

Assessment of quality parameters of blueberries and cherry tomatoes treated by micro torch of cold atmospheric pressure plasma.

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Abstract: The cold atmospheric pressure operating plasma /CAPP/ offers attractive opportunities for various surface decontamination treatments of both food products and non-food materials. The technology is especially considered as promising mild but efficient surface treatment of fresh food products in order to extend their shelf life and sustain quality. Here we report evaluation of the effect of CAPP micro torch treatment of Canadian blueberries and cherry tomatoes related with the fruit quality and possible cell wall damages and changes of the total anthocyanins content of treated fruits. The problems and opportunities for further application of plasma jet generated CAPP treatment for fresh fruit decontamination are discussed. The research is funded by the Bulgarian National Science Fund under Grant DN08/8-2016.

KEYWORDS: COLD ATMOSPHERIC PRESSURE PLASMA, PLASMA JET, MICROWAVE DISCHARGE, FRESH FRUIT TREATMENT, FRUIT QUALITY

1. Introduction

The increasing consumer demand for high quality, fresh and safe food products led to the development of novel nonthermal technologies including “cold” atmospheric pressure plasma /CAPP/ technology [1, 2]. Generated at ambient temperature and atmospheric pressure CAPP offers an attractive opportunity for the decontamination of fresh food products as berries and vegetables [3-5]. The decontamination effect of CAPP is attributed to microbial death or cell injury following the oxidation and damages of membrane and vital components of microbial cells by the CAPP species including ions, radicals, photons, reactive oxygen and nitrogen species [6, 7]. The CAPP treatment could be carried out under different operation modes [3]. In previous study we reported that CAPP treatment of small fresh fruits via microwave-sustained plasma micro torch in argon at atmospheric pressure results in partial inactivation of bacteria presence on fruit surface [8]. The study shows that the CAPP treatment doesn't reduce significantly the level of antioxidant activity of the fruit, but the decontamination efficiency depends from the kind of the fruits and is most pronounced for Canadian blueberries. Furthermore, the thermal imaging of the treated fruits shows some increase of surface temperature in the fruit surface directly treated by the torch, which may affect the fruit metabolite composition and especially anthocyanins. Here we report further assessment the effect of the CAPP micro torch treatment through the evaluation of possible cell wall damages and changes of the total anthocyanins content of treated Canadian blueberries and cherry tomatoes

2. Materials and Methods

Experimental Setup

The experimental setup of plasma jet generated microwave-sustained plasma micro torch in argon at atmospheric pressure, used in the present study, is described into details in [8]. Briefly, the solid-state microwave generator operating at 2.45 GHz (Sairem, Neyron, France, GMS 200 W) was connected to a commercial electromagnetic surface wave resonator (Sairem, SURFATRON 80). Microwave (MW) power was adjusted to 9 W. The surfatron resonator was cooled by the ambient air flow of 4 L/min. Argon (purity of 99.999%) flow of 7 L/min was controlled by Omega FMA-A2408 mass flow controller. The discharge was created inside a quartz tube with 8 mm outer diameter and 3 mm inner diameter. The end of the quartz discharge tube was 2 mm outside the surfatron resonator and the plasma jet length was 9 mm. The ambient air (temperature of 25 °C at a relative humidity of 35 ± 2 %) was surrounding the plasma effluent just behind the resonator.

The system axis was installed vertically with the gas flow from top to bottom.

Plant Material and CAPP Treatment

Canadian blueberries were purchased from the market and yellow cherry tomatoes were collected from experimental field of AgroBioInstitute. Fruits with intact surface and uniform size were selected for the experiment. The fruits were divided into 3 groups (each one representing one repetition) of 5 pieces and treated by exposure of CAPP micro torch for period of 1, 2 and 4 minutes. Each group of fruits was placed in a lid of a sterile glass petri dish. All fruits were treated individually with the plasma torch as the petri dish was moved slowly in a manner that the CAPP plasma to get uniformly in contact with the upper fruit's surface.

Electrolyte Leakage

Following the CAPP treatment, the fruits were transferred to 50 glass tubes and left for 5 min at room temperature. Then, 25 mL of deionized water were added to the tube and the fruits were incubated for another 5 minutes at room temperature. Untreated fruits, processed in parallel, were used as untreated control. After the incubation, each tube was briefly shaken by hand and the electrical conductivity (EC) of the liquid was measured using HI 8733 Conductivity meter (HANNA Instruments, USA), providing electrical conductivity values of treated (EC_{tr}) and control (EC_{con}) samples. The glass tubes with the samples were further autoclaved for 20 min. at 121°C and cool down to room temperature. Then the electrical conductivity of each sample was measured again providing maximal (EC_{max}) value related to complete disruption and maximal electrolyte leakage of each sample. The obtained experimental data were further used for calculation of Index of Injury (Id) for each treated sample as described by Schön et al. 2019, [9]. Briefly, $Id = 100 \times (R_{tr} - R_{con}) / (1 - R_{con})$, where $R_{tr} = EC_{tr} / EC_{max}$ for each treated sample and $R_{con} = EC_{con} / EC_{max}$ for control sample.

Determination of Total Anthocyanins

Three hours after treatment, treated and untreated control samples were frozen in liquid nitrogen, stored at -80°C and prior analysis homogenized using the TissueLyser (QIAGEN, Hilden, Germany). One hundred milligrams (fresh weight) of the obtained powder, placed in a tube, were extracted with three hundred microliters (weight/volume ratio of 1/3) 70% aqueous methanol. The extraction was conducted on a multi vortexer (VWR) at 1000 rpm for 1 h at room temperature. After the extraction, the samples were centrifuged at 12,000 rpm for 15 min and the supernatants were further analyzed for their anthocyanins content. Total

anthocyanins were determined by the pH-differential method based on structural changes of the anthocyanins chromophore and anthocyanin pigments colour with pH, according to Lee et al. 2005, [10]. After pH of samples were adjusted to pH 1.0 and pH 4.5 they were read at 520 and 700 nm using 96- well microplate reader CLARIOstar Plus, (BMG Labtech GmbH). Results were calculated according to Lee et al. 2008 [11] and were reported in equivalents of cyanidin 3-galactoside.

3. Results and Discussion

Preserving intact the tissues of treated fruits, their color and content of health-related compounds is an essential requirement for further practical application of the decontamination treatment of fresh plant and food products. Beside the surface decontamination, CAPP treatment may cause cell wall damages in the tissues directly exposed of the micro torch. The CAPP treatment may also reduce the contents of anthocyanins, which have lower thermostability and could interact with reactive species present in the cold plasma. In order to assess the possible negative impact of CAPP micro torch treatment and evaluate the levels of the possible plant tissues and cell damages we compare the levels of electrolyte leakage from treated and untreated samples for each of the tested treatment. Accordingly, the obtained data were used to determine the Index of Injury (Id) for the samples obtained by each treatment. The results, described in Figure 1, demonstrate low level of tissue and cell damages after CAPP treatment, which increase with the length of treatment, reaching Id of 0.43 ± 0.069 % after 4 min. treatment of blueberries and 0.12 ± 0.032 % for cherry tomatoes, Table 1. The determined indexes of injury related to levels of electrolyte leakage from damages cells and tissues of CAPP treated fruits are significantly lower than reported from application of other treatments like decontamination of tomatoes via aqueous ozone washing techniques [12] or treatment of sodium hypochlorite [13], or gamma irradiation of blueberries [14].

Table 1: Index of Injury determined for blueberries and cherry tomatoes treated with CAPP micro torch for 1, 2 and 4 minutes. *Note: Average and standard deviation values of the Index of Injury for each group of treated fruits presented in percentage.

Fruits	Duration of CAPP micro torch treatment		
	1 min	2 min	4 min
	Average value (%) of the Index of Injury*		
blueberries	0.00 ± 0.007	0.29 ± 0.05	0.43 ± 0.069
tomatoes	0.03 ± 0.007	0.09 ± 0.003	0.12 ± 0.032

Anthocyanins are pigments which largely determine blueberry color quality and health promoting effect. CAPP treatment may affect and reduce the anthocyanin content in the blueberries due to the elevated temperature of fruits upon treatment or their reaction with reactive oxygen species present in the plasma [15, 16]. To evaluate the possible negative impact of applied CAPP micro torch exposure on quality of treated blueberries we compare of the total anthocyanin content of treated and untreated fruits. The results demonstrated no significant changes and reduction the anthocyanin content after applied CAPP micro torch treatment Table 2, and suggests it is a mild treatment preserving fruit quality. Similar results also reported for CAPP treatment of blueberries using diffuse coplanar surface barrier discharge plasma unit [7].

Table 2: Anthocyanin content of CAPP treated blueberries based upon fresh weight of berries. *Note: Anthocyanin concentration based upon cyanidin-3-glucoside as standard and presented as milligrams per 100 grams of sample fresh weight.

Fruits	Duration of CAPP micro torch treatment			
	untr.*	1 min	2 min	4 min
	Anthocyanin content (mg/100 g)*			
blueberries	118.8 ± 2.7	119.0 ± 2.1	118.4 ± 2.9	118.9 ± 2.5

The results of present and earlier [8] studies of CAPP treatment of small fresh fruits using microwave-sustained plasma micro torch in argon at atmospheric pressure demonstrate that this CAPP generating unit could be used for mild and quality preserving decontamination of fresh fruits. At the same time the partial reduction of microbial load on the surface of the treated fruits [8] suggests the main challenge for converting of this type of CAPP treatment into fresh fruit decontamination technology will be the development of micro torch based CAPP unit providing uniform treatment of the fruits at elevated productivity. Accordingly, the development of effective CAPP units involving array of plasma jets [17-19] and/or scale up the plasma jet nozzle [20] will be an essential step toward related technology development and application.

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4. References

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