, E. (2013). Influence of different packaging solutions on qualitative and quantitative properties of fresh tomato variety Izmir during storage at market conditions. *Food and Feed Research,* 40, 85–92.

Tzortzakis, N. G. (2010). Ethanol, vinegar and Origanum vulgare oil vapour suppress the development of anthracnose rot in tomato fruit. *International Journal of Food Microbiology*, 142, 14–18.

Recived: 12.04.2016

Accepted: 20.05.2016