GRAPE PROCESSING TECHNIQUES IN A HIGH FREQUENCY ELECTROMAGNETIC FIELD

Livia Bandici[1], Gheorghe Emil Bandici[2]
[1]University of Oradea, Faculty of Electrical Engineering and Information Technology, Electrical Engineering Department, Postal address1, 1 Universitatii Street, 410087 Oradea, Romania, e-mail: lbandici@uoradea.ro
[2]University of Oradea, Faculty of Environmental Protection, Department of Agriculture and Horticulture, 26 Gen. Magheru St., 410048 Oradea, Romania, e-mail: gbandici@yahoo.com

ABSTRACT: This paper presents results obtained by numerical modeling and experimental results of grape processing in a high frequency electromagnetic field. Numerical modeling was performed using the HFSS 15.0 software, and for experimental measurements we used an applicator with adjustable power. We analyzed the behavior of three varieties of grapes characterized by different flavor and color. In our study we aimed at establishing effective processing techniques both energetically and to obtain a high quality final product.

KEYWORDS: modeling, techniques, electromagnetic field, grapes.

1. INTRODUCTION

Wine quality depends to a very large extent on the manufacturing technology. The technological scheme of grape processing is determined by the type of wine that we will obtain, by compliance with specific oenological requirements for winemaking, and economic factors. Electromagnetic methods can be considered to be the most effective procedures to improve liquid-solid separation. Injecting a direct current has been studied in literature, leading to the conclusion of an increased efficiency, thanks to the combination of the pressure and electroosmosis effect.

Identifying technological opportunities to improve grape processing, conditioning the must and obtaining wine are very useful and effective. Unfortunately, uncontrolled use of the high frequency electromagnetic field can have undesirable effects on the quality of the final product (wine).

Finding more efficient technologies of grape processing by extracting as complete as possible useful compounds in wine products is a current approach for researchers.

The sensitivity of microorganisms in processing in a high frequency field depends on the characteristics of the cells, such as structure and size [1]. Also, factors such as: pH of the product, the presence of water, and the electrical conductivity may influence the effectiveness of this technology on biochemical reactions that contribute to the inactivation of microorganisms [2].

Although the underlying mechanisms of processing in a high frequency field are not yet fully explained on a molecular basis, the obtained results show significant changes in the permeability of the cell membrane [3].

The power of the electric field, temperature, the duration of treatment and the specific energy consumption are the main parameters affecting the degree of microbial inactivation [4]. In order to ensure effective microbial inactivation, it is recommended that the intensity of the electric field be 20...50 kV/cm, the impulse duration between 1...10 μs, and specific energy between 50...1000 kJ/kg [5]. However, the multitude of variable parameters produced by applying a high frequency field, and the characteristics of food require a systematic study of the individual influence of these parameters on the reactions.

In the study we conducted we took into consideration three varieties of grapes: Muscat Ottonel, Merlot, and Pinot Noir. In the first stage of the technological winemaking we have applied a high frequency field (MW) to a given quantity of these varieties of grapes.

In this paper we followed the effect of the treatment in a high frequency electromagnetic field applied in the technological process of winemaking.

2. THE ANALYSIS OF THE ELECTROMAGNETIC FIELD

The analysis of the electromagnetic field in processing in a high frequency field is based on Maxwell's equations [5], [6]:

$$\nabla x\mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t};\ \nabla x\mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t};\ \mathbf{D} = \varepsilon\mathbf{E};$$
$$\mathbf{B} = \mu\mathbf{H};\ \mathbf{J} = \sigma\mathbf{E} \qquad (1)$$

In the case of nonlinear fields J=f(E).

When processing in a high frequency field, the alternating electric field has the form $E_{max}e^{j\omega t}$:

$$\nabla x\underline{\mathbf{H}} = \underline{\mathbf{J}} + j\omega\varepsilon_0\varepsilon'\underline{\mathbf{E}} \quad (2)$$

If we only take into account the effect of the electrical conduction of free loads under the action of the electric field, and if we assume the dielectric constant to be real, only contributing to energy storage in the system, equation (2) can be written as [5]:

$$\underline{\mathbf{J}} = \sigma \cdot \underline{\mathbf{E}} + j\omega\varepsilon_0\varepsilon'\underline{\mathbf{E}} = (\sigma + j\omega\varepsilon_0\varepsilon')\cdot\underline{\mathbf{E}} \quad (3)$$

or

$$\underline{\mathbf{J}} = j\omega\varepsilon_0(\varepsilon' - \frac{j\sigma}{\omega\varepsilon_0})\cdot\underline{\mathbf{E}} \quad (4)$$

In the free space $\sigma = 0$, we obtain:

$$\underline{\mathbf{J}} = j\omega\varepsilon_0\varepsilon'\underline{\mathbf{E}} \quad (5)$$

where:

$$\underline{\varepsilon} = \varepsilon' - \frac{j\sigma}{\omega\varepsilon_0} = \varepsilon' - j\varepsilon'' \quad (6)$$

The dielectric properties of grapes are defined by the dielectric constant (ε') and the loss factor (ε''). The dielectric constant ε' measures the ability of a material to couple with the high frequency energy, while ε'' measures the ability of a material to absorb heat through microwave energy. The loss factor refers to the effective loss factor, which includes the effect of conductivity.

The dielectric constant and the loss factor of the grapes vary depending on the moisture content and temperature. Thus, at a temperature of 25 ^{o}C und moisture of 80 %, the dielectric constant (ε') has the value 72, and the loss factor (ε'') 17, while at a temperature of 70 ^{o}C (ε') it has the value 58, and (ε'') 12. At lower moisture contents, such as 15 %, and a temperature of 25 ^{o}C, the dielectric constant (ε') has the value 8, the loss factor (ε'') has the value 2, and at 70 ^{o}C, (ε') has the value 14,9 and (ε'') is 8.

In the case of the loss factor, at high moisture contents of 80[%], 60[%] and 40[%], ε'' decreases with increasing temperature, while at low moisture contents of 15[%] the tendency is to increase. This decrease is due to the interaction of the dipolar losses and conductivity with progressive decrease of free water, and the increase in the values of ε'' at low moisture contents (15[%]) is due to the presence of dissolved salts.

The presence of salts is inversely proportional to the initial moisture content of the grapes; thus, grapes with low moisture content can have a higher salt concentration compared to grapes with high moisture content. The salt concentration determines a higher ionic conductivity and hence higher loss factors. With increase in temperature dipolar losses decrease; this decrease is balanced by the increased conductivity losses, therefore the dielectric constant (ε') has constant values [7].

3. NUMERICAL RESULTS

For the numerical analysis of the penetration of the electromagnetic field in a dielectric (grape samples) we used the HFSS 15.0 numerical modeling software, acquired through the Project POSDRU/89/1.5/56287. This program uses the finite element method to generate the electromagnetic field solution. For this method, the space of the problem is divided into thousands of smaller regions, while the field in each sub-region is represented by a local function.

This program offers a clear image of the placement of the dielectric inside the applicator, the distribution of the field both inside and on the surface of the dielectric. To obtain a uniform electromagnetic field on the surface of the dielectric we considered the possibility of moving the load inside the applicator.

Figure 1 shows the geometry of the applicator and the placement of the dielectric inside the applicator.

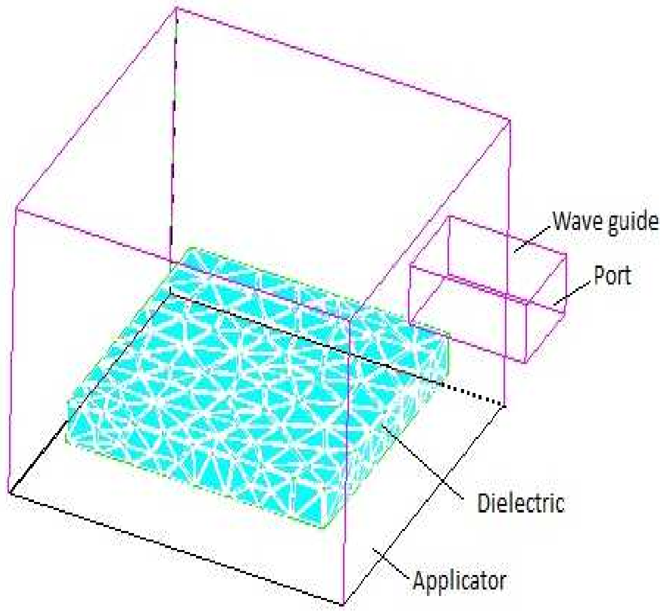

Figure 1. The geometry of the applicator

Figures 2 and 3 show the distribution of the electric field on the surface of the dielectric placed in the center of the applicator at a distance of 10 mm, and 20 cm, respectively, from the basic plan, the input power being 100 W.

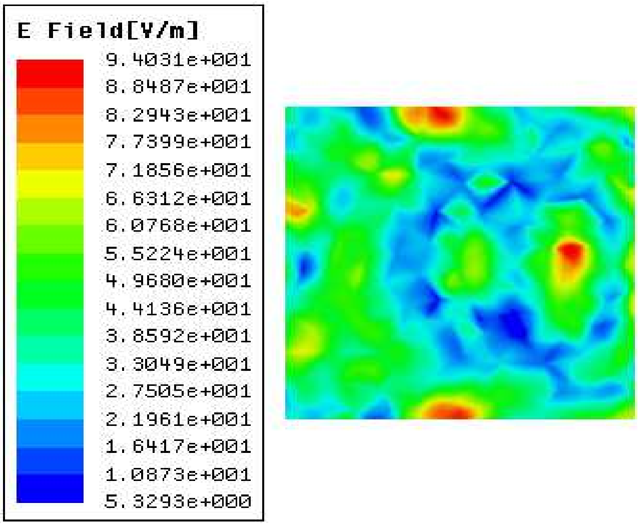

Figure 2. The distribution of the electric field on the surface of the dielectric placed 10 mm from the basic plan, P=100 W

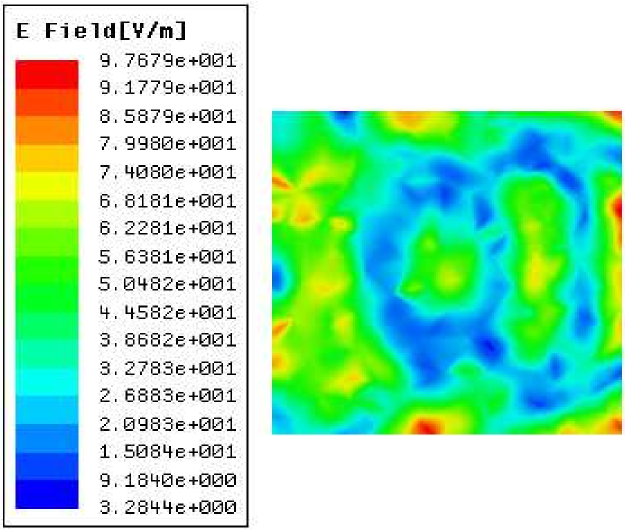

Figure 3. The distribution of the electric field on the surface of the dielectric placed 20 mm from the basic plan, P=100 W

Figures 4 and 5 show the distribution of the electric field on the surface of the dielectric placed in the center of the applicator at a distance of 10 mm, and 20 cm, respectively, from the basic plan, the input power being 200 W.

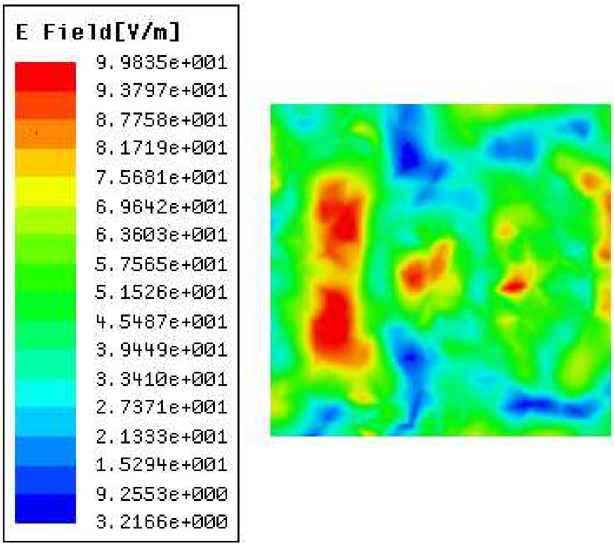

Figure 4. The distribution of the electric field on the surface of the dielectric placed 10 mm from the basic plan, P=200 W

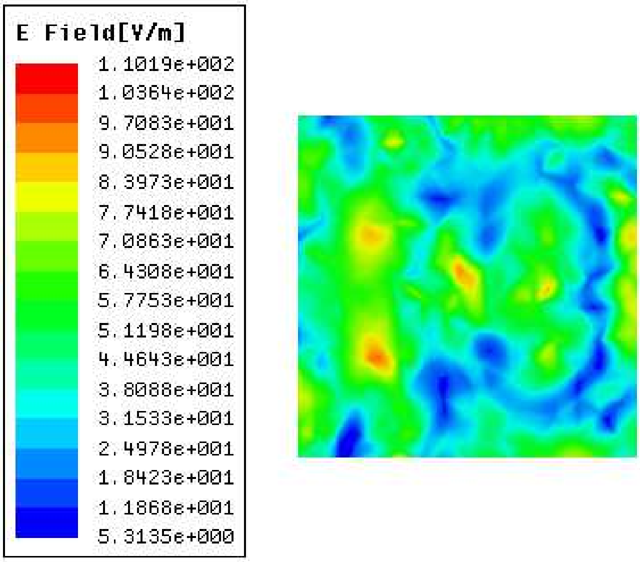

Figure 5. The distribution of the electric field on the surface of the dielectric placed 10 mm from the basic plan, P=200 W

By analyzing the results obtained from numerical modeling we notice an increase in the distribution of the electric field both by changing the position of the dielectric and by changing power. Therefore, at a power of 200 W and a distance of 20 cm from the basic plan we obtain a more uniform distribution of the high frequency field.

4. EXPERIMENTAL MEASUREMENTS

Experimental measurements for treating mash/ pomace have been carried out using a processing installation in a high frequency field with adjustable power from 100 to 1000 W. We processed the following varieties of grapes: Muscat Ottonel, Merlot, and Pinot Noir. The three varieties of grapes are characterized by different color and flavor that change very quickly. The aim of our study was to establish efficient processing techniques in terms of energy and to obtain a high quality final product.

We considered samples of the same weight (600 g), the processing time being 420 s for all studied samples, the temperature being measured at 1 minute intervals using a FLUKE Thermograph thermal camera.

By applying a power of 100 W, we obtain a maximum temperature between 38,4-39,5 (^{o}C), that is insufficient for conducting the technological process; by applying a power of 400 W, the temperature varies between 90,2- 97,6 (^{o}C). The sudden increase in temperature leads to the degradation of the product, because the maximum temperature should not exceed 70 (^{o}C).

We opted for a power of 200 W, the temperature reaching values between 67,4 - 69 ^{o}C, while for each variety of grapes 5 samples have been processed. Table 1 shows the temperature values for the samples of grapes processed in a high frequency field.

Table 1. The values of temperature for the three varieties of grapes processed

Processed varieties of grapes	m_i [g]	t [s]	θ[°C]				
			Number of studied samples				
			1	2	3	4	5
MUSCAT OTTONEL	600	0	21,1	21,3	21,0	21,2	21,0
		60	22,6	22,7	22,6	22,8	22,7
		120	29,5	30,0	30,1	30,1	30,2
		180	38,6	38,8	39,0	39,1	39,3
		240	47,1	47,4	47,5	47,4	47,7
		300	55,2	55,4	55,7	55,8	55,7
		360	61,6	61,9	61,9	61,6	61,8
		420	67,6	67,7	67,8	67,7	67,9
PINOT NOIR	600	0	21,2	21,2	21,1	21,2	21,2
		60	23,4	24,0	24,0	23,7	23,8
		120	33,2	33,7	33,8	33,8	33,7
		180	43,2	43,6	43,6	43,5	43,6
		240	53,8	53,7	53,6	53,8	53,6
		300	58,5	58,4	58,2	58,5	58,6
		360	65,6	65,5	65,7	65,8	65,9
		420	68,8	68,9	69	68,8	69
MERLOT	600	0	21,3	21,2	21,2	21,3	21,2
		60	25,2	25,6	25,7	25,6	25,8
		120	32,9	32,8	32,7	32,8	33,0
		180	44,1	44,0	43,9	44,0	44,1
		240	50.1	50,2	50,1	50,1	50,0
		300	53,3	53,4	53,0	53,2	53,0
		360	61,7	61,9	61,8	61,9	61,7
		420	68,9	68,7	68,8	68,6	68,9

Subsequently, for the three varieties of grapes (Muscat Ottonel, Merlot, and Pinot Noir) we performed physicochemical and biochemical analyses in different stages of the winemaking process [8]. As a result thereof we noticed a change in the pH, conductivity, Brix index, the refraction index. All of these parameters have higher values for samples processed in a high frequency field.

Figures 6, 7, 8 present experimental results of the processing of the three varieties of grapes in a high frequency field.

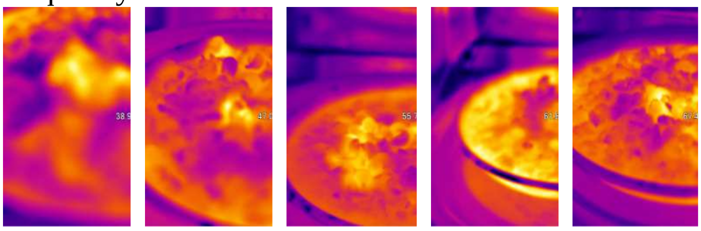

Figure 6. Experimental results of the processing of samples of MUSCAT OTTONEL grapes in a high frequency field

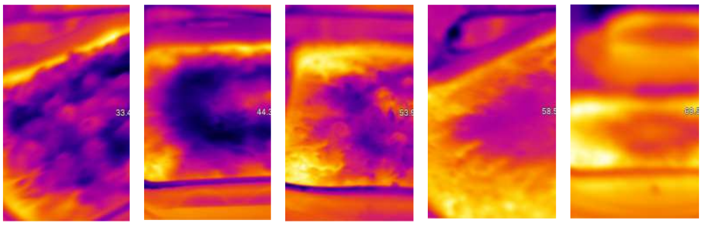

Figure 7. Experimental results of the processing of samples of PINOT NOIR grapes in a high frequency field

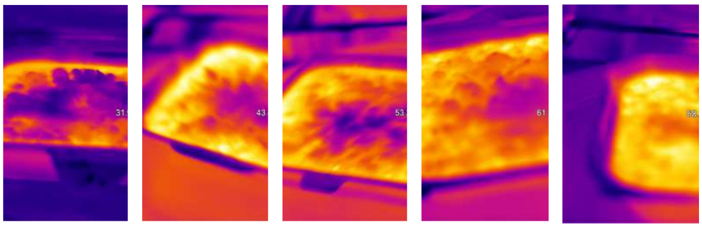

Figure 8. Experimental results of the processing of samples of MERLOT grapes in a high frequency field

In the case of red grapes the mash treated in a high frequency field and the untreated one have been maintained at room temperature for 3 days followed by the pressing process to obtain the must and by seeding with selected yeasts. Finally, after several steps, we obtained the wine that has undergone, in addition to physicochemical and biochemical analyses, also sensory analyses.

Before the biochemical analyses, we performed a UV-VIS screening of all the samples of the three stages in order to observe maximum absorptions specific to different bioactive compounds [9].

The red and rosé wines (Merlot, Pinot Noir) have intense and darker color tones.

5. CONCLUSIONS

The dielectric parameters of grapes change with temperature; the dielectric constant ε' measures the capacity of a material to couple with high frequency energy, while ε'' measures the capacity of a material to absorb heat through microwave energy. The presence of water in food causes high frequency energy absorption, the higher the moisture content, the stronger the heating effect.

Regarding the physicochemical and biological analyses of the studied samples we noticed a significant change for samples processed in a high frequency field.

Sensory analysis proves that processing in a high frequency field has beneficial effects on the transfer of substances in skin and clusters, giving additional color, flavor, and corpulence.

By applying the high frequency electric field we obtain a microbial inactivation in wine and an increase in the quality of the final product.

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