Research Scientific Report

2018-2019

concerning the implementation of the project PN-III-P4-ID-PCE-2016-0277, no. 15/12.07.2017

***Increasing the Agricultural Production in Greenhouses using Non-Thermal Plasma Activated Water Technology for Irrigation* (AWAG)**

The following is a synthesis of the scientific activity for the years 2018 and 2019. The report assesses the degree of implementation of the project in correlation with the scientific dissemination in scholarly journals, as well as the increase of the project's visibility on a national and international scale through participations at scientific conferences.

The objectives have had an experimental and research character, doubled by the intermediary dissemination of data obtained by the project team.

To assess the characteristics and the efficiency of the reactor, we studied the influence of the polarity of DC pulse power supply for different values of pulse frequencies, gas and water flowrates. The DC pulse power supply provides a higher energy efficiency in generating hydrogen peroxide in water compared to an AC high voltage supply.

It was performed an analysis of the influence of different parameters on energy efficiency of a spray, point-to-point, non-thermal plasma (NTP) reactor in plasma activated water generation. The polarity of the DC pulse power supply is assessed for different input parameters such the frequency (60, 150 and 250 Hz), water flowrate (5, 10, 15 and 20 mL/min) and gas flow rate (1 and 2 L/min Ar). There are also presented the values of important electrical parameters of the plasma such the average power or discharge energy. The concentration of hydrogen peroxide generated into plasma activated water was considered as indicator of the energy efficiency.

The H_2O_2 concentration has been determined using a colorimetric method based on titanium sulphate ($TiOSO_4$), which acts like reagent. The absorption spectra of the solution provide peaks proportional with the hydrogen peroxide concentration for the wavelength λ_{H2O2}= 410 nm.

The obtained results, illustrated in Figure 1, indicate the fact that not the entire quantity of energy delivered by the power supply is transferred to plasma when the reverse polarity is considered. The average power is higher for direct polarity for all the considered frequencies and gas flowrates. The average power is not influenced by the water flowrate and for this reason the authors chose to present the average values obtained for a specific frequency. Consequently, as the average power is considered for computing the discharge energy, there are also differences between the two HVPS polarities, the highest values being obtained for a frequency of 250 Hz.

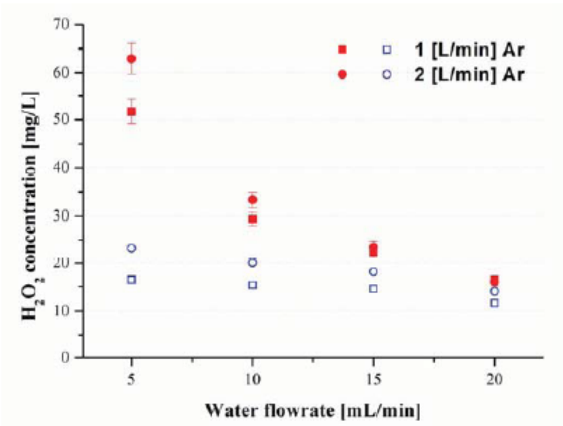


Figure 1 Evolution of the H_2O_2 concentration with the variation of the water flowrate and gas flowrate for a frequency of 250 Hz

Comparing the two polarities, direct and reverse, we can observe in Figure 2 that there are important differences of the H_2O_2 concentration in PAW. These differences are higher when higher frequencies are used and decreasing with the increase of flowrate. To assess the influence of the polarity on PAW parameters, the energy efficiency was also determined (EEf [g/kWh]).

Experimental data leaded to the conclusion that EEf is not considerable modifying with the water flowrate for DP, while in the case of RP, the efficiency is consistently higher for higher water flowrates. As in the case of H_2O_2 concentration, a higher gas flowrate is improving also the efficiency of the NTP reactor.

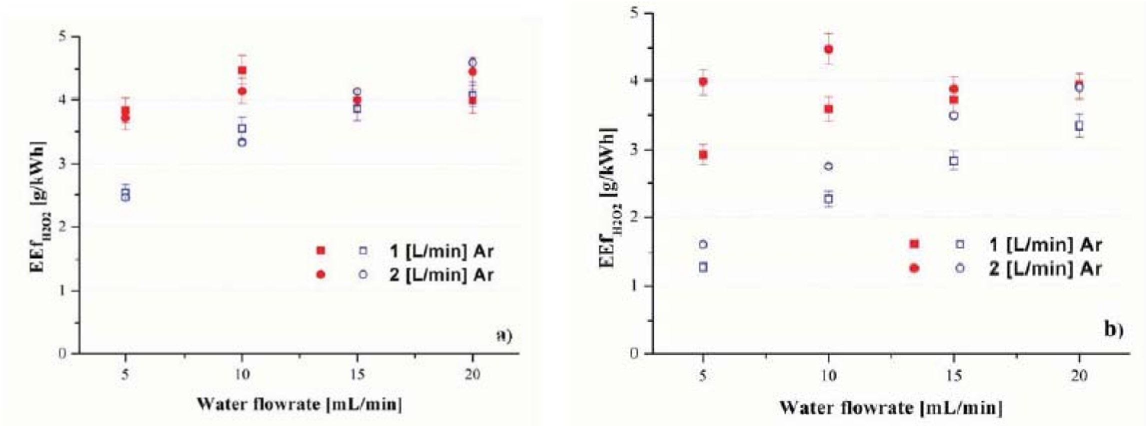


Figure 2 Evolution of H_2O_2 generation efficiency with the variation of the water flowrate and gas flowrate for a frequency of a) 60 Hz and b) 250 Hz

The evaluation of the electrical parameters showed that the average power of the discharge, which increases with the frequency, is slightly higher for the case of a direct polarity even though the power supply has similar parameters. This means that in the case of reverse polarity the energy loses (e.g. by thermal loses) are higher.

It was also evaluated the energy efficiency in generating H_2O_2 in PAW using a two cylindrical electrodes reactor and two high voltage power supplies (HVPS). The hydrogen peroxide (H_2O_2) was considered as an indicator in the evaluation of the energy efficiency due to its most important effect on disinfection (in agriculture applications) and because its concentration can be relatively precisely measured when Ar is used as a carrier gas.

The correlation between the H_2O_2 concentration and the interest peak amplitude was performed based on a calibration curve obtained for standard H_2O_2 concentration solutions. The evaluation of the test repeatability shown that the applied method presents a good reproducibility of the results obtained for each specific test conditions.

The results concerning the hydrogen peroxide (H_2O_2) concentration in the plasma-activated water revealed that the highest concentrations, up to 53 mg/L, were obtained for using the AC HVP for all water flowrates.

The H_2O_2 concentration is lower when the DC pulse HVP is used, decreasing with the frequency and, consequently, with the decreasing of the average power. As it can be observed in Figure 3, the H_2O_2 concentration decrease with the water flowrate increasing for all types of supply considered. This effect is due to a higher residence time of the solution in the plasma region for low flowrates, which involves a higher chemical conversion.

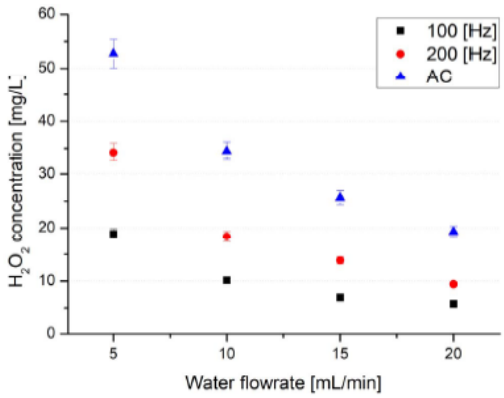


Figure 3 Evolution of the H_2O_2 concentration with the variation of the water flowrate for the considered HVPS.

The evaluation of the test repeatability illustrated in Figure 4, shown that the applied method presents a good reproducibility of the results obtained for each specific test conditions.

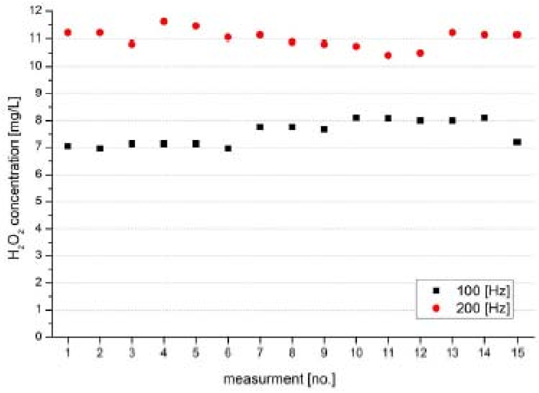


Figure 4 Measurement errors and repeatability of tests

The results presented allow choosing the optimum parameters for producing PAW for a specific application (required H_2O_2 concentration) such as the nature of electrical supply or the water flowrate while consuming the minimum of energy. The energy efficiency determinations showed an important difference between the two supplies, the highest values being obtained for the DC pulse HVPS. Contrary to the variation of the concentration with the water flowrate, the maximum efficiency values have been obtained for higher flowrates.

In agriculture applications, non-thermal plasma activated water (PAW) have been proved has positive effects on plants growing. For these applications, the activated water is sprayed on the plants leaves in addition to regular irrigation of the plants. The most important plasma induced reactive species that interact with the plants are nitrates and hydrogen peroxide.

In this research project, was proposed a new solution for PAW generation, that consists in a NTP reactor that combines the spraying system and the NTP reactor in one simple, robust and reliable system, which does both functions in one special design reactor.

For this type of reactor, it was filed a patent application.

In order to emphasize the effect of the plasma produced in the new reactor on the water treated, the reactive species production in deionized water, such as hydrogen peroxide and nitrates have been measured.

The new reactor combines the technical solution of spraying the water through a two-port nozzle, directly into the plasma zone, generated by a pulsed high voltage electrical discharge between two electrodes, placed in a narrow chamber, forcing the water droplets to get into contact with the plasma.

The low power of the plasma does not increase significantly the temperature of the water droplets in the reactor, and therefore, enhance the energy yields for NO_3 and H_2O_2 production due to suppression of quenching reactions of radicals with other molecular species.

The main advantages of the new reactor, compared to the other NTP reactors are due to its technological simplicity and operating conditions (atmospherically pressure and temperature), which make it suitable for agricultural and biological applications.

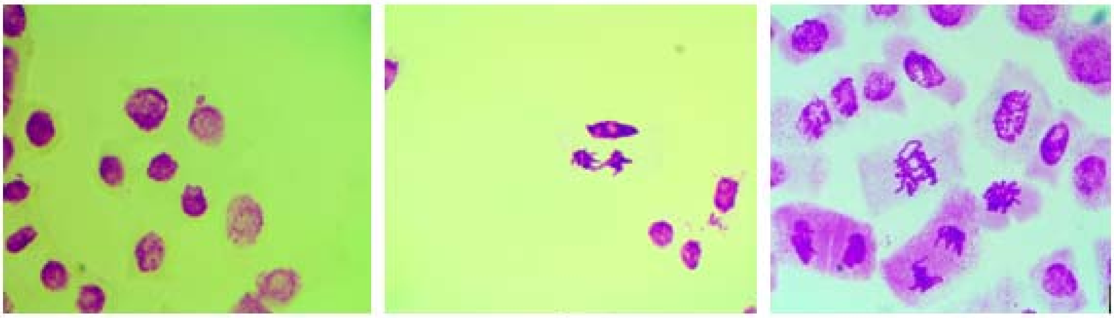
The PAW produced can be directly sprayed on the plant's leaves or on the surfaces subject of disinfection. To increase the volume of treated solution, in our case, is better to develop and design a larger NTP reactor unit that uses a large number of mini-reactors.

In order to highlight the effect of activated water on plants at different stages of development, a series of preliminary horticultural tests and biochemical analyses of the leaves, supplemented by numerous biometric and phenological determinations, have been carried out.

Two concentrations of cold plasma activated water were established with which treatments were applied to seeds and then to mature plants of Lactuca sativa.

After applying the treatments, the aspects were investigated:

- the mythical index;
- the proportion of aberrant cells;
- types of structural anomalies of mitotic chromosomes;
- frequency of chromosomal abnormalities (Figure 5);
- biometric measurements in seedling dynamics



a b c

Figure 5 Micronucleus in interface (a); chromosome bridge telophase (b); multiple bridge anaphase (c)

Increasing the international visibility

The project's website was designed and continuously updated. All the members of the project have participated to three major international scientific events.