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INFLUENCE OF ELECTRIC FIELD ON THE SPEED OF CONVECTIVE REMOVAL OF WATER FROM WHEAT GRAIN*

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A b s t r a c t. Electric field can change the speed of convective drying since it generates accompanying phenomena in dried materials or changes the heat and mass transfer between the material and the drying medium.

These accompanying phenomena generated in the material are electrostriction forces. Electrostriction forces can cause deformations inside grain through the compression or tension of particular layers. The most visible effects of compression and tension of objects should then occur in the laminar and elastic objects. These include wheat grain.

Intensification of the heat and mass transfer between the water surface and the drying medium in the presence of an ionic wind in the electric field has already been described (see references). However, the tests to examine the influence of the ionic wind and the electric field on water evaporation from particular materials have not been carried out.

This paper presents the test results of convective drying of wheat in the electrostatic field and in the ionic wind. Intensified drying processes are illustrated by the curves of drying.

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

INTRODUCTION

After exposing wheat grain to an electric field some forces and phenomena can appear caused by:

- The presence of free charges which grain can be charged with the ionised environment.
- Luck of balance in the electric charge inside grain [1].
- Charges induced at the border of grain layers (electrostrictive forces) [5].
- Free charges which can appear in the environment (corona wind) [3].

It seems that electrostrictive forces and corona wind are the most important factors, which can change the course of convective drying.

The electrostriction force value can be determined from the following Eq. [2]:

$$\overline{F}_s = \frac{1}{2}\varepsilon_0 \int_V grad\left(E^2 \frac{\partial \varepsilon}{\partial \tau}\tau\right) dV \qquad (1)$$

where: F_S - electrostriction forces, N; τ - mass density, kg m^{-3}; $\partial\varepsilon/\partial\tau$ - partial change of specific inductive capacity caused by deformation; V - volume, m^3; E - electric field intensity, V m^{-1}; ε_0 - permittivity of vacuum ($\varepsilon_0 = 8.8542\ 10^{-12}$ F m^{-1}); ε - dielectric constant (relative dielectric permittivity).

Equation (1) points out to the potential possibility of using electrostrictive forces acting on the internal grain structure. Mechanical tension generated in the strong electrostatic field cause structure microchange, which reduce moisture retention and minimise energy consumption in the convective drying processes. It was calculated that the volume of the electrostrictive forces is much too low to cause

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macroscopic grain deformation but the possible influence of these forces on drying processes has not been excluded. The electrostrictive forces are one of the agents increasing heat transfer in liquids. Senftleben and Braun [4] carried out this type research in 1936. The experimental layout used by Senftleben and Braun is shown in Fig. 1A.

In 1972, Sadek *et al.* [3] published the results of another type of research on the heat and mass transfer process in the convective drying of a sponge with water (Fig. 1B). The sponge was exposed on the flat, grounded electrode above which the wire matrix was put. The result showed that the agent increasing heat and mass transfer is the corona wind.

electrode, m^2; s - spacing between the electrodes, m; V - electrode voltage (V_0 - threshold voltage below which ionic current is insignificant), V.

In 1995, Wolny and Kaniuk [6] carried out a similar type of research. Experiments on the convective drying of ceramic substance and water vaporisation from surfaces were carried out in electric field in the presence of the corona wind. Results of the research confirmed the importance of the influence of the corona wind on the heat and mass transfer at low air velocity.

The purpose of our tests was to determine if it is possible to intensify convective drying of wheat using the electrostatic field and ionic wind.

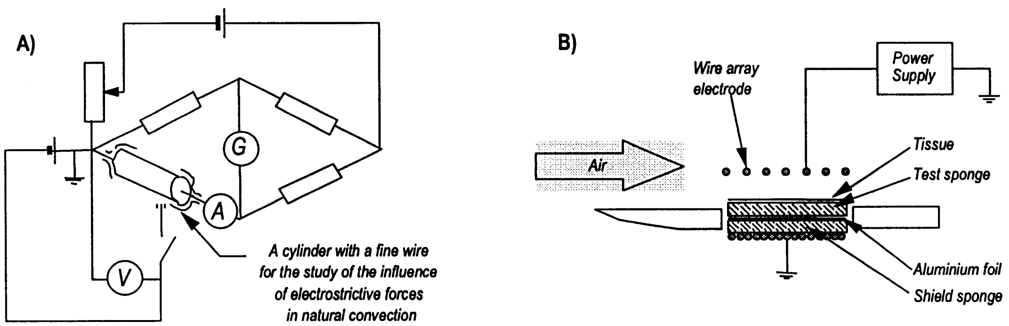

Fig. 1. The experimental layout used by Senftleben and Braun [4] (A), and schematic diagram of the test stand used by Sadek *et al.* [3] (B).

When voltage higher than the threshold voltage is applied to the pin (or wire) matrix, the gas ionisation will occur near the electrode. These ions are propelled by the Coulomb forces towards the opposite electrode. As they travel, the ions collide with the ionised gas molecules. The result of this is corona wind. An additional ion-drag force increasing heat transfer that acts as normal on a grounded electrode is:

$$F_c = \alpha \varepsilon A \left(\frac{V - V_0}{s} \right)^2 \quad \text{for } V > V_0, \qquad (2)$$

where: F_c - ion-drag force, F_c=0 for $V \leq V_0$, N; α - a numerical factor depended on the system geometry (α=8/9 for parallel electrodes), ε - dielectric permittivity, F m^{-1}; A - area of the flat

TEST STAND AND PROCEDURE

The main element of the test stand was the drying chamber (Fig. 2). The measurement capacitor was inside it (Fig. 3). The drying samples of Roma wheat grain were placed on the lower electrode. The measurement capacitor was attached to the string of the balance. The electronic balance (type: Precisa 5000D -12000G, manufactured by "Oerlikon" AG, Switzerland) sends information about the current mass of the dried sample to the computer. The electronic balance allows for mass measurements with 0.1 % accuracy. The supply was DC high voltage (maximum voltage was 12 kV). The fan-heater was placed in the inlet of the chamber.

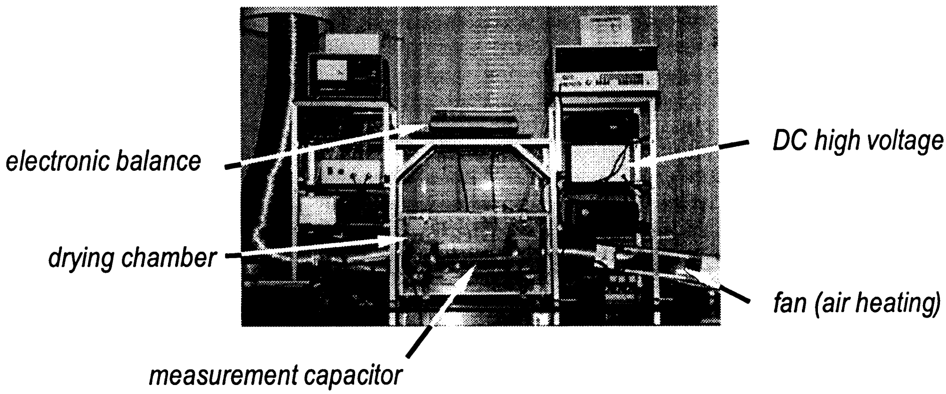

Fig. 2. Test stand.

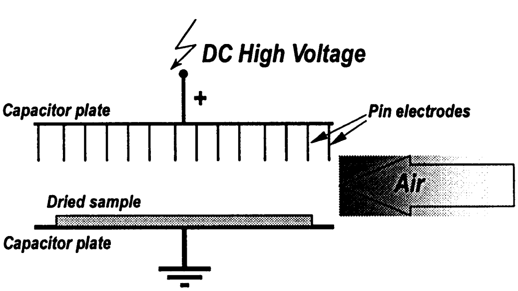

Fig. 3. Measurement capacitor.

The drying chamber is rectangular. The voltage is applied to the electrodes of the capacitor. During the experiments a few types of capacitors were used. In the case of the pin matrix an increased drying was observed. Capacitor design allowed for the generation of corona wind.

The drying sample was artificially moistened to the level of 20 %. The initial mass of each specimen was 100 g. Each time two series of drying were carried out. In one of them the sample was exposed to the electrostatic field and in the other it was not. Each drying process lasted of 1.5 h. The computer registered loss of the vaporised mass of water every 2 min.

The following series of measurements were carried out:

- in the configuration with flat electrodes and with the upper electrode equipped with a pin matrix,
- the range of drying air velocity was from 0.3 to 1.4 m s^{-1},
- field intensity was at the levels of 0, 200, 300 and 400 kV m^{-1},
- level of air temperature was - 303, 313 and 323 K.

RESULTS

The experimental data received during drying are presented in Table 1.

The following results have been found:

- In the flat capacitor, in which the corona wind was not generated, there was no measurable influence of the field on the drying process. Probability of the different course of the drying process (based on the Student's differences method) is less than 30 %. It means that in a given configuration, there is no mass transfer augmentation caused by electrostrictive forces.
- In neither types of capacitors, at high air velocity, the mass transfer augmentation exist. With the air velocity higher than 0.3 m s^{-1} it was impossible to register measurable changes in two types of drying processes.

The most visible effects of the field influence on the wheat were observed at the maximum electric field intensity and the maximum temperature (323 K) (Figs 4-6).

CONCLUSIONS

On the basis of the present measurements the following conclusions can be drawn:

- In each group of measurements in which the corona wind occurs, drying process was

T a b l e 1. Selected results of convective drying of Roma wheat with electric field and corona wind (air temperature 323 K, mean electric field intensity 400 kV m^{-1})

Time of drying (s)	Mean electric field intensity (kV m^{-1})										
	0	200	300	400	200	300	400	0	200	300	400
	Water content ($g\ H_2O/g$ d.m.)				Probability of different courses of drying processes (based on the Student's differences method) (%)			Mass of vaporised water (g)			
0	0.250	0.250	0.250	0.250	-	-	-	0.00	0.00	0.00	0.00
600	0.234	0.234	0.229	0.220	4.88	99.93	100.00	1.24	1.25	1.72	2.40
1200	0.219	0.218	0.209	0.197	35.05	100.00	100.00	2.48	2.55	3.25	4.25
1800	0.205	0.203	0.194	0.181	56.76	100.00	100.00	3.61	3.77	4.48	5.55
2400	0.192	0.189	0.181	0.169	65.94	100.00	100.00	4.66	4.87	5.52	6.45
3000	0.181	0.178	0.170	0.159	64.87	100.00	100.00	5.54	5.78	6.40	7.30
3600	0.172	0.167	0.161	0.150	78.85	100.00	100.00	6.28	6.62	7.08	8.00
4200	0.164	0.159	0.153	0.143	80.30	100.00	100.00	6.90	7.30	7.73	8.55
4800	0.156	0.151	0.146	0.137	80.26	100.00	100.00	7.49	7.92	8.28	9.05
5160	0.153	0.147	0.143	0.134	84.41	100.00	100.00	7.79	8.27	8.58	9.30

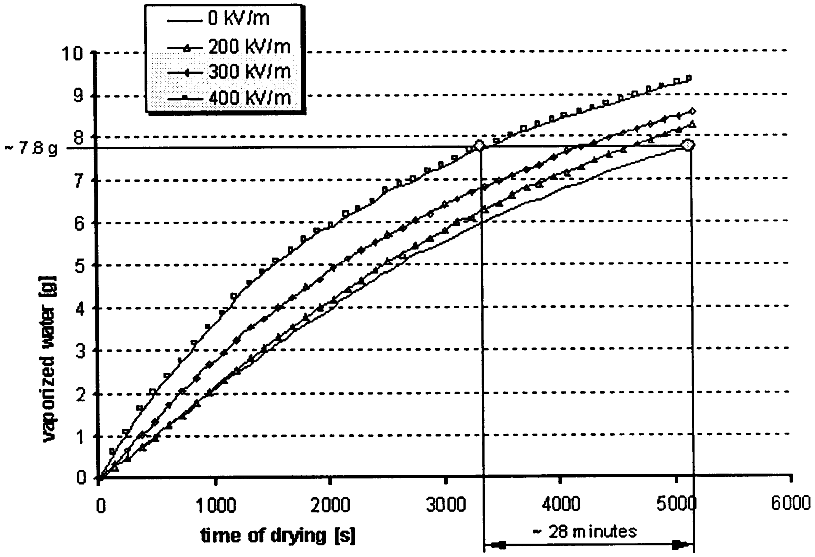

Fig. 4. Water removed from the sample of wheat versus drying time.

accelerated. In the presented group of results (at the temperature 323 K), it took 86 min for vaporising 7.79 g of water without electric field. In the field of intensity 400 kV m^{-1}, the vaporisation of 7.85 g of water took 58 min.

– An increase in the electric field intensity and an increase of the corona wind caused an increase of the rate of vaporisation. The initial rate of drying in the presence of electric field can be about 1.4÷2.1 times the rate of convection drying without the electric field.

REFERENCES

1. **Mohsenin N.N.:** Electromagnetic Radiation Properties of Foods and Agricultural Products. Gordon and Breach Science Publishers, New York, 379-399, 1984.
2. **Pietrzyk W., Krakowiak J.:** Utilization of strong electrostatic field in drying process. 7th International Symposium on High Voltage Engineering, Dresden, 37-38, 1991.

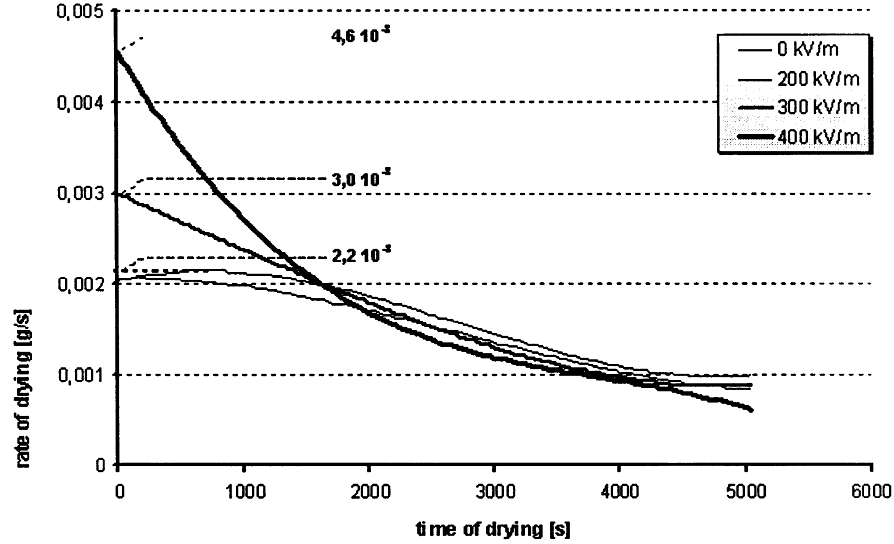

Fig. 5. Drying rates for Roma wheat samples.

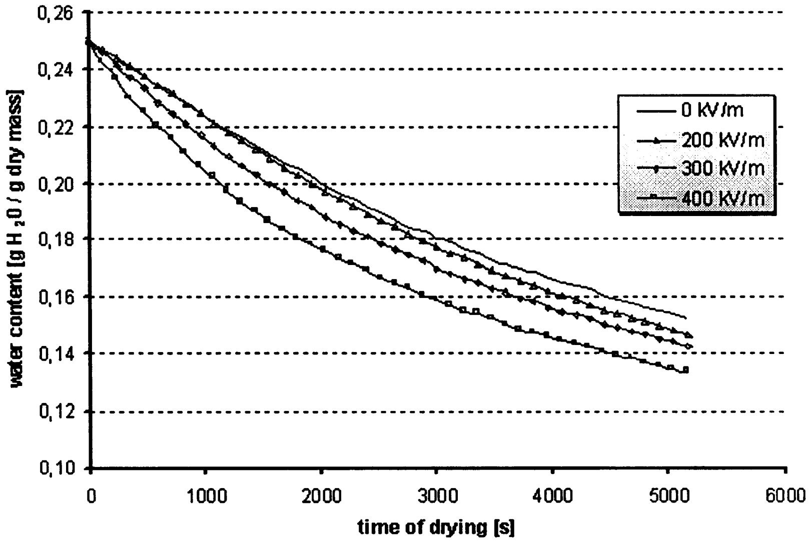

Fig. 6. Drying curves of Roma wheat at the temperature of 323 K.

3. **Sadek S.E., Fax R.G., Hurwitz M.:** The influence of electric fields on convective heat and mass transfer from a horizontal surface under forced convection. J. Heat Transfer, Trans. ASME, 94, C, 2, 144-148, 1972.
4. **Senftleben H., Braun W.:** Der Einfluss elektrischer Felder auf den Wärmestrom in Gasen. Z. Pys., 102, 480-506, 1936.
5. **Tarushkin W.I.:** Distribution of ponderomotive forces on grains during separation (in Russian). M. and E. S. Ch., 12, 35-39, 1983.
6. **Wolny A., Kaniuk R.:** Vaporisation from flat and cylindrical surfaces in electrical field (in Polish). 15th Scientific Chemical and Processing Engineering Conference, Gdańsk, Poland, 139-144, 1995.