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Effect of Treatment with Electric Field Pulse on the Extraction of Polyphenols

Regad Mohamed*[1], Ahmed Lemrabout[2], Rachid Taleb[1], Abdelfettah Kerbouac[3], Abdelkader Mahmoud[2]

[1]Electrical Engineering Department, Hassiba Benbouali University of Chlef, Algeria, Laboratoire Génie Electrique et Energies Renouvelables (LGEER)
[2]Laboratory of Research Applied to Renewable Energies 'LRAER', Modern University of Nouakchott, Mauritania
[3]Higher School Of Applied Sciences - Tlemcen, Algeria

Abstract - The Pulsed electric field (PEF) is recently used in medicine for the treatment of cancers and tumors in addition to this it is widely used in the food industry as a pre-treatment of the food for the conservation and extraction of vegetal compounds. This paper addresses the application of electrical pulsed generator to extract the polyphenol from vegetal component like the thyme. An experimental study is done and compared to other classical methods. The simulation of the electric field between two flat electrodes gives the optimum value of the electric field which must be applied. t is observed that during treatment with PEF, the temperature increases according to the treatment time, because of the heat dissipated by the joules effect which causes increase in the conductivity of the medium which improves the extraction of polyphenols provided that it must not exceed 50C °. The results found shows that the quantity taken out and the performance of extraction, polyphenol are greater after treatment by Pulsed electric field.

Keywords: Electrical field pulsed, Extraction, polyphenols, thyme

INTRODUCTION

Recently, the technique of permeabilization of cell membranes by field pulsed electricity is the subject of studies by several research teams. It appears, according to the literature, that the formation of local instability in the cell membrane by an electric field causes the creation of pores. This electroporation phenomenon plays a role major in the action of the pulsed electric field on cells.

High intensity pulsed electric fields (PEFs) have long been used in genetic engineering and biotechnology, where the destructive effect on microorganisms is explored. In the food industry, most PEF applications as a non-thermal technique focused on the pasteurization of liquid foods such than milk or fruit juices. The use of the pulsed electric field is a technology emerging in the medical field for the treatment of cancer and tumors.

Several studies develop the concept of a combined treatment of plant tissues by the simultaneous application of pressure and a pulsed electric field for extraction juices from high water content fabrics (George et al., 2001).

The objective of this work is to study the effect of PEF treatment on the improvement of extraction from plants. The effects of electrical treatment on the quantitative aspect of excerpts will be discussed. This study will improve understanding of the mechanism of treatment with PEF.

Very few studies have looked at the application of PEF treatment in extraction phenolic compounds contained in plant materials; this is the objective of our study and compares it to classical biological methods.

LITERATURE REVIEW

*Corresponding author:
Email: m.regad@univ-chlef.dz (R. Mohamed),

The application of the pulsed electric field in the extraction is a new electro non-thermal processing technology that is useful in preserving the quality of food produced during storage (Takaki et al., 2011). This pretreatment method just replaced several other chemicals and thermal used for the treatment of food or medicine. Currently, pulsed electric fields have taken on another dimension. The domain application of the PEF in the food industry remains narrow: it is essentially a question of the destruction of microorganisms at low temperature using high PEF intensities and the extraction of cellular constituents from plants using PEF of medium intensities (Zderic et al., 2013).

Treatment techniques

The food processing techniques are divided into two: (Alster and Garg, 1996)

1. thermal techniques
2. non-thermal techniques

a) Thermal techniques

Heat treatment of food is the most important technique today long-term storage. Its objective is to destroy or inhibit the enzymes and microorganisms and their toxins, the presence or proliferation of which could alter the food in question or make it unfit for human consumption (Vorobiev and Lebovka, 2010).

b) Pasteurization

The purpose of pasteurization is to destroy pathogenic microorganisms and alteration. The technique used is to subject the food to a temperature below 100°C and suddenly cool them. It preserves the characteristics foodstuffs, in particular organoleptic (Liegeois 2001).

Pasteurized foods are thus usually kept cold (+ 4°C). This technique concerns, for example, milk and dairy products, fruit juices, vinegar, honey (Liegeois, 2001 and Khalil, 2011).

c) Sterilization

Micro-organisms (bacteria, moulds, etc.) cannot withstand a temperature high, can be destroyed by sterilization or pasteurization. Sterilization occurs at a temperature above 100 ° C: the food thus treated is rendered sterile. Sterilization is used in industrial and household canned goods (Liegeois 2001).

d) Holmic heating

Holmic heating is an electro thermal treatment, which consists in putting the product at process between two electrodes subjected to a potential difference. The passage of a current through the product causes it to heat up by the Joule effect. The product in this case plays the role of electrical resistance. This technique is applied to liquids containing free ions and which are therefore electric conductors (Grimi, N., 2009).

Electrical energy is transformed into heat depending on the conductivity of the food. Thus, the entire product is heated evenly, regardless of its consistency and homogeneity, unlike the usual techniques, based on heat transfer, which produces local overheating of the product on contact with surfaces hot.

Non-thermal techniques

Cold is a food preservation technique that stops or slows down activity cellular, enzymatic reactions and the development of microorganisms. It thus extends the shelf life of fresh products, plants and animals by limiting their alteration.

a) Refrigeration

Food can be kept for a few days, stored at temperatures included between 2 and 8 ° C. The development of pathogenic bacteria is slowed down at this temperature. The evolution of perishable foodstuffs is increased by a few days; the cycles of distribution of fresh produce are elongated. This concerns all food. The healthier the refrigerated product is initially, the longer it takes to conservation (Liegeois 2001).

b) Freezing

Maintains the core temperature of the food down to -18 ° C. This process causes the ice crystallization of water contained in food. We then witness a decrease of the water available, either to a drop in water activity (Aw), which slows down or stops the microbial and enzymatic activity. Freezing, therefore, allows the preservation of longer-term foods than refrigeration (Liegeois 2001).

c) Irradiation

Food irradiation involves subjecting food, packaged or in bulk, to an ionizing process from three possible sources: X-rays, Gamma rays ET Electrons: generated by devices emitting radiation of 10 MeV or less.

d) HP or high-pressure treatment

High-pressure processing also called cold pasteurization, is a process, which consists of applying pressure, using water, up to 6000 times greater than the atmospheric pressure, on the packaging that contains the product to be treated. The pressure used in the HP treatment is roughly equivalent to the weight of an elephant applied over one cm2. This technique is interesting because it uses reticulated water to a greener approach and allows increasing the storage time of food until three times for some of them.

e) Pulsed energy treatment

This technique is a non-thermal method, which increases the preserving of food using short pulses of electricity. The impulses to high voltage kill microorganisms by breaking down their cell membranes. Treatment at pulsed energy is usually used for liquids or semi-liquid foods. The liquids are pumped continuously while using electrical pulses, which cannot be done with solid foods. The fact of not using heat, as in the case of pasteurization, allows keeping intact a greater quantity of nutrients. This technique has the advantage of minimally affecting the nutritional quality of food while retaining the correct flavour and increasing the cooking time life of the food. Electric field treatment involves the passage of a much-raised in food placed between two electrodes. The electric field is normally applied at room temperature or refrigerated for less than one second. Inactivation bacteria it produces can be explained by structural changes in membranes and the appearance of pores. During this treatment, there is little or no heating of the food; his appearance, its physicochemical and nutritional characteristics are maintained intact. This treatment can be considered for liquid foods: orange juice, apple juice, milk, Etc. (Hoeschele, D. F., 1994 and Salinas, 2014).

Principle of action of pulsed electric fields (PEF)

PEF consists of the application of pulses of short duration (µs or ms) (figure 1). This treatment triggers the process of pore formation in the membrane cellular. The formation of pores can be temporary (reversible: opening then closing pores) or permanent (irreversible: the pores remain open).

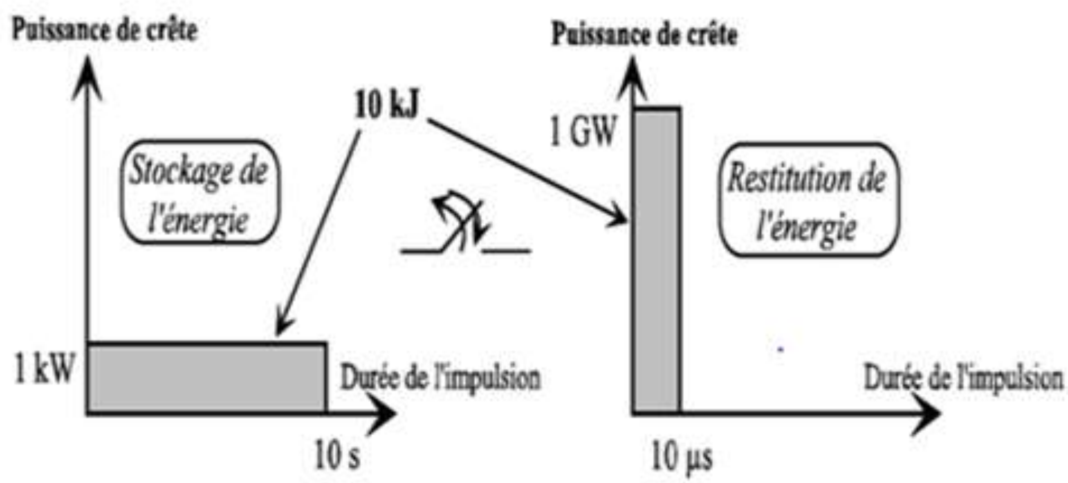

Figure 1: Principle of pulsed power production

ELECTROPORATION

The phenomenon of cell damage, called "electroporation", causes permeabilization of cell membranes (Neumann et al., 1972). The mechanism of electroporation is not yet fully understood. Many models have been proposed to explain this phenomenon. These are mainly based on increased Transmembrane potential. Cell permeabilization requires two stages: the formation of pores by electric fields and the stabilization of these pores to promote interactions between intra and extracellular media. There are only a few information on the time between the change from reversibility to the irreversibility of the pores during or after treatment with electric fields (Neumann and al., 1972, Rajha et al., 2015).
Biological cells are made up of a cytoplasm surrounded by a membrane. The cytoplasm can be considered as an electrical conductor and the membrane, made of a double lipid layer, like an insulator. These biological cells make part of a liquid or solid medium, more or less conductive. The application of a field Electricity creates a polarization of the cell membrane, which behaves like a capacitor (figure2).

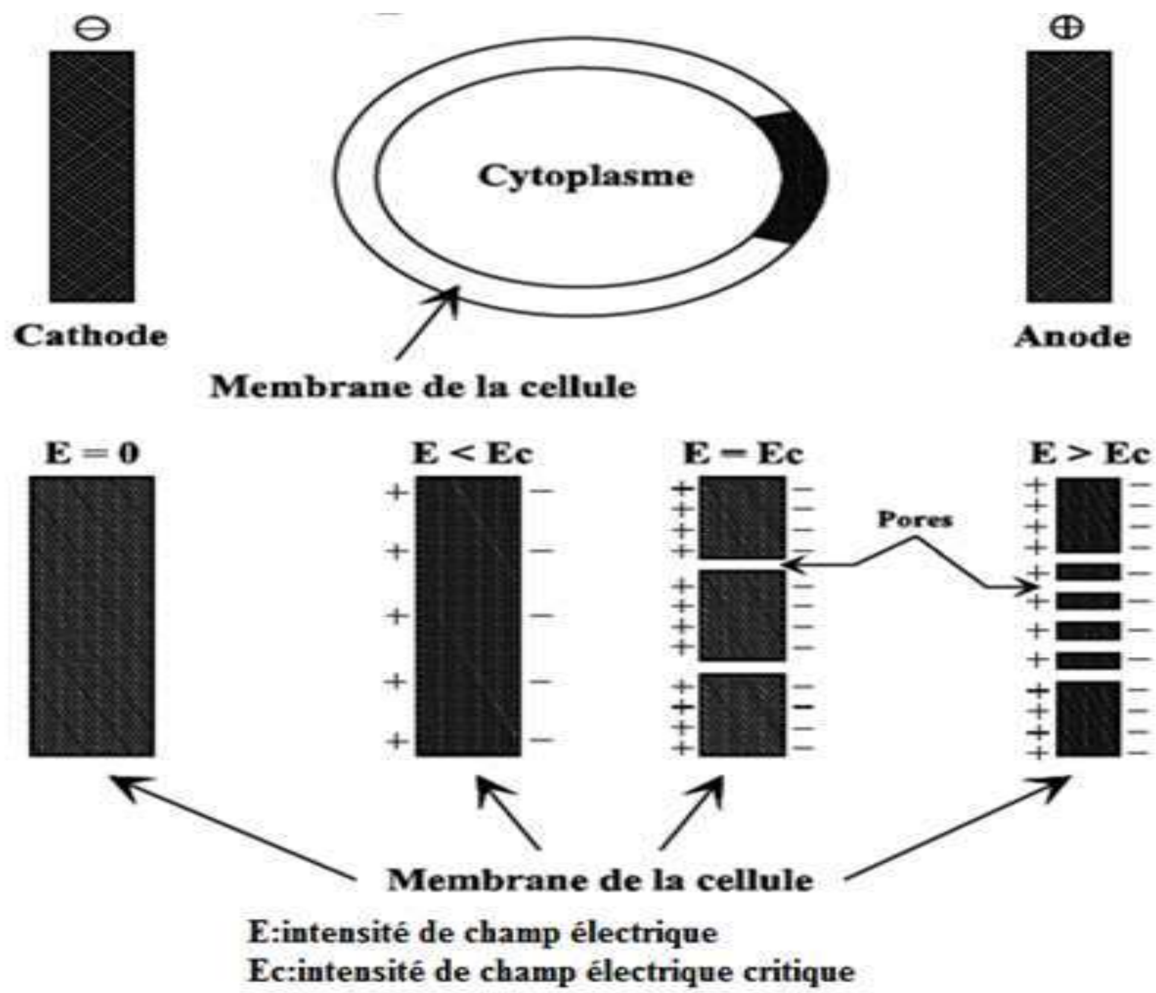

Figure 2: Principle of the effect of an electric field on a cell membrane

When the applied electric field increases, the number of electric charges on both sides of the membrane, increases as well as the electrostatic pressure exerted on some parts of the membrane. The thickness of the latter then decreases, resulting in embrittlement, which can lead to the appearance of pores. This electroporation occurs for a critical value of about 1 Volt (Touya, G., 2003). Which corresponds to an applied field of the order of ten kilovolts per centimeter (the biologists speak rather of potential, here trans membrane, while electronics prefer to reason in terms of field) (Touya, G., 2003). Electroporation is reversible as long as the applied field does not reach values too high, or not applied for too long. Otherwise, electroporation results in cell death (Touya, G., 2003).

MATERIALS

During this study, we used several electrical materials necessary for the extraction of polyphenols.

The plant material

The plant material is the thyme leaf, which was harvested in the Mascara region in Algeria.

Materials used in the electrical laboratory

In the LSTE scientific research laboratory of the University of Mascara, we have used the following materials:

1- A high voltage generator
2- HV ceramic capacitors
3- Spark gap which allows the discharge of stored energy
4- Treatment chamber comprising two electrodes between which are arranged foods to be processed.

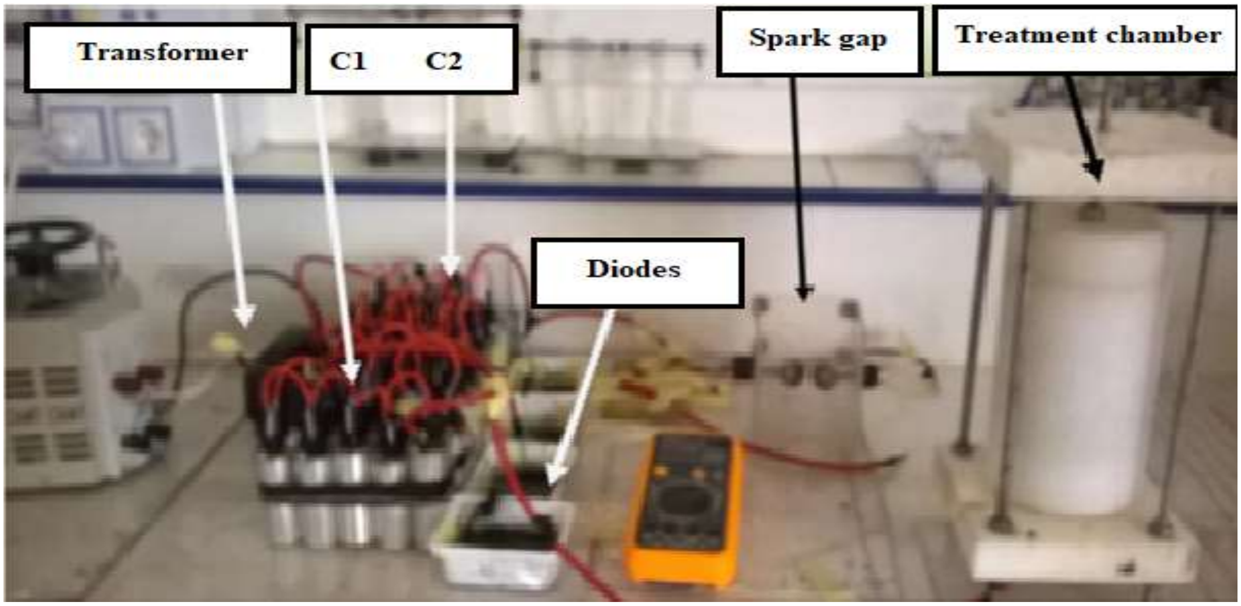

Figure 3: Pulsed electric field treatment equipment

Simulation of the electric field by "Comsol"

COMSOL interface

COMSOL Metaphysics is an environment for simulation and modelling of almost all physical. Its strong point: the coupling between different phenomena.Optional modules offer specialized interfaces in acoustics, engineering chemical, geophysics, electromagnetism, heat transfer, MEMS, Plasma, Batteries & Fuel Cells, CFD and structural mechanics. This software is used to simulate the distribution of the electric field between the electrodes of a treatment chamber. The 2d simulation for the plane-to-plane electrode configuration as shown in the main window of the simulator.

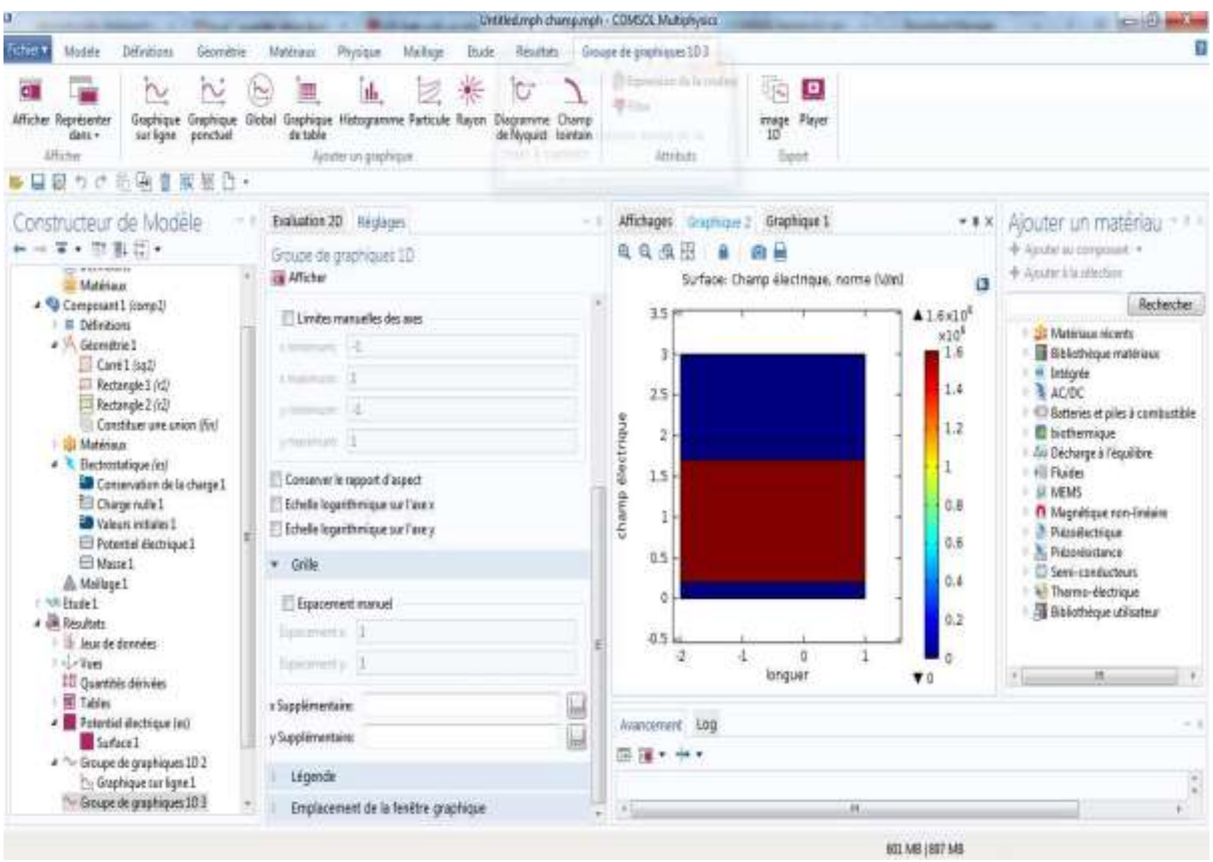

Figure 4: The main window of plane-to-plane configuration simulation

We simulate the electric field between the two electrodes of the treatment chamber, therefore, we have fixed the distance between the electrodes, and the diameter of the latter is 7cm. The volume of the chamber used for the treatment is given by the following formula:

$$V = n * r2 * d$$

With:
V: volume of the treatment chamber.
r: radius of the plane electrode
d: the distance between electrodes

RESULTS AND DISCUSSION

The simulation of the electric field between two flat electrodes gives the value optimum electric field to be applied. The benefit of using two electrodes planes is to cover the entire processing volume.
We set the inter-electrode distance at 1.7cm to have an electric field of 16kVolts / cm for a voltage of 28KVolts, the results are shown in the figure.5:

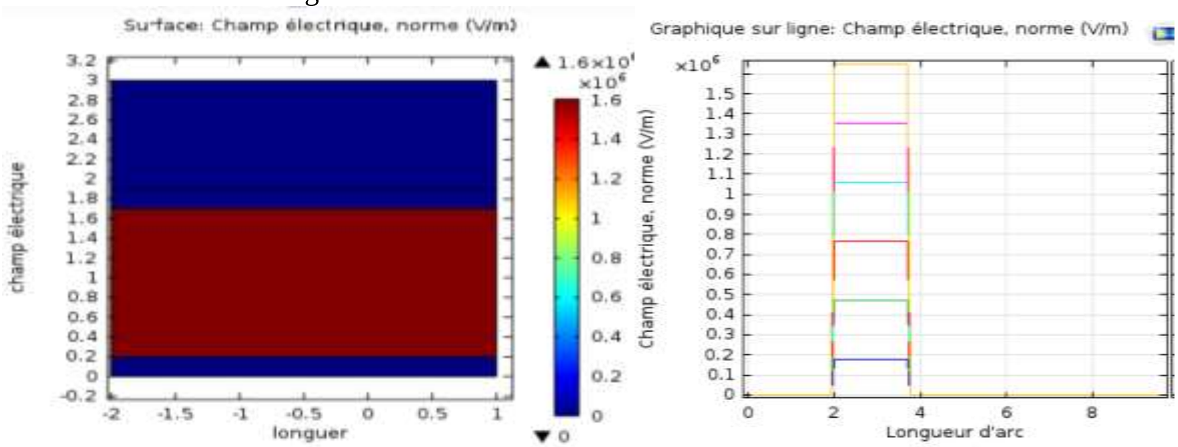

Figure 5: Electric field intensity along the vertical cutting axis

The simulation shows that for an inter-electrode distance d = 1.7cm, the value of the pulsed electric field is 16KVolts, and this is the value required for electroporation cells. Therefore, we see that the field is uniform between the plane electrodes and it is null outside the treatment surface and one notices that the form of field electric is rectangular.

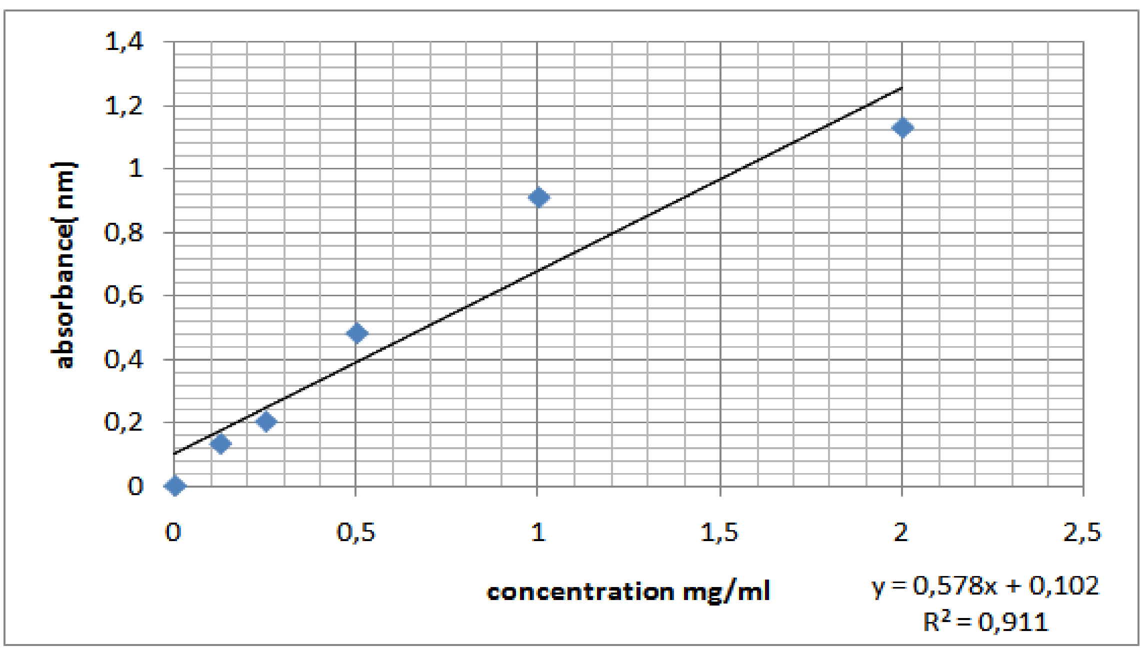

Figure 6: the Gallic acid calibration curve

The curve of the figure.6 gives the variation in polyphenol concentration in as a function of the absorbance for Gallic acid. So we determined the polyphenol concentration for different extracts, then we calculated the number of total polyphenols.

Pulsed electric field treatment

After treatment with PEF under two different voltages, we found the results, which are presented in the table. 1

Table 1: the results of treatment by a pulsed electric field

Extraction Time	Quantity extracted at 24Kv	Quantity extracted at 18Kv	Extraction yield at 24Kv	Extraction yield at 18Kv	Temperature at 24KV	Temperature at 18KV
15min	1,1	1,07	23,17%	22,5%	32C°	30C°
10min	1,3	1,27	39.56%	28,5%	43C°	40C°
5min	0,85	0,7	21,71%	18,8%	46C°	42C°

The figure 7 shows the variation for extraction as a function of time for two voltages 18 and 24 volts.

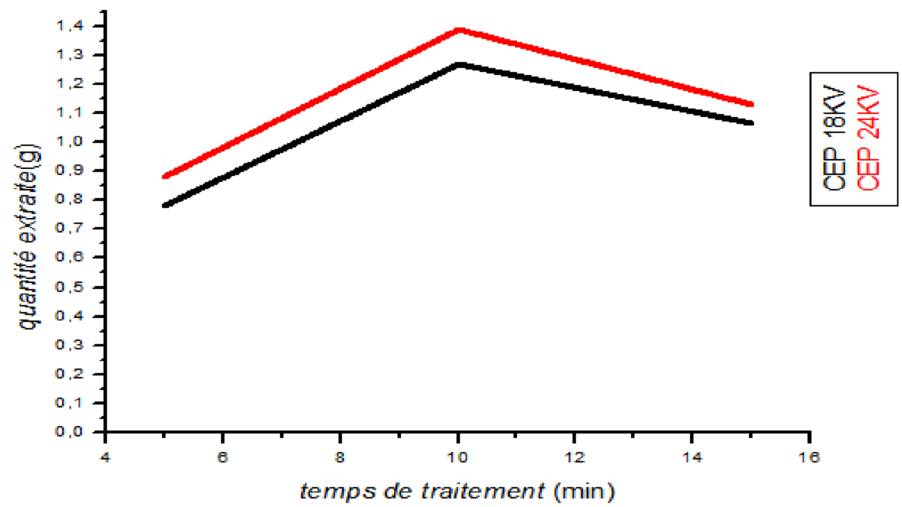

Figure 7: The representative curve of the number of polyphenols as a function of treatment time

Note that the electric voltage and the extraction time influence the quantity extracted, which is very important for treatment at 24Kvolts for 10 minutes extraction.

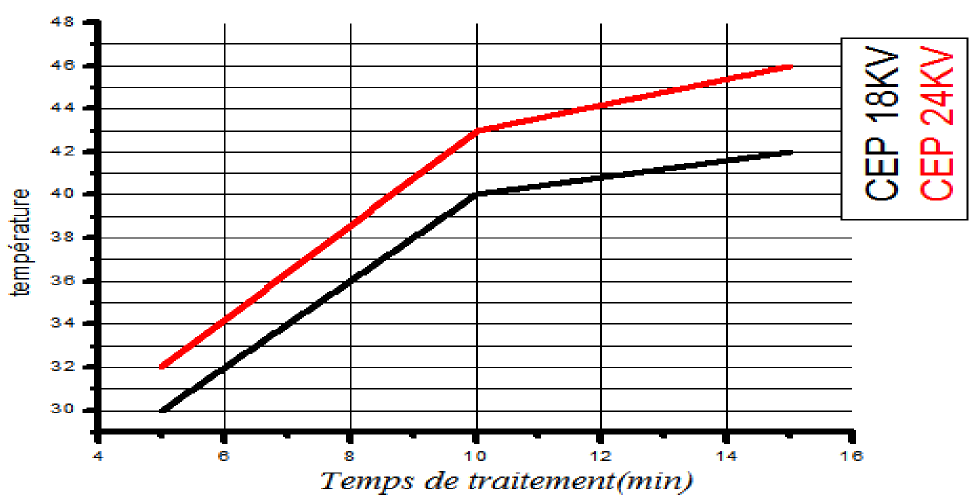

Figure 8: The representative curve of the treatment temperature as a function of time

It is observed that during treatment with PEF, the temperature increases according to the treatment time, because of the heat dissipated by the joules effect which causes the increase in the conductivity of the medium which improves the extraction of polyphenols at provided that this must not exceed 50C °.
Raising blood pressure for a long time may decrease the rate of polyphenols due to the increase in temperature.

CONCLUSION

From these results, it can be concluded that treatment with the pulsed electric field (PEF) makes it possible to rapidly and efficiently permeabilize thyme cells at ambient temperature and in a very short time, therefore at low energy cost since it has a direct influence on the cells by phenomenon electroporation. Besides, this treatment no longer affects the polyphenols because there is no thermal or chemical effect on the cells unlike biological methods (maceration and decoction) which use solvents and temperature, which influences the quality of extracts. During this study, it was also found that the yield of polyphenols from thyme by PEF depends on different processing parameters (electric field intensity and processing time) which were applied to study their effect on the extraction of polyphenols. The results of efficient polyphenol extraction could be explained by the fact that treatment with a pulsed electric field of moderate-intensity gives the extraction efficiency and the most extracted quantity of polyphenols.

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