THE DRYING PROCESSES OF CORN SEEDS IN A MICROWAVE FIELD

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Abstract
This paper present aspect regarding the drying of corn seeds in a microwave field. The main part of this work stays in the applicative, experimental part, by finding out the drying corn seeds parameters, with extension possibility for other cereal grains. Our purpose is to find out the influence that drying with microwaves without cold or hot air stream to eliminate the water from the seed bed has on the corn seeds composition and germination. In the drying process the seeds tolerate high temperatures, for each species being registered a limit value of the temperature, beyond that the germination is being affected.

Key words: germination, corn seeds, dielectric properties, microwave heating, numerical modelling.

INTRODUCTION

Microwaves with their ability to rapidly heat dielectric materials are commonly used as a source of heat. In the food industry microwaves are used for heating, drying, thawing, tempering, sterilization etc. The number of applications using microwave radiation as a source of thermal energy has increased in the recent past, mainly due to two major advantages over conventional heating techniques: quick start-up periods and the ability to heat a material evenly. Radiation whose frequencies range from 300 MHz to 300 GHz with wavelengths ranging from a few mm to 30 cm are referred to as microwaves and heat effects that occur in this frequency range will be referred to as microwave heating (Maghiar and Soproni, 2003).

The temperature distribution in a product submitted to microwave radiation is governed by the interaction and absorption of radiation by the medium and the accompanying transport process due to the dissipation of electromagnetic energy into heat. This phenomenon is described as Microwave Heating (Bandici and Molnar, 2007).

MATERIAL AND METHODS

The use and expectations of seed treatments are greater today due to the impact of environmental regulations that have either banned or restricted the use of older fungicides and the development of biological and chemical control agents that offer the potential to control bacteria, viruses, and insect and provide plant protection well into the growing season.

The agricultural cultures may tolerate high temperatures of the hot air in the first stage of the drying process. This tolerance is limited to the temperature at which the germination is affected (Metaxas and Meredith, 1983).

The hot air injected in a high frequency dryer usually insures the transfer of the vapors from within the enclosure to the exterior. By recirculation the evacuated vapors which insure the heating of the air pumped into the drying enclosure, a large part of the latent heat of the vapors can be transferred to the air flux which enters the applicator, determining a substantial increase of the efficiency of the used drying chamber (Nelson, 1995), (Molnar et al., 2008).

The experiment was made on the corn seeds, type Turda Super (type semi early) using the power of the microwaves without air stream.

The seeds were dried using an installation from the Laboratory of Microwave Technologies, Electrical Engineering Department, Faculty of Electrical Engineering and Information Technology, University of Oradea.

This microwave system has three base components: a microwave generator with a maximum power of 850W, waveguide and applicator. The microwave system also has an absorbent charge, a directional coupler and an impedance adapter with 3 divers.

The stand is supplied at the tension of 220V±5%, 50 Hz frequency.

With the help of the measurement devices we monitored the parameters of the process: the power of the microwaves, the direct power, the humidity air stream at exit, the position of the divers at the adaptation of the charge impedance, the temperature of the air stream which is set so that it doesn't exceed 55^0C±5%, the temperature from the microwave seed bed and in the close proximity of the system.

At the end of each experiment the seeds were marked and placed into paper bags and sent to a specialized lab for determining the germination rate.

Electric field equations in microwave regime and thermal field equations are those well known (Metaxas and Meredith, 1983), (Datta, 2001).

The power dissipated in the heating systems with microwaves is proportional with the frequency, the dielectric permittivity and the distribution of the electric field (Zhang and Datta, 1999):

$$P = \omega \cdot \varepsilon_0 \cdot \varepsilon' \cdot \tan\delta \cdot E^2 \cdot V \quad (1)$$

Where E is the intensity of the electric field [V/m], f is the frequency [Hz]; V is the volume of material [m^3].

The change of microwave energy absorption value by the corn seed bed appears because of the material properties variation with temperature and humidity.

These parameters are dielectric constant (ε'), the dielectric loss factor (ε''), that lead to the calculation relation for permittivity:

$$\underline{\underline{\varepsilon}} = \varepsilon' - j\varepsilon'' \quad (2)$$

The relation between the dielectric loss factor and the dielectric constant is the tangent of the loss angle:

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (3)$$

To simplify the simulation model we considered a Teflon tray with corn seeds a homogeneous medium with equivalent dielectric properties, taking into account the dielectric properties of corn seeds, water and air. (Palade et al., 2010)

The dielectric properties of the reduced homogeneous model (ε_{equiv}) are computed by energy-based equivalence, considering that the total absorbed power and total electric energy have the same values in the heterogeneous (composed by i different sub-domains) and equivalent homogeneous models (Morega, 2006):

$$\int_i \frac{1}{2}\varepsilon_i (E_i)^2\, dv = \frac{1}{2}\varepsilon_{equiv} \int_i (E_i)^2\, dv \quad (4)$$

The equivalent mass densities are approximated by weighted arithmetic mean.

Through the numerical modelling we determined the electromagnetic field distribution in the multimode cavity and in the corn seeds mass after a given time of exposure to microwave radiation (Metaxas, 2001). We have used the facilities offered by commercial software HFSS (High Frequency Structure Simulator) for the electromagnetic field problem.

In Fig. 1 is shown the electric field distribution on the dielectric surface and Fig. 2 shows electric field distribution E [V/m] in a plane passing through the dielectric's middle.

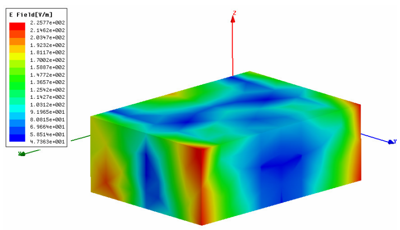


Fig. 1. Electric field distribution on the dielectric surface, z component [V/m]

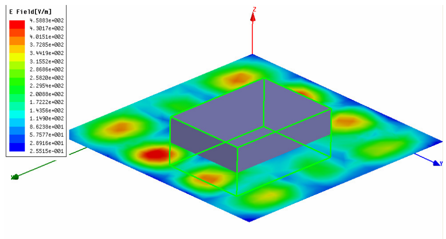


Fig. 2. Electric field distribution in the dielectric, z component [V/m]

RESULTS AND DISCUSSION

Before each experiment the balance was adjusted so the mass of 0.0g (tare) may be displayed with the weighing bowl placed on the platform. The measurements were performed every 30 seconds without interrupting the functioning of the installation. In order to see and study the influence that the microwaves have on the seeds treated in a microwave field the corn grains were placed for germination and the progress of the germination process was monitored. Thus we want to determine which conditions of temperature, power and humidity are favourable to the germination of the corn seeds treated in microwave field.

For determining the percentage of humidity of the dried seed sample we use the mass of the seed before drying, m_i, and after drying m_u:

$$\text{U [Humidity]} = \frac{m_i - m_u}{m_u} \times 100[\%] \tag{5}$$

The two samples that will be presented were treated in microwave field, without air stream to eliminate the water from the seed bed.

For the first case we used a constant power of 50W for 15 minutes (see Fig. 3), having an initial mass of wet corn seeds of 107.11g and a final mass of 97.49 g. After drying the corn seeds in the microwave field we noticed a loss of 9.62 g of water that has evaporated from the seed bed. The humidity eliminated from the seed bed is only of U=9.86%. After drying we could see water on the surface of the seed bed, because we used only the microwave power, without air stream that would eliminate the vapors from the seed bed. During our testing the outside air temperature and the temperature from the seed bed had a constant growth. The humidity from the seed bed had a big growth in the first four minutes from 54.5% to 92%.

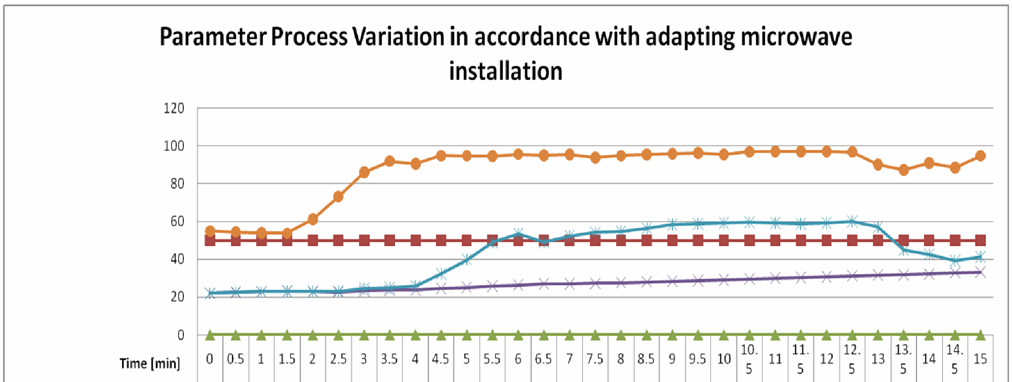
The rate of germination for this sample is very low, only G=10% and it could be seen a weak improve of the corn seeds.

The parameters obtained after this experiment is being presented in the next table (see Table 1):

Table 1

Parameters in constant heating

Constant Power	50 W
Initial weight	107.11 g wet corn
Final weight	97.49 g dried corn
Initial seed bed humidity	54.5%
Final seed bed humidity	94.8%
Humidity(calculated with (5))	U=9.86%
Germination	10%
Initial Seed Bed Temperature	22.4^{0}C
Final Seed Bed Temperature	33.3^{0}C
Initial temperature of the outside air stream	22.72^{0}C
Final Temperature of the outside air stream	41.27^{0}C



Time [min]	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5
Supply Power	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Direct Power	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Reflected Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seed Bed Temperature	22	22.4	22.8	23	22.8	22.7	23.2	23.6	23.9	24.5	25.2	25.8	26.4	27.1	27	27.3
Output Air Temperature	22	22.7	22.8	22.9	23	23.2	24.5	25.1	25.9	32.4	39.9	48.9	53.5	49	52.3	54.2
Humidity	55	54.5	54	53.8	61.3	73.2	86	92	90.6	94.9	94.9	94.7	95.6	95	95.5	93.9

Time [min]	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Supply Power	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Direct Power	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Reflected Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seed Bed Temperature	27.6	28	28.4	28.8	29.2	29.7	30.1	30.4	30.7	31.3	31.7	31.8	32.2	32.9	33.3
Output Air Temperature	54.7	56.3	58.3	58.9	59.2	59.6	59.2	58.9	59.3	60.1	57	44.9	42.5	39.2	41.3
Humidity	94.9	95.5	95.9	96.3	95.6	96.9	97	97.2	97	96.9	90.2	87.4	91	88.5	94.8

Fig. 3. Parameters variation in constant heating 50W/15min., U=9.86%, G=10%, using microwave heating

For the second sample we used a constant power of 20W for 15.5 minutes, having an initial mass of 105.42 g of wet corn and obtaining after drying in the microwave field 102.87 g of dried corn (see Fig.4).

We noticed a very low difference between the initial and final mass – 2.55 g of evaporated water from the seed bed. The humidity eliminated from the seed bed is U=2.47%.We remarked the fact that when using a constant power of 20W the temperature from the seed bed had a big growth from 21.4^0C to 63.5^0C (see minute 15.5). Because the seeds that were used for the second sample had a bigger mass, were wetter and more compact than the others, it absorbed more energy.

The rate of germination in this case was G=70%, the seeds presenting a very good develop.

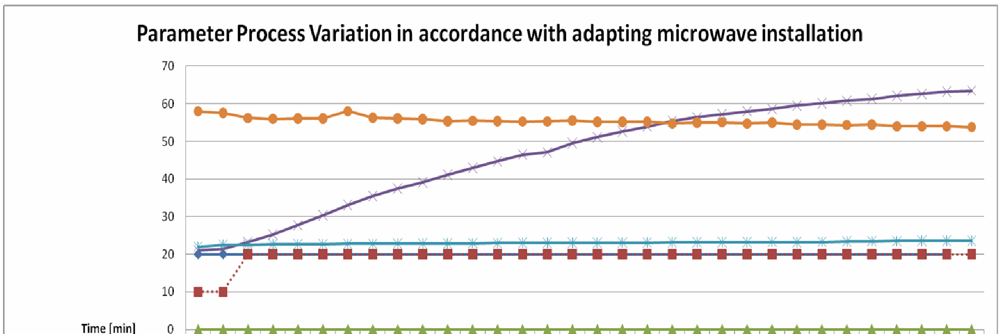
Table 2

Parameters in constant heating

Constant Power	20 W
Initial weight	105.42 g wet corn
Final weight	102.87 g dried corn
Initial seed bed humidity	57.57%
Final seed bed humidity	53.82%
Humidity(calculated with (5))	U=2.47%
Germination	70%
Initial Seed Bed Temperature	21.4^0C
Final Seed Bed Temperature	63.5^0C
Initial temperature of the outside air stream	22.49^0C
Final Temperature of the outside air stream	23.63^0C

From the experimental data obtained till now, using only the power of the microwaves, this sample presents the best rate of germination and the best develop of the plants. This fact can be explained by the thing that we used a low power of the microwaves and the temperature from the seed bed didn't rise over the value of 63.5^0C.

For the first sample, the low rate of germination is being caused by the thermal instability and by the impossibility of measuring the temperature in each point of the seeds bed.



Time [min]	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	15.5
Supply Power	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	
Direct Power	10	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Reflected Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seed Bed Temperature	21	21.4	23.2	25.2	27.7	30.3	33.1	35.5	37.5	39.1	41.1	42.9	44.7	46.5	47.1	49.5	51.1	52.6	54	55.4	56.4	57.2	58	58.6	59.5	60.1	60.8	61.3	62.1	62.6	63.2	63.5
Output Air Temperature	22	22.5	22.6	22.6	22.7	22.7	22.8	22.8	22.8	22.9	22.9	22.9	23	23	23	23	23.1	23.1	23.1	23.2	23.2	23.2	23.3	23.3	23.3	23.3	23.4	23.5	23.5	23.5	23.6	23.6
Humidity	58	57.6	56.2	56	56.1	56.2	58	56.3	56.1	55.9	55.4	55.5	55.4	55.3	55.3	55.5	55.2	55.2	55.2	54.8	55	55.1	54.8	55	54.4	54.4	54.4	54.5	54	54	54	53.8

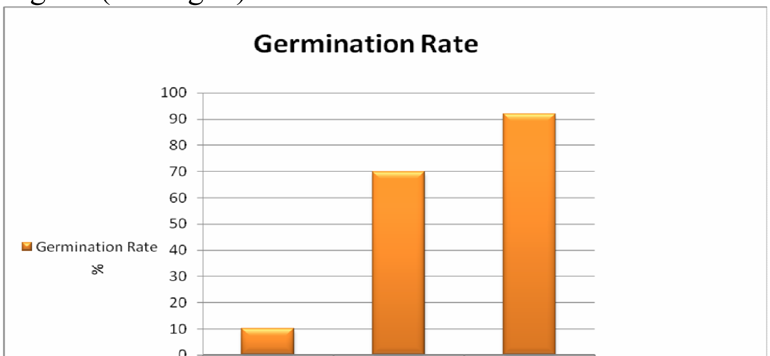
Fig.4. Parameters variation in constant heating 20W/15.5min., U=2.47%, G=70%, using microwave heating

The germination is determined with germinators of type Linhard, sterilized; one uses filter paper moistened with tap water, kept under niche at 20^0C±2-3^0C (Boldor et al., 1981).

We used 160 seeds of each sample, which we distributed evenly in straight, equidistant rows; the germinators were covered with bottle lid, they were labelled and placed in a glass drawer at constant humidity and temperature.

The germination is considered finished when the root has a length equal to the length of the seed, and the stem has ½ this length (Davidescu and Davidescu, 1981).

The germination rate of these two samples is being presented in the next figure (see Fig. 5):



	Sample 1	Sample 2	Witness Sample
Germination Rate	10	70	92

Fig. 5. Germination Rate measured after 14 days

CONCLUSIONS

We observe from the numerical modelling that the electric field inside the corn seeds mass is not homogenous; in some areas it has greater values than in other, that leading to high temperature areas that can destroy the seeds rate of germination. For this reason, from the experimental result we obtained a low rate of germination for the first sample, caused by the thermal instability and by the impossibility of measuring the temperature in each point of the seeds bed, when we used a high power of the microwaves.

From the experimental data obtained till now, using only the power of the microwaves, the second sample presents the best rate of germination and the best develop of the plants. This fact can be explained by the thing that we used a low power of the microwaves and the temperature from the seed bed didn't rise over the value of 63.5^0C.

We could say that a constant temperature and humidity has a good influence on the germination rate of the corn seeds. Using air stream is important to eliminate the water from the seed bed and to avoid the hot spots, so there could be a homogenous medium in what concerns the temperature in the whole mass of the seeds.

Because these samples were the first experimental data obtained we used samples of corn with a low rate of germination caused by the improper way of keeping the seeds in the Microwave Technologies Laboratory. In the present we obtained for some types of seeds a growth of the rate of germination over the witness sample's rate of germination, which is a big step forward.

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