NUMERICAL MODELLING OF FRUITS DRIED IN MICROWAVE FIELD

Vicaş (Coman) Simina*

* University of Oradea, Faculty of Environmental Protection,
26 Gen.Magheru Street, Oradea, 410059,
Romania, e-mail: simina_vicas@yahoo.com

***Abstract*:**
The present study analyzes the electromagnetic field distribution of apple fruits inside microwave field at a frequency of 2.45 GHz. The process of drying dielectric materials in high frequency field depends on many factors: humidity, temperature, power, dielectric properties, frequency. The purpose of the present work is to achieve a uniform field inside the microwave applicator in order to obtain a dried quality product.

Keywords: apple fruits, microwave field, dielectric properties, numerical modeling, Ansoft HFSS

INTRODUCTION

The authors that studied the drying process of fruits and vegetables are Nelson, in 1978, who studied the dielectric properties corn seeds, in 2001 Garcia presented in his studies data concerning the analyze of grape juice, fruits like banana, orange and peach were discussed by Seaman and Seals in 1991, and pea puree by Tong in 1994. The author Nelson, collected all his research in processing fruits in microwave field and in 1994 has conducted a big project in which are being described and discussed the dielectric properties of fruits. In the project are presented the measurements of dielectric properties for 23 types of fresh fruits, having a frequency range between 200 MHz and 20GHz, with a temperature of 23°C (Sipahioglu and Barringer, 2003), (Garcia et al, 2001).

Nelson began on studying the dielectric properties of fruits and vegetables due to the need of a high quality product. It is known the fact that a non appropriate value of the generated power could destroy the quality of the dielectric (Wang et al, 2005). The electrical characteristics of fruits and vegetables indicate us the absorption of energy. The author Nelson conducted studies regarding dielectric properties of fruits and vegetables during years 1980, 1983 and 1992 (Nelson, 2008), (Kuang and Nelson, 1997).

Pilot systems that are using radio and microwave frequencies were developed to treat post harvested fruits and nuts. The process of drying was conducted in order to eliminate the insects. Researches in the field were carried out by Wang in 2001, Birla in 2004, Mitcham in 2004. Using radio frequency to dry fruits has the advantage of fast core heating of materials due to the direct interaction between RF energy and fruits tissue to quickly raise the center temperature, especially in case of large fruits.

Many authors suggested the use of microwave and radio frequency in the treatments of control post harvested insects: Andreuccetti in 1994, Hallman and Sharp in 1994, Nelson in 1996, Ikediala in 1999; Tang in 2000 and Wang in 2002 (Wang et al, 2005), (Birla et al, 2008), (Kumar et al, 2007).

MATERIAL AND METHODS

The measurement of dielectric properties of fresh apples was conducted by Thompson and Zacharia in 1971 at frequencies between 300 to 900 MHz. Tran, Stuchly and Kraszewski measured also the dielectric properties of apples with frequencies between 100MHz to 12Ghz. In 1991 Seaman and Seals measured the electrical characteristics of apples, both on external surfaces and exposed flesh at 150MHz to 6.4Ghz frequencies, and on internal tissues at frequencies of 200MHz to 20GHz were reported by Nelson, Forbus and Lawrence in 1994.

In 2000 the dielectric properties of four apple cultivars were also measured on frequencies of 30MHz to 3GHz by Ikediala, Tang, Drake and Neven.

In 2003 was studied the temperature dependence of the dielectric properties of apples at 2450 MHz by Sipahioglu, Barringer and in the frequency range from 10 to 1800 MHz by Nelson (Wen-Chuan Guo et al, 2007), (Garcia et al, 2001), (Feng et al, 2002).

The dielectric properties of materials are described by permitivity, that influences the reflection of electromagnetic waves at interfaces and the attenuation of the wave energy within materials. Relative permittivity describes permittivity related to free space. The real part is expressed in terms of the dielectric constant (energy stored) which influences the electric field distribution and the phase of waves traveling through the material. Dielectric loss factor, which is the imaginary part, mainly influences energy absorption and attenuation. The equation for relative permittivity is (Ikediala, 2000):

$$\varepsilon = \varepsilon^{'} - j\varepsilon^{''} \quad (1)$$

where ε is the relative permittivity

$\varepsilon^{'}$ is the dielectric constant

$\varepsilon^{''}$ is the dielectric loss factor

$j = \sqrt{-1}$.

The loss angle tangent is being calculated with the relation between the loss factor and dielectric constant:

$$tg\delta = \frac{\varepsilon^{"}}{\varepsilon^{'}} \qquad (2)$$

The penetration depth of microwaves is defined as the depth where the power is reduced to 1/e ($e = 2 \cdot 718$) of the generated power. The radio frequency energy penetrates further into fresh fruits and nuts than microwaves because of the much longer wavelength of radio frequency waves.

The penetration depth is described by the relationship (Wang et al, 2003):

$$d_p = \frac{c}{2\pi f \sqrt{2\varepsilon^{'}[\sqrt{1 + (\varepsilon^{"} / \varepsilon^{'})^2} - 1}} \qquad (3)$$

where c represents the speed of light in free space- $3 \times 10^8 ms^{-1}$
f is the frequency (Wang et al, 2003);

NUMERICAL MODELING

In the present study we numerically simulated the apple fruits inside a commercial microwave oven. The distribution of the electric field through the dielectric and cavity was followed. The dimensions of the cavity are x=330 mm, y=350 mm and z=400 mm. The dielectric is supposed to be in the middle of the cavity in order to have the best position for a uniform distribution of the field. The boundary conditions were defined as Perfect E on the cavity's faces. The dielectric properties of the apple, at a humidity of 34.6% are $\varepsilon^{'}$=19.7 and $tg\delta$ =0.33 (Feng et.al, 2002).

The numerical simulation was made using the commercial software Ansoft HFSS (High Frequency Structure Simulator).

In figure 1 is presented the settings concerning the mesh of the dielectric material.

For a better understanding of the geometry that was created for the present numerical simulation, figure 2 describes the cavity, the position of the dielectric material, in our case the apple fruit and the position of the waveguide and port.

In figure 3 it is described the electric field distribution through the faces of the dielectric material.

The electric field distribution on the base of the cavity is being presented in figure 4, with the remark that the highest values of the electric field are on the margins of the cavity, as it also can be observed in figure 3.

Figure 5 describes the distribution of the electric field on the cavity's faces and in the wave port, remarking the highest values of the electric field at the entrance of the waveguide, in the port.

In order to point out the electric field distribution inside the cavity, were made nine planes, cut off planes, that show the field values in specified areas of the cavity (figure 6).

The magnetic field distribution through the surface of the cavity and dielectric is presented in figure 7.

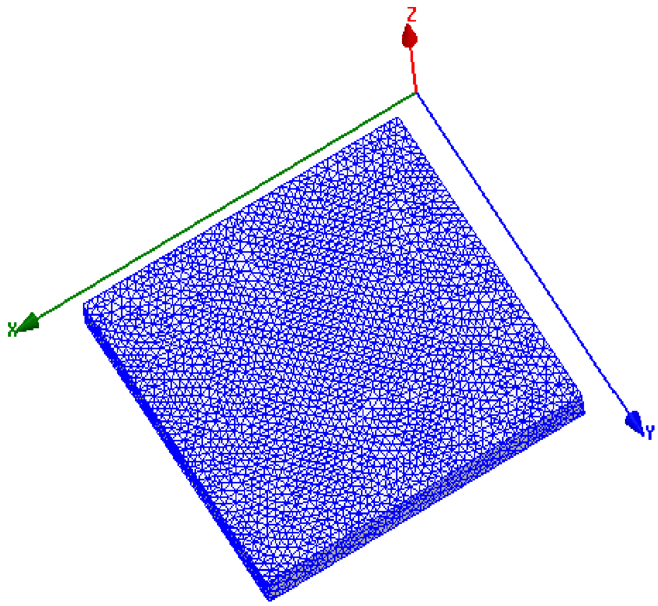

Fig.1 Mesh settings in the dielectric material

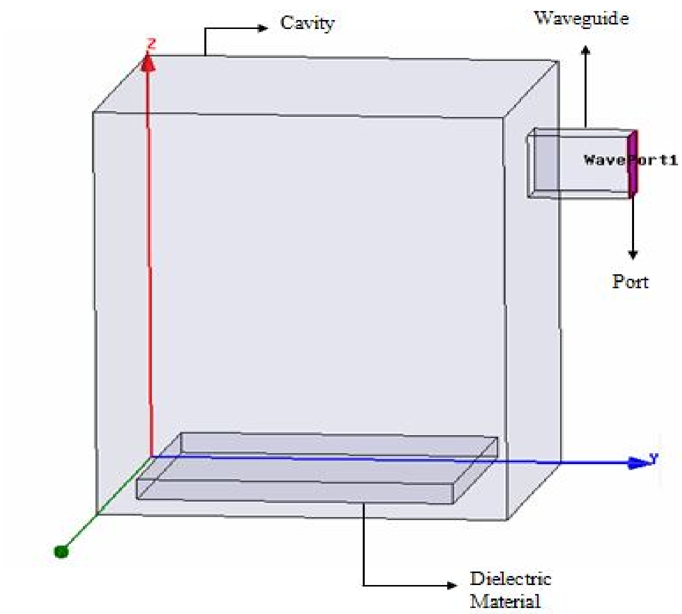

Fig. 2 The geometry of the cavity

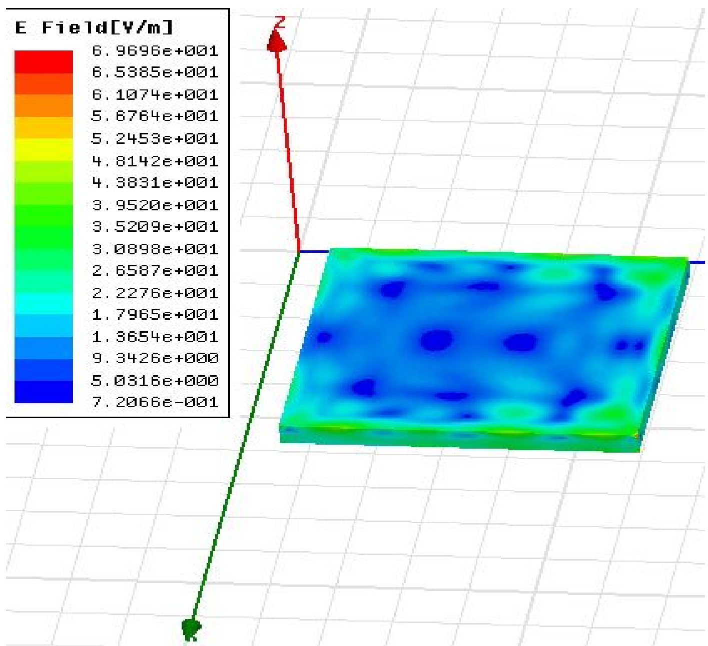

Fig.3 The Distribution of the Electric Field through the Dielectric

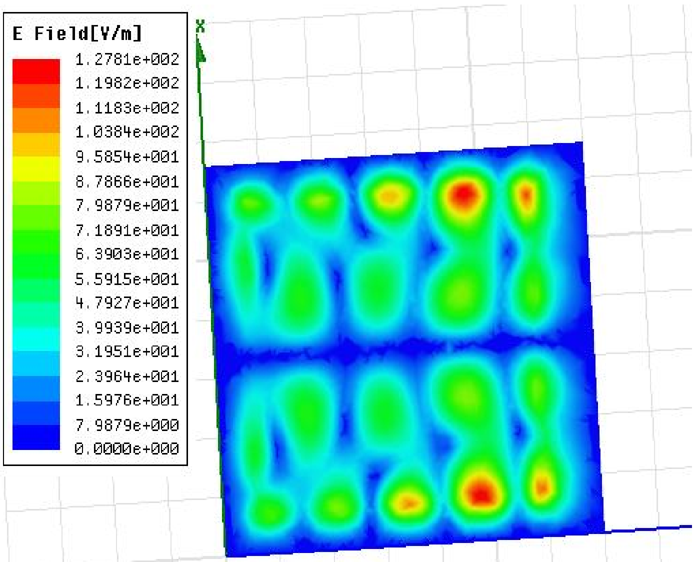

Fig.4 The Distribution of the Electric Field Through the Cavity's Face

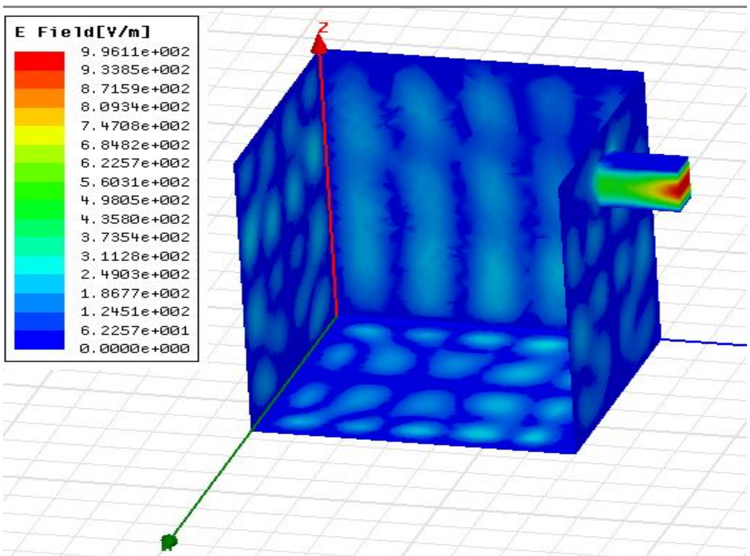

Fig.5 The Distribution of the Electric Field Through the Faces of Cavity and Wave Port

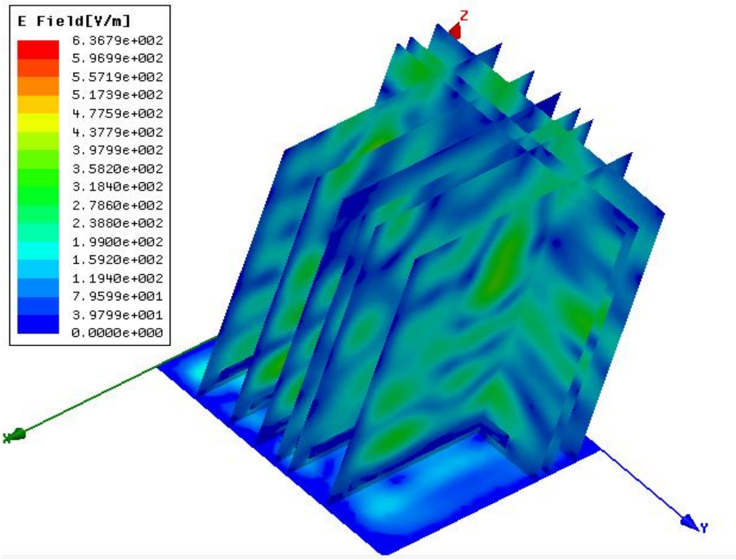

Fig.6 Distribution of electric field with nine planes in the cavity

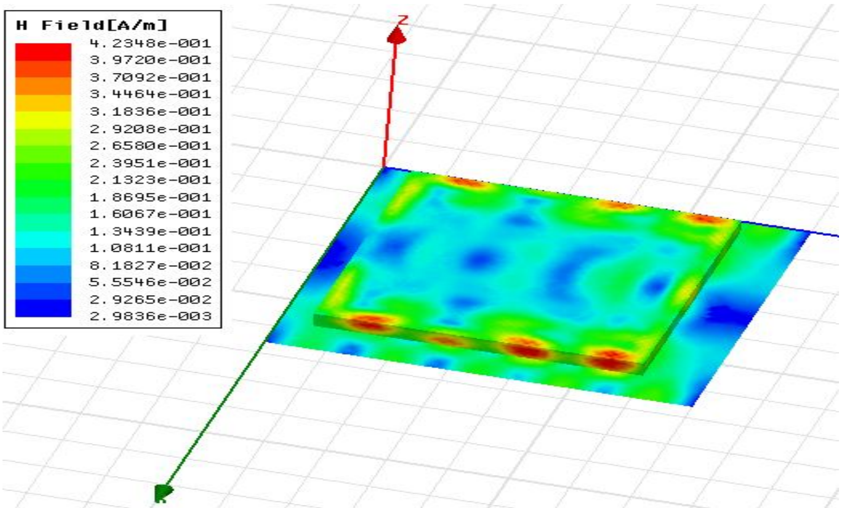

Fig.7 The Distribution of the Magnetic Field Through the Dielectric and Cavity

CONCLUSIONS

When drying dielectric materials in microwave field there has to be taken into account de position of the material in the cavity. Another important issue are the dielectric properties of the materials, the frequency, the applied power.

During drying of fruits and vegetables that have a higher moisture content than other products it is important to use airing in the cavity to avoid forming a film of water on the surface of the fruit. If the water forms on the surface of any dielectric, that water will absorb differently the power of the microwaves and it will create a non homogenous distribution of the temperature.

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