Corona Discharge in Electroporation of Cell Membranes

R Cramariuc, A Tudorache, M E Popa, E Brandus, L Nisiparu, A Mitelut, M O. Turtoi and L Fotescu

1The Competence Centre in Electrostatics and Electrotechnologies, Romania; 2Research Institute of wine processing, Valea Mantei Street, No.1, Valea Calugareasca, Romania; 3Biotechnology Faculty, University of Agronomical Sciences and Veterinary Medicine, Romania

Abstract. The objective of the present work is to demonstrate that electrical corona discharge is very efficient in cellular membrane electroporation due to current pulses with sharp front (2-5 ns) and to the fact that corona discharge is associated with UV radiation and micro particles emission. A comparison between DC and AC at 800 Hz and a special waveform to corona application is presented. The comparison is analyzed by means of applying all these in the maceration process (electroplasmolysis) of red wine production and in the inactivation processes of different types of the microbes.

1. Introduction
The major interest in the PEF treatment of cellular materials derived from nonthermal applications, needed for cellular permeability. The dielectric breakdown or the electroplasmolysis of biological cells during the PEF treatment generally leads to electroporation. This means that the pores in the biological membrane form and evolve as a result of polarization with external electrical field. The nature of electroplasmolysis and the pores’ localization during the PEF treatment are still not very well understood. The generally accepted mechanism of cells’ electro permeability in suspension as microorganisms and erythrocytes consists in pore formation in the lipid matrix of the cellular membrane. The objective of the present work is to demonstrate that electrical corona discharge is very efficient in cellular membrane electroporation due to current pulses with sharp front (1-5 ns) and to the fact that corona discharge is associated with UV radiation and micro particles emission.

2. Experimental setup

2.1. Schematic diagram of electroplasmolysis, applied in maceration phase

![Schematic diagram of electroplasmolysis](image)

Figure 1. a) Schematic diagram of electroplasmolysis; b) The wave form of the corona discharge
2.2. Electric corona discharge

The electrical corona discharge is produced by applying a high voltage between a Wo wire network (0.4 mm diameter) and a stainless steel plate (fig. 1b.). This assembly is introduced in a reactor. On the bottom of it the plate (where the mashed grapes settle down) is set to be treated. The pulse duration (fig.1b.) is 60 ns, with a very short front, 0.7-1 ns, very efficient for electroplasmolysis. This system is very appropriate for industrial applications.

![Image of experimental apparatus](image)

Figure. 2. The experimental apparatus for applying electroplasmolysis in the maceration process. (1),(2) blocks that form the high voltage generator, that supplies 0÷40 kV, + or - polarity, current 0–400mA. The HV is connected to a corona wire (5) through a protection resistor (4) with a HV cable (3). Between the corona wire and a grounded plate (6) an electrostatic field of 100 – 400 kV/m forms, in which 10⁶ ÷ 10⁸ air ions /cm³ are transported towards the plate (6). Corona discharge with dielectric barrier with AC (silent corona)

2.3. Tested variants:

| The variable factor                              | Treatment time | Cod of variant |
|--------------------------------------------------|----------------|---------------|
| PEF power supply                                 |                |               |
| Corona in DC                                     | 30 s           | 2             |
| Corona in DC                                     | 60 s           | 3             |
| Corona in AC                                     | 30 s           | 4             |
| Corona in AC                                     | 60 s           | 5             |
| Corona discharge with dielectric barrier         | 15 min         | 6             |
| Corona discharge with dielectric barrier         | 5 min          | 7             |
| Corona discharge with resistive barrier in DC    | 15 min         | 8             |
| Corona discharge with resistive barrier in AC    | 5 min          | 9             |
| Corona discharge with resistive barrier in AC    | 15 min         | 10            |
| Corona discharge with resistive barrier in AC    | 10 min         | 11            |

3. Experimental results

3.1. Microscopic analyses

Results are shown in Table 2

3.2. Work materials and methods for electroplasmolysis

Products denomination: 1. Cabernet Sauvignon; product code CS207_1 (control) and 2. Cabernet Sauvignon; product code CS207_2 (trials)

3.3. Experimental results

Results obtained from experimental work are presented in tab. 3; 4 for a single sample out of a total of 11 analysis (variant 3: corona discharge in DC).
### Table 2

| Cod of variant | The repetition | No. of pores | No. of pores with the diameter of: |
|----------------|----------------|--------------|----------------------------------|
|                |                |              | 2µm  | 4µm  | 6µm  | 8µm  | 10µm |
| 1              | 1              | 25           | 3     | 4     | 5     | 6     | 7     |
|                | 2              | 7            | 3     | 3     | 1     |
|                | 3              | 3            | 2     | 1     |
|                | 4              | 2            | 1     | 1     |
|                | Average        | 3.75         | 3     | 6     | 6     |
| 2              | 1              | 7            | 3     | 3     | 1     |
|                | 2              | 5            | 3     | 2     |
|                | 3              | 8            | 3     | 5     |
|                | 4              | 9            | 1     | 6     | 2     |
|                | Average        | 9.25         | 1     | 3     |
| 3              | 1              | 8            | 4     | 1     | 3     |
|                | 2              | 8            | 5     | 2     | 1     |
|                | 3              | 7            | 5     | 1     | 1     |
|                | 4              | 5            | 3     | 1     |
|                | Average        | 7            | 2     | 4     | 1     |
| 4              | 1              | 7            | 3     | 4     | 3     |
|                | 2              | 6            | 2     | 4     |
|                | 3              | 7            | 4     | 3     |
|                | 4              | 7            | 4     |
|                | Average        | 6.75         | 4     | 3     |
| 5              | 1              | 12           | 2     | 4     | 1     |
|                | 2              | 15           | 4     | 3     | 2     |
|                | 3              | 12           | 4     | 3     |
|                | 4              | 9            | 2     | 4     |
|                | Average        | 12           | 2     | 4     | 1     |
| 6              | 1              | 7            | 2     | 5     |
|                | 2              | 6            | 2     |
|                | 3              | 7            | 4     | 3     |
|                | 4              | 7            | 4     |
|                | Average        | 6.75         | 3     | 3     |
| 7              | 1              | 14           | 9     | 3     | 2     |
|                | 2              | 7            | 2     | 5     |
|                | 3              | 23           | 19    | 1     | 2     | 1     |
|                | 4              | 11           | 10    | 1     |
|                | Average        | 13.75        | 4     |
| 8              | 1              | 27           | 8     | 9     | 5     |
|                | 2              | 21           | 14    | 2     | 5     |
|                | 3              | 28           | 17    | 7     | 2     | 1     | 1     |
|                | 4              | 22           | 12    | 3     | 7     |
|                | Average        | 24.5         | 5     | 7     |
| 9              | 1              | 15           | 14    | 1     |
|                | 2              | 10           | 3     |
|                | 3              | 11           | 11    |
|                | 4              | 7            | 3     | 3     | 1     |
|                | Average        | 10.75        | 4     | 3     |
| 10             | 1              | 17           | 8     | 7     | 2     |
|                | 2              | 24           | 11    | 1     | 10    | 2     |
|                | 3              | 12           | 5     | 1     | 4     | 4     |
|                | 4              | 7            | 2     | 4     | 1     |
|                | Average        | 15           | 5     |
| 11             | 1              | 10           | 4     | 2     |
|                | 2              | 9            | 3     |
|                | 3              | 9            | 3     | 3     |
|                | 4              | 10           | 5     | 2     | 3     |
|                | Average        | 9.5          |

#### 3.3.1. Selected sample

| No. | Sample code   | Current source | Polarity | Wave form | Time(s) |
|-----|---------------|----------------|----------|-----------|---------|
| 1   | M (Control)   |                |          |           |         |
| 2   | Variant 3     | 40kV D.C.      | +        | Corona    | 60      |
3.3.2. Polyphenolic composition of wine

Table 4

| No | Sample     | IF  | Anthocyanide (mg/l) | Tannin (g/l) | Flav.polyphenols |
|----|------------|-----|---------------------|--------------|-----------------|
| 1  | M(Control) | 23.1| 209                 | 1,025        | 7.73            |
| 2  | Variant 3 | 26.5| 234                 | 1,226        | 8.63            |

Fig.3 Polyphenolic composition of wine: IF total polyfenols from table 4 presented bars charts

4. Microorganisms inactivation with corona electric discharge

The following table presents experimental results from microorganism inactivation using corona discharge with dielectric barrier, at 800Hz A.C.

4.1. Microorganisms inactivation

Tab. 5

| Sample | Cure time minutes | E. coli | Aeromonas |
|--------|-------------------|---------|-----------|
|        |                   | 10⁴     | 10⁵       | 10⁶       |
|        |                   | I | II  | I | II  | I | II  |
| Control| 0                 | 90%| 70% | 90%| 95% | 100%| 95% |
| 1      | 5                 | 0% | 0%  | 0% | 0%  | 0% | 0%  |
| 2      | 10                | 0% | 0%  | 50%| 45% | 0% | 0%  |
| 3      | 15                | 0% | 0%  | 20%| 15% | 0% | 0%  |
| 4      | 20                | 0% | 0%  | 0% | 0%  | 0% | 0%  |

5. Conclusions

The influence of corona discharge upon electroporation of cellular membranes and upon microorganism inactivation was studied. The corona discharge changes the membrane cell porosity. The number of pores, in the end, depends on the tested variant and on the cure period. The pores’ dimension ranges from 2 to 10μm. Four measurements for each variant of test were made. About the extraction of polyphenols, that are important for red wine production, the most efficient variant is number 3, with a corona discharge, in D.C., at 40kV, with a cure period of 60s. Values greater than control sample were obtained for test variants: 2, 4, 5, 7 and 9 but these are lower than the test variant number 3. In the test variants: 7, 8, 9, 10 and 11 the average number of pores was greater than the one in test variant number 3. The extraction process of juice and the behavior of pores resulted from the cure are more complex and involve more unclear aspects.

6. References

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