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THE ELECTRIC FIELD INFLUENCE ON DRYING CURVES OF GRAIN SEEDS IN A FLUIDAL LAYER

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A b s t r a c t. This paper presents results of an investigation carried out for determining the influence of electrostriction forces in a convection drying process of grain seeds. These investigations were carried out in a drying chamber operating in a fluid bed mode. Experiments involved drying samples of wheat and rape seeds. The following parameters were varied during tests: drying temperature, electrical field intensity in the drying chamber.

K e y w o r d s: grain seeds, drying, electric field

THEORY

From the physical point of view, grain seeds are dielectric with low polarizability and non-uniform structure. Their resistivity, dielectric permeability and loss tangent depend on many factors, but the most important are, humidity, internal structure and temperature [1,3].

The dependence of a permeability on the seed's mechanical properties, especially its density, influences the electrostriction force in a dielectric field.

Volume forces which arise in the seed follow the field influence on displacement charges induced in the result of its polarization.

If volume free charges are located with a density within the space of the dielectric, then the following force acts on its volume unit Eq.(1):

$$f = \rho E - \frac{1}{2}\varepsilon_0 E^2 \,\mathrm{grad}\varepsilon + f_t = f_p + f_t \tag{1}$$

where ρE is a force acting on free charges, $\frac{1}{2}\varepsilon_0 E^2 \mathrm{grad}\varepsilon$ - a force that follows the preliminary dielectric non uniformity, $f_p = \rho E - \frac{1}{2}\varepsilon_0 E^2 \mathrm{grad}\varepsilon$, f_t - an electrostriction force.

The first two components appear as an orientation moment.

The electrostriction forces Eq.(2) can be determined from the expression (1) :

$$f_t = \frac{1}{2}\varepsilon_0 \mathrm{grad}\left(E^2 \tau \frac{\partial \varepsilon}{\partial \tau}\right) \tag{2}$$

where τ is a seed density, kg/m^3; $\frac{\partial \varepsilon}{\partial \tau}$ - the change of a seed permeability caused by a the change of density τ during the distortion.

These forces occur on particular layer of the seed. They tend to displace parts of the environment in relation to one another. This leads to flexible stresses in the environment (the compression and the tension of layers) and can cause internal distortions in the seed.

Assuming that free charges are absent in the examined environment ($\rho = 0$) and the seed model layers are homogeneous ($\mathrm{grad}\varepsilon = 0$), the expression (1) has the form Eq.(3):

$$f = f_t \quad (3)$$

whilst Eq.(4):

$$f_t = -\frac{1}{2}\varepsilon_0(a_1 + a_2)\text{grad}E^2 \quad (4)$$

where a_1 is the parameter that expresses some increase of resulting from the tension of layers parallel to the electrostatic field forces [1], a_2 - the parameter that expresses some increase of ε correlated to the tension perpendicular to the electrostatic field forces [1].

Grain seeds have a laminar structure. Particular layers contain different amounts of water. This causes differences among the dielectric constants of the layers. The seed exposed to the electric field is therefore compressed or stretched. This can lead towards some changes in humidity retention ability. In this case, the electric field could be used to reduce the energy consumption of the drying process.

THE CONSTRUCTION OF THE LABORATORY STAND

The diagram of the laboratory stand is presented in Fig. 1.

The samples of seeds that are being dried are placed in the capacitor. HV source makes possible a fluent adjustment of the electric field intensity in the capacitor. The heating element warms up the air flux coming from the fan, to the assumed temperature. The supplier of the heating element operates in the automatic control system. The air flux that is needed to dry the seeds is generated from the fan driven by the DC motor. Constant rotational speed was maintained during all experiments.

RESULTS AND DISCUSSION

The experiments were carried out using wheat and rape seeds. There were four series of experiments for each temperature 318 and 328 K and also for three voltages, i.e.: 0, 2, 4 kV.

Drying curves for wheat seeds in temperatures 318 and 328 K and electric field intensities: 0, 1 and 2 kV/cm are presented in Fig. 2 and 3 and measurement results in Table 1.

Drying curves for rape seeds in the temperature 318 K, for electric field intensities: 0 kV/cm, 1 and 2 kV/cm are presented in Fig. 4 and measurement results - in Table 2.

Energy saving $q_{\%}$ of the drying process which is a result of the electric field influence is computed on the basis of the assumption [2] that two samples dried in the same conditions and time, absorbed the same amount of heat energy Q required to evaporate water although one sample was subjected to the electric field. Thus, it can be noted that:

$$Q_1 = Q_2 \quad (5)$$

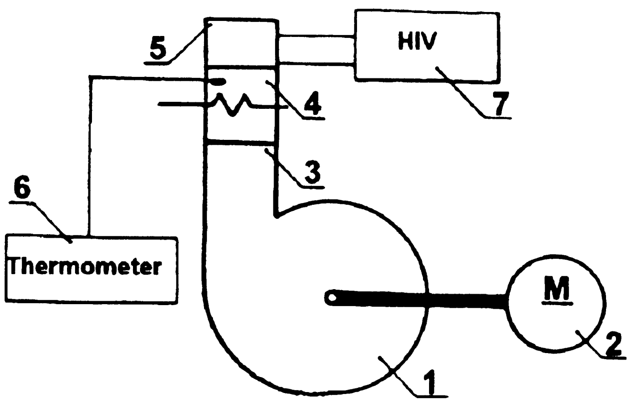

Fig. 1. The diagram of the laboratory stand to dry a fluidized layer of seeds: 1 - a fan; 2 - DC motor; 3 - air inlet pipe to a seed container; 4 - a chamber and its heating element; 5 - a flat capacitor (a container of dried seeds); 6 - a thermometer, 7 - HIV source (NW).

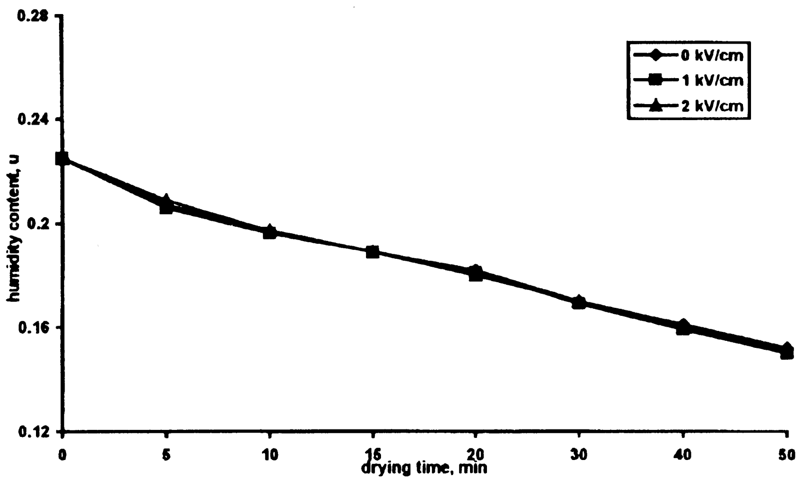

Fig. 2. Drying curves of wheat seeds in temperature T=318 K.

Table 1. Drying curves of wheat seeds of a mean preliminary humidity w_p = 18.4 % in temperatures T = 318 and 328 K, and electrostatic field intensities: E = 0, 1 and 2 kV

Drying time τ (min)	Humidity content in wheat u ($kg_{H_2O}/kg_{d.m.}$)					
	Drying temperature T (K)					
	318			328		
	Electric field intensity E (kV/cm)					
	0	1	2	0	1	2
0	0.225	0.225	0.225	0.225	0.225	0.225
5	0.207	0.206	0.209	0.202	0.200	0.200
10	0.197	0.196	0.197	0.186	0.183	0.183
15	0.189	0.189	0.189	0.174	0.169	0.173
20	0.182	0.181	0.180	0.164	0.159	0.163
30	0.170	0.169	0.170	0.151	0.146	0.151
40	0.161	0.159	0.160	0.140	0.136	0.140
50	0.152	0.150	0.151	0.130	0.127	0.129
Energy saving $q_{\%}$ (%)	-	2.7	1.4	-	3.1	1.0

d.m. - dry mass.

where Q_1 is amount of heat absorbed by the sample not subjected to the electric field, J; Q_2 - amount of heat absorbed by the sample subjected to the electric field, J; but:

$$Q = m\, r \tag{6}$$

where m is mass of evaporated water, kg; r - heat of vaporization, J/(kgK).

After some tranformations, the Eq.(7) can be obtained:

$$q_{\%} = \left(\frac{u - u_2}{u - u_1} - 1 \right) 100\ ,\ \% \tag{7}$$

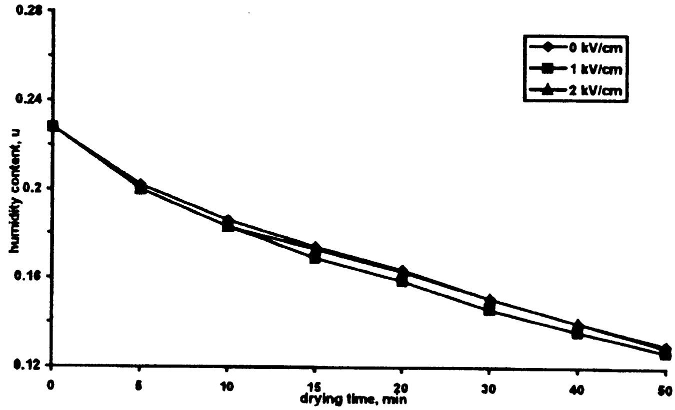

Fig. 3. Drying curves of wheat seeds in temperature T = 328 K.

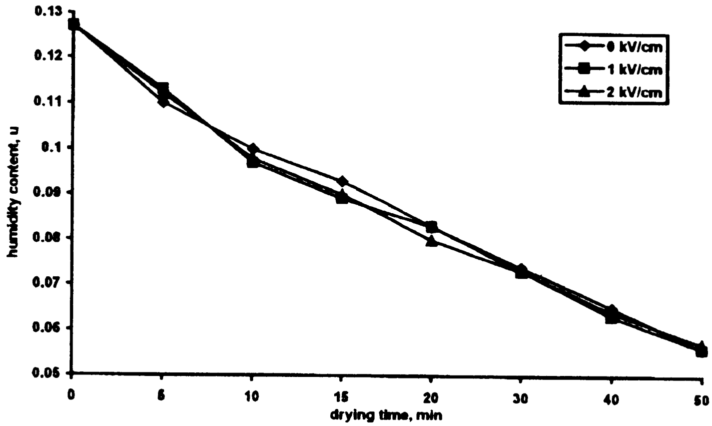

Fig. 4. Drying curves of rape seeds in temperature T = 318 K.

Table 2. Drying curves of rape seeds in temperatures T = 318 K, and electrostatic field intensities: E = 0, 1 and 2 kV

Drying time τ (min)	Humidity content in wheat u ($kg_{H_2O}/kg_{d.m.}$)		
	Electric field intensity E (kV/cm)		
	0	1	2
0	0.127	0.127	0.127
5	0.110	0.113	0.112
10	0.100	0.097	0.098
15	0.093	0.089	0.090
20	0.083	0.083	0.080
30	0.074	0.073	0.073
40	0.065	0.063	0.064
50	0.056	0.056	0.057
Energy saving $q_{\%}$ (%)	-	0	- 1.4

where u is humidity content in samples prior to the drying process; u_1 - humidity content in samples, following the drying process without the electrostatic field; u_2 - humidity content in samples, following the drying process accompanied by the electrostatic field.

Water content was determined on the basis of mass measurements of the tested grain samples.

The statistic analysis (t-Student test for means at the significant level 0.95) shown that there are no statistically significant differences during the drying with or without the electric field for all tested kinds of grains (Fig. 5).

The graph presents water decrements during wheat grain drying at T= 318 K. The values have been computed on the basis of mass measurements of the tested samples.

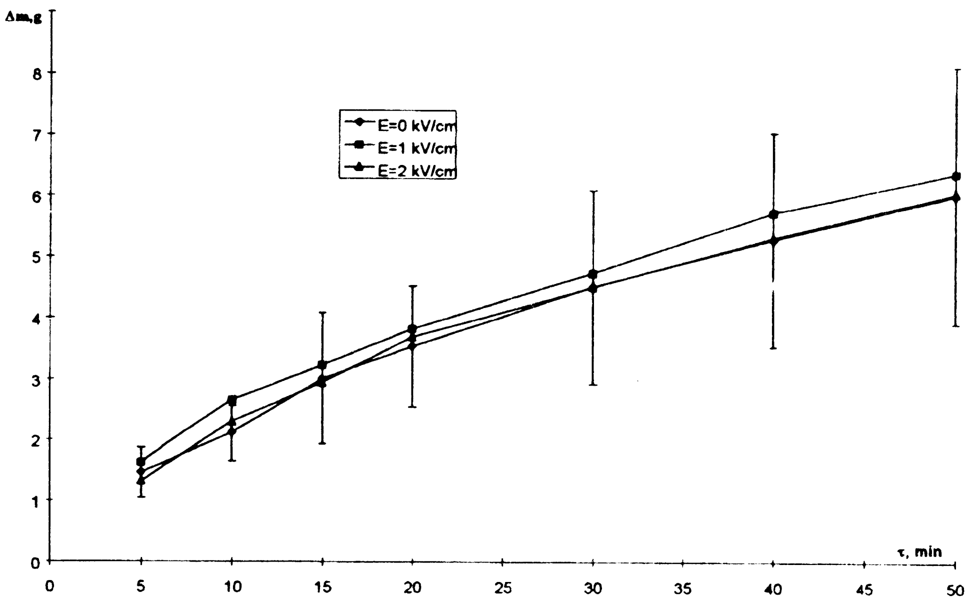

Fig. 5. Water mass decrements from wheat samples at $T = 318$ K; $E = 0, 1, 2$ kV/cm.

The confidence intervals are also indicated for the measurement carried at $E = 0$ kV/cm.

CONCLUSION

It can be found from the presented curves that measurements results at $E = 1$ and 2 kV/cm are incorporated in the presented limit of error. Thus, it is not possible to define the electric field influence on drying curves. This can lead to the conclusion that the hypothesis stating that the electric field reduces energy consumption in the drying process has not been proved by the model that has been established.

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