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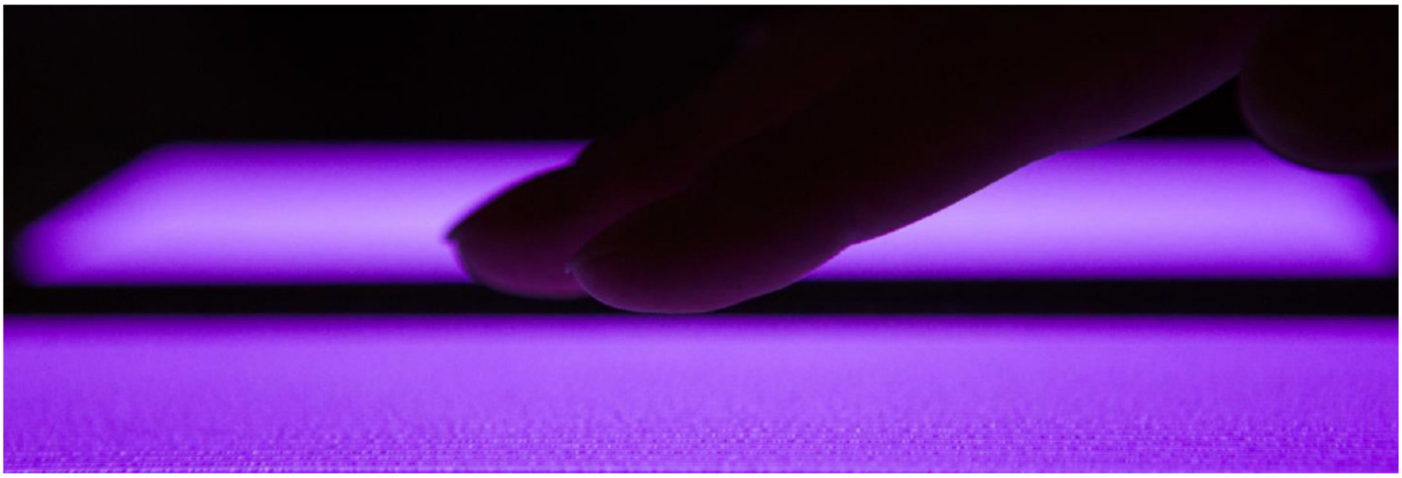
with joint COST TD1208 workshop Non-Equilibrium Plasmas with Liquids for Water and Surface Treatments



Book of Contributed Papers

Masaryk University

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Non-Equilibrium Plasmas with Liquids

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COLD AIR PLASMA PASTEURISATION OF FRESH APPLE JUICE

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Transient spark and streamer corona discharges were tested for a non-thermal pasteurization of fresh apple juice. The juice was treated in two systems – electro-spray system and static (batch) system. The inactivation rate of model pathogens (*Escherichia coli*) of contaminated juice showed high efficiency for the transient spark, especially for the static treatment. The presence of food borne pathogens and their effect on the juice life time was also tested. A minimal effect of cold plasma on juice chemical and sensory properties (pH, color) was shown. Measured concentrations of nitrites and nitrates formed in the juice by plasma treatment were shown to be lower than the acceptable daily income dose.

Keywords: cold air plasma; non-thermal pasteurization; apple juice

1 Introduction

Sterilization is one of the most important technologies in food processing and food safety. The traditional methods for inactivation of food borne pathogens in different types of food are based on thermal processes, typically referred to as pasteurisation. Unfortunately, the use of high temperatures is not convenient for heat-sensitive products and may lead to the loss of food quality (loss of nutrition values and vitamin content, changes in sensory properties like taste or color, and others). Therefore in recent years, non-thermal methods of food processing have been investigated – such as high hydrostatic pressure, pulsed electric fields, ionizing radiation and non-thermal plasma [1-2]. Cold plasmas are known for bactericidal effects on variety of bacteria, bacterial spores, biofilms or yeasts [3]. These properties predetermine cold plasma for the applications in sterilization/pasteurization of fresh food products or food packaging [4-6].

Consumers demand for the freshly squeezed fruit juices with high nutritional values that were not thermally pasteurized. The object of this work was to test the use of cold plasma generated by transient spark and streamer corona for fresh apple juice non-thermal pasteurization. The apple juice was selected, because is the most consumed fruit juice (together with orange juice).

2 Experimental set-up and methods

2.1 Cold plasma discharges

DC discharges used in this study - transient spark discharge (TS) and streamer corona (SC) were generated in ambient air at atmospheric pressure in point-to-plane geometry producing cold plasma. SC is typical with small current pulses of streamers (~ tens of mA) with a repetitive frequency ~ 10-30 kHz, during which the discharge voltage remains fairly constant. TS is a self-pulsing repetitive streamer-to-spark discharge with the duration of spark current pulse (~ 5-30 A) shorter than 100 ns. The repetitive frequency is ~1 kHz [7-8]. Two different systems with TS or SC for juice treatment were used – the electro-spray system (ES) and the static system (SS). High voltage electrode was represented by the hypodermic hollow needle. In the electro-spray system, juice was pushed by the syringe pump directly through the needle, which enabled the direct contact of the discharge with sprayed droplets of the treated juice.

The effect of electro-spraying of juice to the micrometric size droplets occurred due to the applied high voltage. This set-up allows increasing the contact of the discharge with the juice surface. The static system is based on the static, i.e. batch treatment by the discharge generated directly over the juice surface, in which the grounded electrode was submerged.

2.2 Juice preparation and treatment, microbial handling

Ripped apples (old Slovak variety Ontario) were harvested and after being washed, they were squeezed by using common juicer (Bosch MES3500). The fresh juice containing the pulp was stored in the freezer at -20°C. We performed several experiments focused on:

a) Inactivation rate of bacteria by cold plasma – juice was thawed at the room temperature and centrifuged to remove the pulp. Subsequently it was inoculated by model pathogens - *Escherichia coli* ATCC 25922 and *Saccharomyces cerevisiae* S228C with the initial concentration ~ 10^6 -10^7 CFU/mL.
b) Effect of cold plasma on shelf life time of juice – thawed juice containing pulp contained only its native pathogens.

In every experiment, the juice was treated by TS and SC in electro-spray and static system. The juice flow rate in ES was 1mL/min and the treatment condition in SS was 1 min treatment per 1 mL of juice. The number of living microbial/yeast cells in the juice after plasma treatment and in the control was evaluated immediately after plasma treatment by classical thermostatic cultivation on Petri dishes. We followed either the inactivation rate or the spoilage rate of treated juice in post treatment time (from 0 up to 21 days). Meanwhile, the juice was stored at 4°C in the refrigerator to simulate the behavior of consumers. Furthermore, we focused on the effects of cold plasma on the chemical, nutrient and sensory properties of treated juice, like pH changes; nitrites/nitrates (measured by Griess assay) and hydrogen peroxide H_2O_2 (measured by Amplex red assay); color changes by measuring juice transmittance and °Brix (content of sugar).

3 Preliminary results

3.1 Effect of cold plasma on juice properties

Cold air plasmas in contact with liquids are known for the formation of short-lived reactive oxygen and nitrogen species (RONS) that lead to formation of long-lived RONS in water, especially nitrites, nitrates and hydrogen peroxides. All these substances may be harmful for human health; therefore their content in foods is regulated. The Joint Expert Committee on Food Additives (JECFA) of the Food and Agriculture Organization of the United Nations/World Health Organization and the European Commission's Scientific Committee on Food have set an acceptable daily intake (ADI) for nitrate of 0-3.7 milligrams nitrate ion per kilogram body weight and for nitrite of 0-0.06 milligrams nitrite ion per kilogram body weight [9]. We calculated the ADI of nitrites and nitrates per average 60 kg person: 36 mg NO_2^- and 222 mg NO_3^-. Concentrations of measured nitrites and nitrates in plasma treated juice in comparison with the ADI are shown in Fig. 1a). Both nitrites and nitrates concentrations are lower than ADI doses and their concentration is decreasing to minimum after 2 days.

The sensory properties of the juice (color, taste, smell) are indicated by the values of total acidity, pH, transmittance and °Brix. We detected no significant changes of pH after plasma treatment of juice – pH dropped from 3.28 to 3.19. Furthermore, measuring of the transmittance showed a slight decrease in the juice treated by transient spark discharge (Fig. 1b).

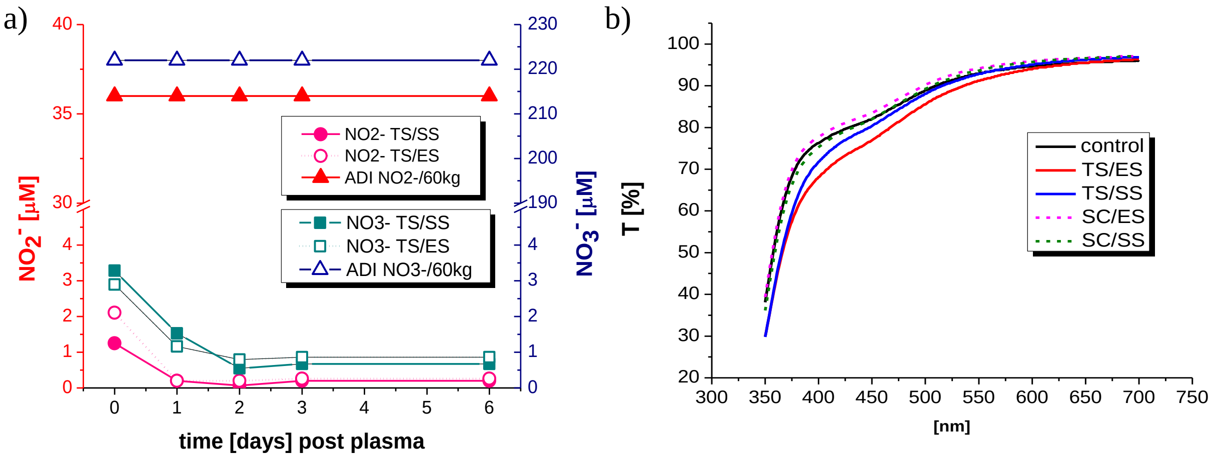

Fig. 1. a) Nitrites and nitrates concentrations measured in cold plasma treated juice compared with the acceptable daily intake (ADI) doses; b) Transmittance [%] of the untreated and treated juice by transient spark and streamer corona.

3.2 Effect of cold plasma on inactivation rate and shelf life time of the fresh juice

The efficiency of cold plasma treatment of the fresh apple juice on the inactivation rate was tested. Juice without pulp was inoculated by model microorganism *E. coli* ATCC 25922 and treated by streamer corona and transient spark in both systems. Fig. 2 shows the bacterial population growth up to 7 days post plasma treatment. In general, streamer corona treatments reached very low efficiency (less than 1 log reduction), which remained in post treatment time without significant change. Transient spark treatment also showed low efficiency (< 1 log) directly after plasma treatment, but the efficiency was increasing with days post TS treatment. TS treatment in static system reached the maximal efficiency (6 log reduction) after 2 days of storage of the juice in the fridge.

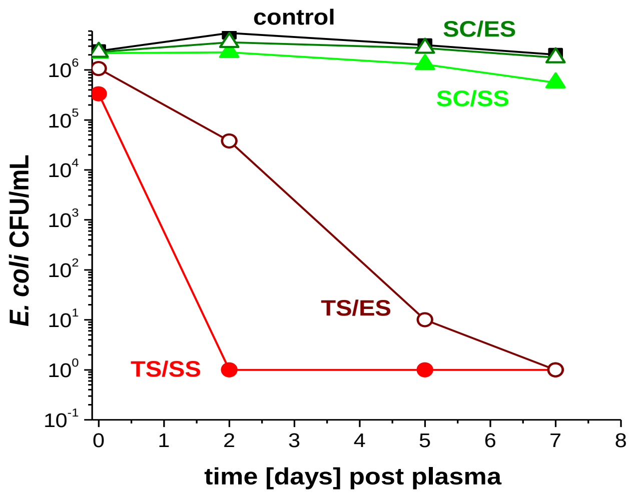

Fig. 2. The inactivation rate of the treated juice contaminated by *E.coli* by streamer corona and transient spark.

Fresh apple juice may contain native food borne pathogens. At first, we tested their presence. The juice containing pulp was kept for 24 hours at 30°C and 24 hours at 35°C to cultivate the native pathogens and then cultivated on Petri dishes. We detected 3 different strains of yeasts and bacteria. These pathogens are responsible for the spoilage of the fruit juice and shortening of the shelf life time. The plasma treated natural juice demonstrated no bacterial or yeast growth up to 7 days post plasma treatment. Further experiments are planned to test the treated juice up to 21-28 days post treatment.

4 Conclusion

Cold plasma is a promising alternative food processing technique for non-thermal pasteurization. Preliminary results with cold air plasma treatment of fresh apple juice are very optimistic: a significant decontamination rate, shelf life time extension, and no chemical and sensory modifications were observed. Further investigation is needed to improve the treatment conditions and treat larger volume of a fresh juice.

Acknowledgement

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References

1. B. H. Lado, Microbs & Infections. 4, 433-440 (2002)
2. B. Niemira, Annu. Rev. Food Sci. Technol. 3, 125-142 (2012)
3. B. Surowsky et al., Int. J. Food Microbiol., 174, 63-71 (2014)
4. K. Lee, J. Microbiol. 44 (2006)
5. D. Ziuzina et al., Food Microbiol. 42 (2014)
6. P. Basaran, Food Microbiol. 25 (2008)
7. Z. Machala et al., Eur. J. Phys. D 54 (2009)
8. Z. Machala et al., Plasma Process. Polym. 10 (2013)
9. European Commission's Scientific Committee for Food Science and Techniques, Opinion of the Scientific Committee for Food on Nitrites and Nitrates, 38th series (1997)