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INVESTIGATIONS OF THE COEFFICIENT OF MOISTURE INTERNAL DIFFUSION IN WHEAT GRAIN

Aleksander Zaremba

During the process of drying an important role is played by the internal exchange of moisture. As is known from the works of Łykow and other researchers [1—3] the process of drying cereal grain can be divided into two periods: of a constant rate of drying and of a diminishing rate of drying. In the first period the process of drying is influenced equally by the internal and external exchange of moisture. In the second period the process is influenced mainly by the internal exchange of moisture. The border moisture content dividing the two periods of drying for grain of the four basic cereals is about 18—19% [2, 3]. According to the investigations of Fąfara and Strutyńska the mean moisture of cereal grain harvested with combined harvesters is in Poland about 18—20% [4, 5]. The drying of such grain takes place in the period of the diminishing rate of drying, in which, as was said above, the interal exchange of moisture determines the process. The main parameter determining the interal exchange of moisture is the coefficient of internal diffusion if moisture. Knowledge of this parameter allows for the obtaining of more exact results of calculations of the process of dyring.

This paper presents the results of investigations of the coefficient of internal diffusion of moisture in wheat grain. The investigations were carried out at different water content in grain, in the range from 0.11 to 0.24 kg H_2O/kg dry mass (10—19%) and for different temperatures of grain heating in the range from 30 to 70°C.

The investigation material was wheat of the Kaukaz variety from the crops of 1975. The wheat was harvested with a combined harvester and its moisture content before investigations was about 19.5%.

The coefficient of internal diffusion of moisture was determined on the basis of the curves of drying obtained experimentally and on the basis of the equation of convectional drying of grain in a thin layer [6, 7].

$$\frac{u_\Theta - u_r}{u\Theta - u_r} = f(Fo_m), \tag{1}$$

where

$$Fo_m = \frac{a_m \Theta}{R^2}. \tag{2}$$

In the equations:

u_Θ — water content in grain in time, Θ (kg H_2O/kg d.m.),
u_o — initial water content in grain, (kg H_2O/kg d.m.),
u_r — equilibrial water content in grain, (kg H_2O/kg d.m.),
Fo_m — Fourier's number for the exchange of mass,
a_m — coefficient of the internal diffusion of moisture, (m^2/s),
Θ — time of drying, (s),
R — equilibrial radius of grain, (m).

In the specialistic literature from the range of heat and mass conductivity equation [1] is met in the form of diagram of the dependence of water content in a body from the Fourier's number for the exchange of mass, for bodies of different shapes [6]. For bodies of spherical shape (wheat grain is approximated to sphere) such a diagram is presented in Fig. 1.

As can be seen from equation [2] for the calculation of the coefficient of the internal diffusion of moisture is necessary the knowledge,

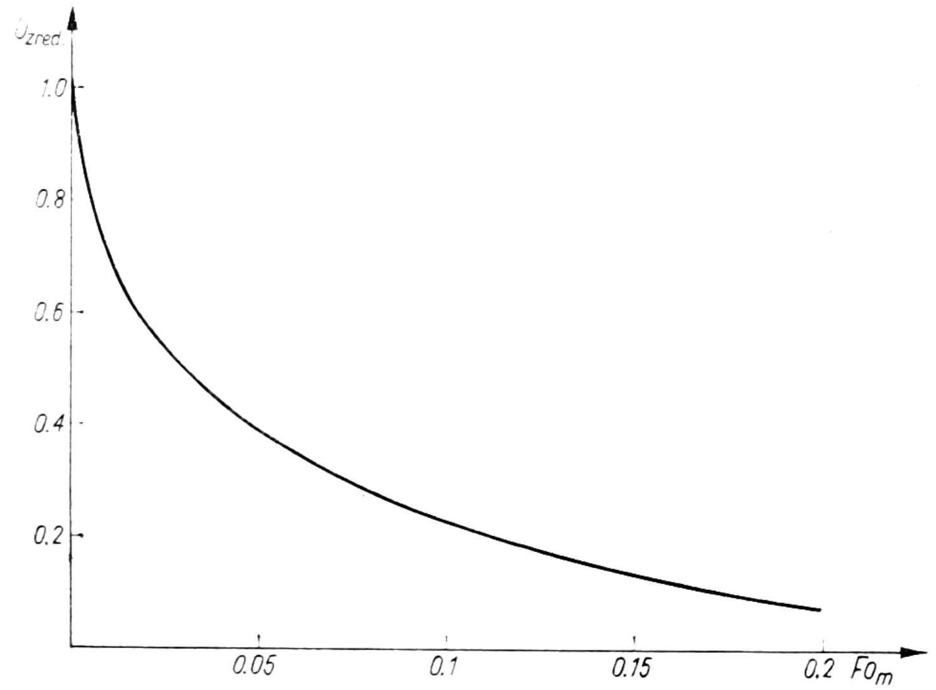

Fig. 1. Diagram of the relation between the reduced water content and Fourier's number

apart from the Fourier's number for the exchange of mass, of the time and the equilibrial radius of grain. The time, for a given water content in grain, was read from the curve of drying. The equilibrial radius of grain was calculated from the equation

$$R = \sqrt[3]{\frac{3\,M_{1000}}{4000\,\pi\rho}} \tag{3}$$

in which

R — equilibrial radius of grain (m),
M_{1000} — mass of 1000 grains (kg),
ϱ — density of grain (kg/m³).

The density of grain was determined with the picnometric method and the mass of 1000 grains according to the valid normatives [8].

For the determination of the curves of drying and of temperature of a layer of grain a measuring stand, schematically presented in Fig. 2, was used.

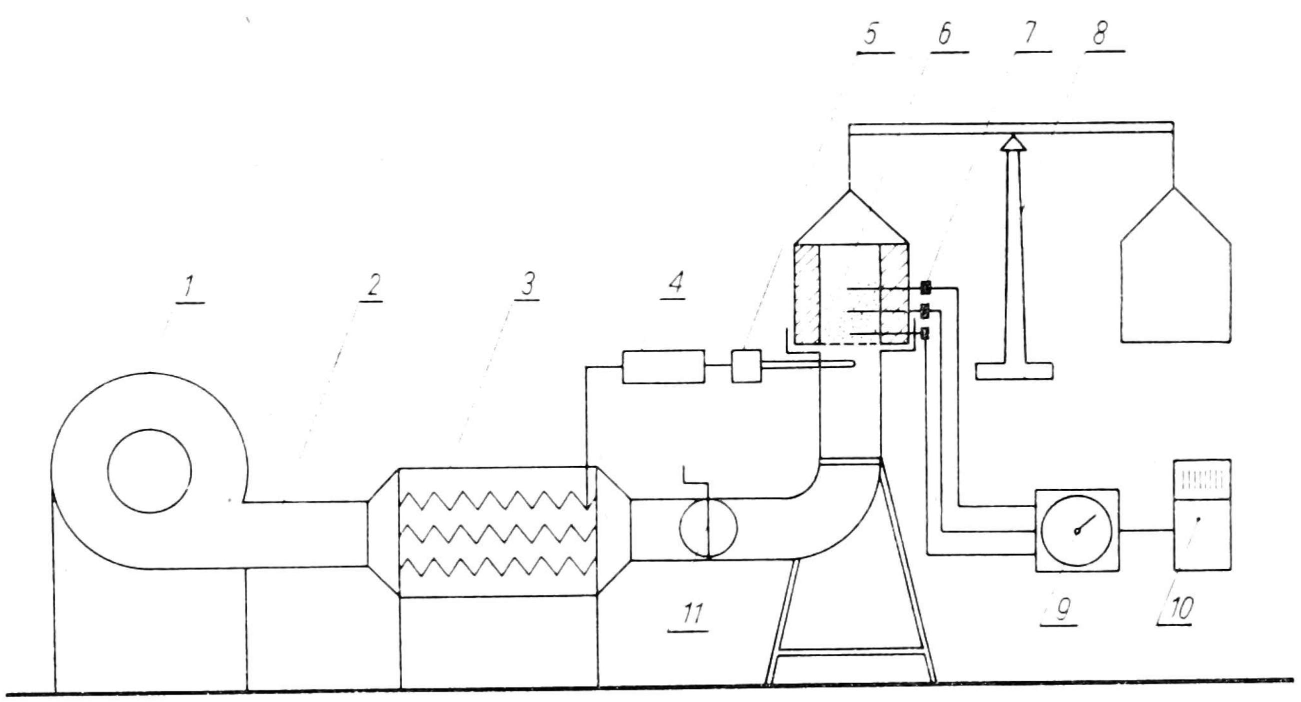

Fig. 2. Diagram of the measuring stand: *1* — fan, *2* — feeding conduit, *3* — heater, *4* — relay, *5* — contact thermometer, *6* — measuring cylinder, *7* — thermocouples, *8* — balance, *9* — thermocouple swich, *10* — galavanometer, *11* — diaphragm

At the begining and at the end of each experiment the moisture content was determined with the drier method. In the course of drying the losses of the mass of water were measured and calculated into the content of water in grain. The curves of drying for wheat grain at different temperatures are presented in Fig. 3.

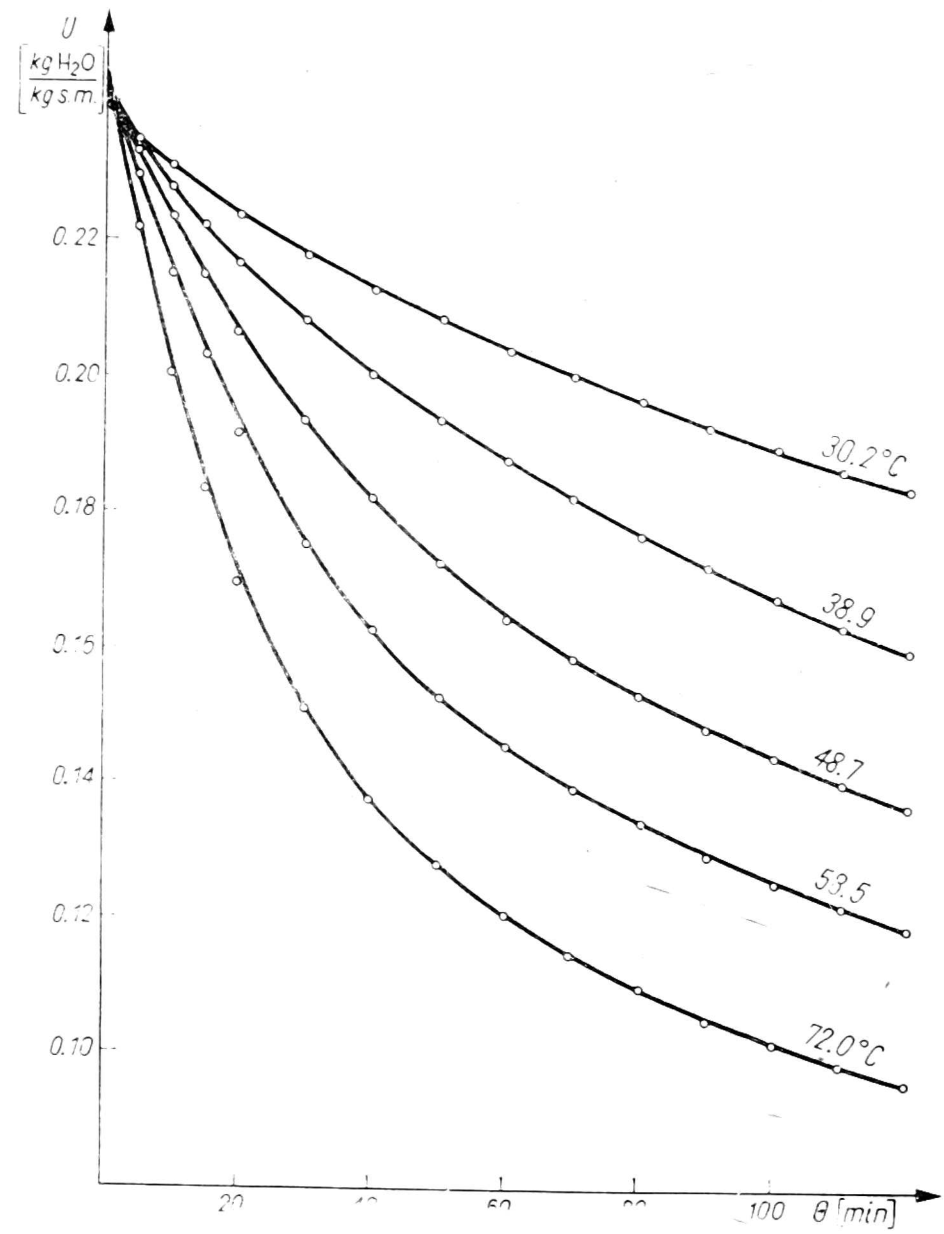

Fig. 3. Curves of drying

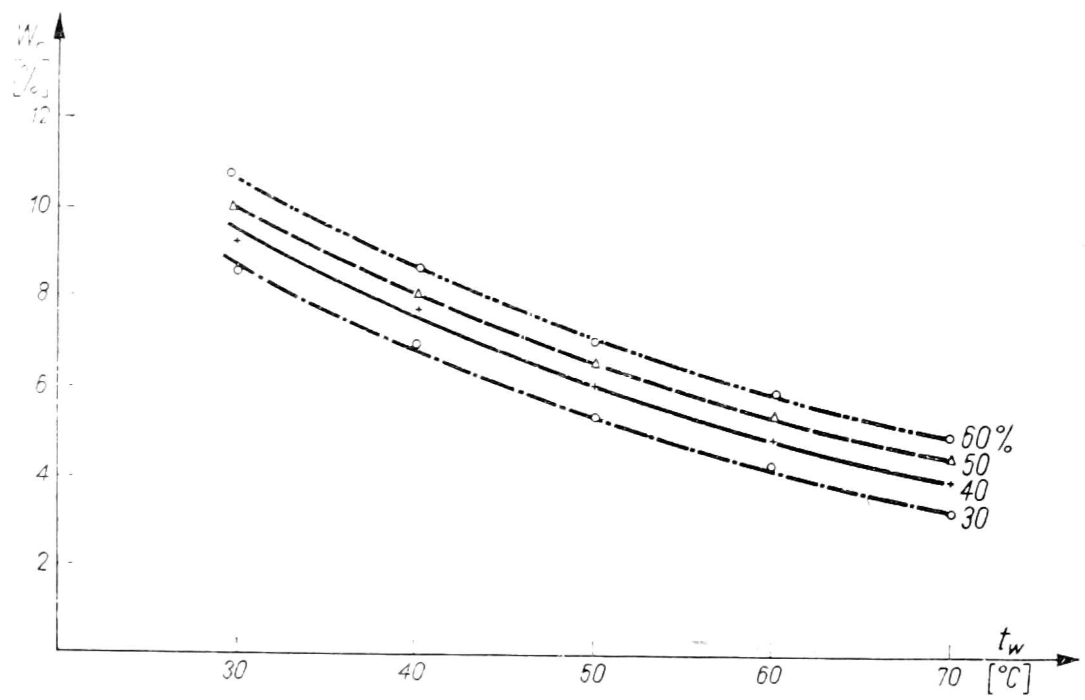

Fig. 4. Equilibrial moisture of wheat grain

The equilibrial content of water, necessary for the calculation of the amount of water reduced, was determined experimentally. The equilibrial moisture content for different temperatures of grain and different moisture of air is presented in Fig. 4.

The thickness of the grain layer in the measuring cylinder was 20 mm. At this thickness of the grain layer and at the transit speeds of the drying agent equivalent to convectional drying (0.1 to 0.3 m/s) the unification of temperature in the whole layer occured after several minutes. Examplary distribution of temperature in a layer of grain at the temperature of the drying agent of 50°C and at the speed of the drying agent of 0.3 m/s is presented in Fig. 5.

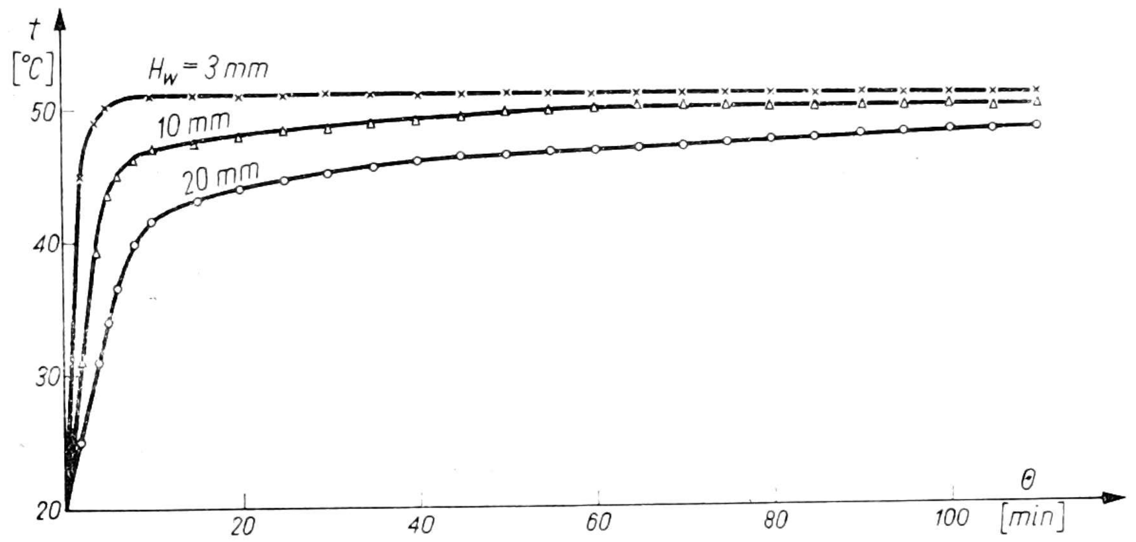

Fig. 5. Temperature distribution in grain layer

The results of investigations are presented in the form of duagrams of dependence of the coefficient of internal diffusion of moisture on the water content in grain and on the temperature of the grain layer. Fig. 6 presentes the dependence of the coefficient of internal diffusion of moisture on the water content at different temperatures of the grain layer. The curves are of the third degree:

$$f(u) = Au^3 + Bu^2 + Cu + D.$$

For example for the temperature of 48.7°C the dependence of the coefficient of diffusion on the water content in wheat grain is described by the equation:

$$a_m = 14861u^3 - 10221u^2 + 2034u - 101.5 \quad \left(10^{-12}\,\frac{m^2}{s}\right)$$

$$\text{at } 0.11 < u < 0.24 \text{ kg } H_2O/\text{kg d.m.}$$

The dependence of the coefficient of internal diffusion of moisture on

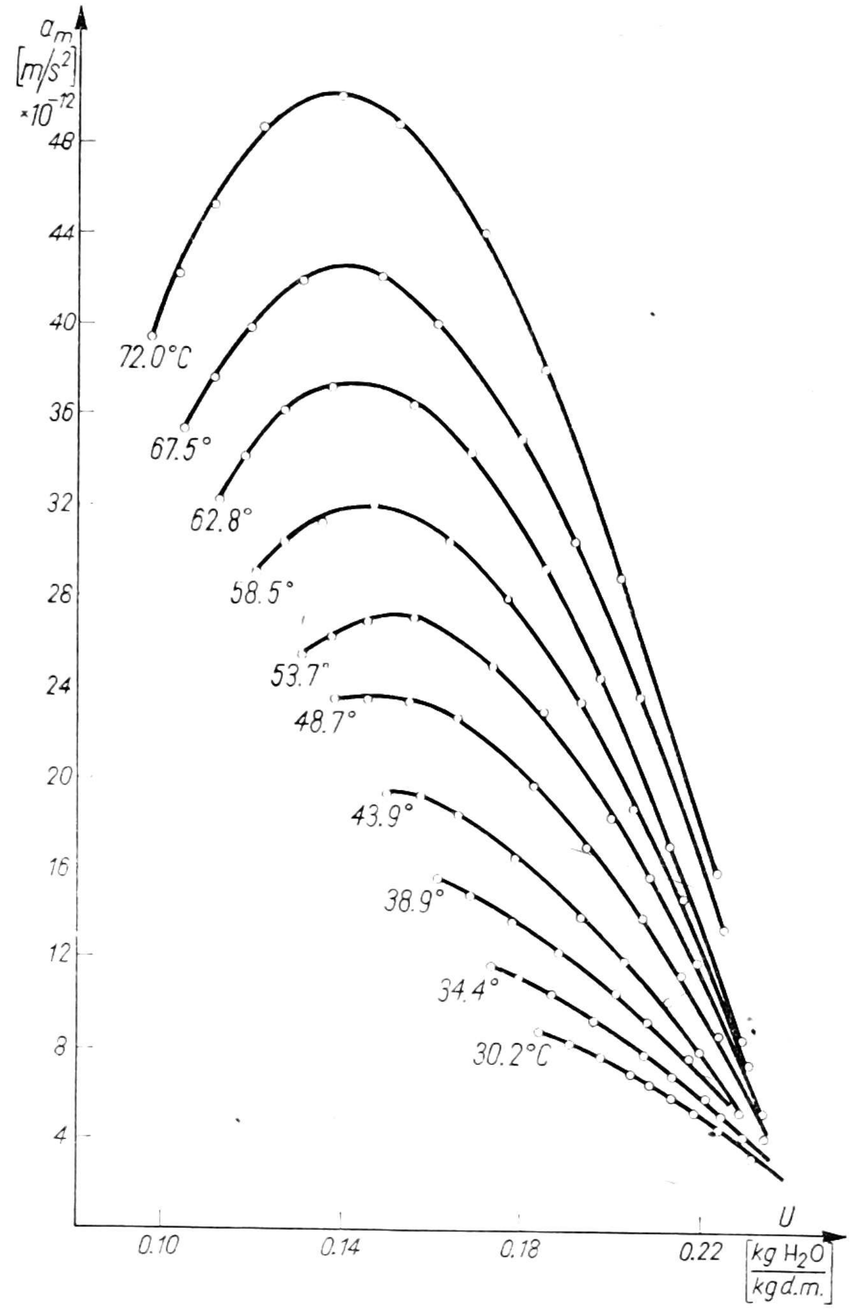

Fig. 6. Dependence of the moisture diffusion index on the water content

the temperature of grain for different water contents is presented in Fig. 7.

These are exponential curves of the type

$$f(t) = A \exp (Bt - Ct^2).$$

For example for the water content in grain of 0.18 kg H_2O/kg d.m. the dependence of the coefficient of internal diffusion of moisture on temperature is described by the equation

$$a_m = 1.39 \times 10^{-12} \exp (0.065t - 0.00026t^2) \text{ m}^2/\text{s}$$
$$\text{at } 30 < t < 70°\text{C}$$

The above given formulae for the functional relationship between the water content and the temperature of grain and the coefficient of

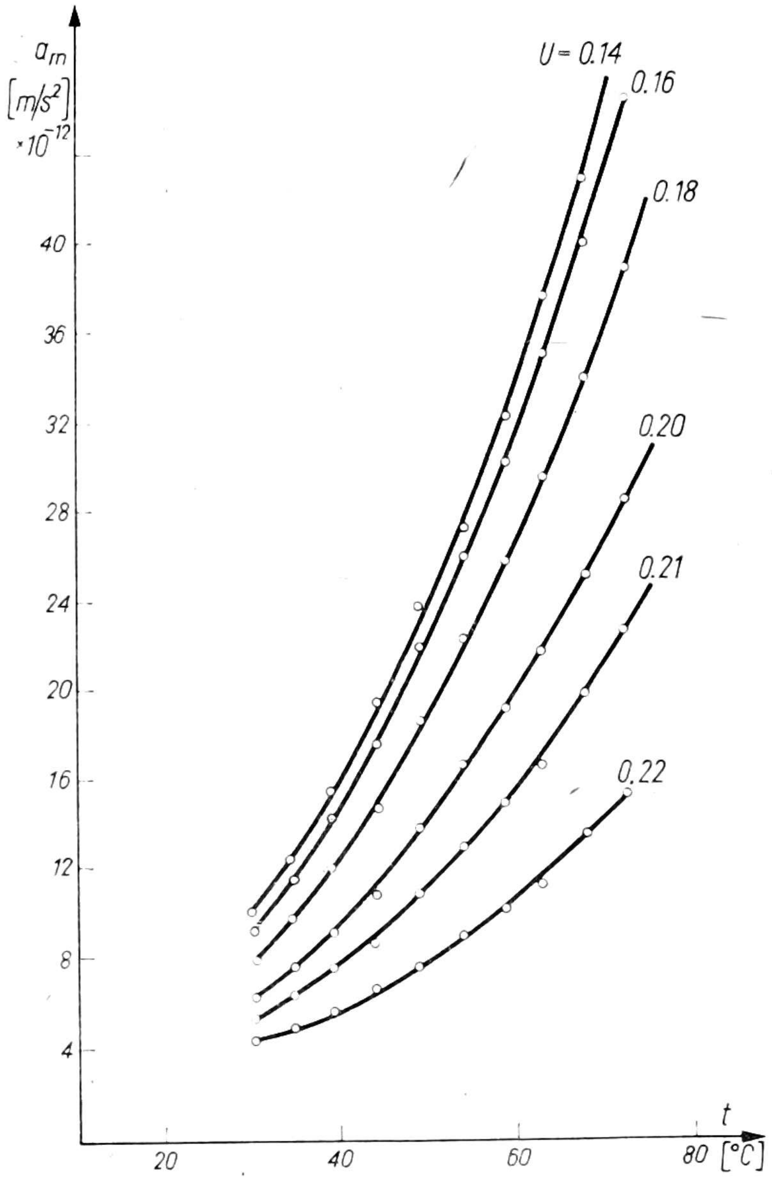

Fig. 7. Dependence of the moisture diffusion index on temperature

internal diffusion of moisture were formulated by approximating the experimental curves for several chosen functions. The numerical parameters for these functions were determined with the method of means. The final form of the formula was accepted basing on the calculation of the mean square deviation that for the equations quoted in the paper had the smallest value.

Analysis of the obtained results proves the influence of both the water content and the temperature of grain on the value of the coefficient of internal diffusion of moisture. In the case of water content the relation is complex. From the water content of 0.10 kg H_2O/kg d.m. to 0.14—0.15 the coefficient of diffusion increases its value, and in the range 0.15—0.24 kg H_2O/kg s.m. it decreases with the increase of water content. The higher the temperature of grain the clearer the differences. The temperature of grain influences exponentially the value of the coefficient of internal diffusion of moisture, but for higher contents of water in grain the influence is lower than for low water contents.

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A. Zaremba

BADANIE WSPÓŁCZYNNIKA WEWNĘTRZNEJ DYFUZJI WILGOCI W ZIARNIE PSZENICY

Streszczenie

Na podstawie krzywych suszenia uzyskanych doświadczalnie oraz na podstawie równania konwekcyjnego suszenia ziarna w cienkiej warstwie wyznaczano współczynnik wewnętrznej dyfuzji wilgoci w ziarnie pszenicy.

Przebadano wpływ zawartości wody w ziarnie w zakresie 0,11—0,24 kg H_2O/kg s.m. oraz temperatury ziarna w zakresie 30—70°C na wartość współczynnika dyfuzji wilgoci.

Podane wyżej zależności przedstawiono w postaci wykresów, jak również opisano odpowiednimi równaniami: zależność współczynnika wewnętrznej dyfuzji wilgoci od zawartości wody w ziarnie równaniem trzeciego stopnia typu $f(u) = Au^3 + Cu + D$,
natomiast zależność współczynnika wewnętrznej dyfuzji wilgoci od temperatury ziarna równaniem wykładniczym typu $f(t) = A \exp(Bt - Ct^2)$.

А. Зaремба

ИССЛЕДОВАНИЕ КОЭФФИЦИЕНТА ВНУТРЕННЕЙ ДИФФУЗИИ ВЛАГИ В ПШЕНИЧНОМ ЗЕРНЕ

Резюме

На основании кривых сушки, полученных экспериментально, и уровнения конвекционной сушки зерна в тонком слое был определен коэффициент внутренней диффузии влаги в пшеничном зерне.

Было исследовано влияние содержания воды в зерне в пределах 0,11-0,24 кг H_2O/кг с.м. и температуры зерна в пределах 30-70°Ц на величину коэффициента диффузии влаги.

Вышеприведенные зависимости представлены в виде диаграмм и описаны соответствующими уравнениями: зависимость коэффициента внутренней диффузии влаги от содержания воды в зерне уравнением третьей степени типа $f(u) = Au^3 + Bu^2 + Cu + D$, а зависимость коэффициента внутренней диффузии влаги от температуры зерна — уравнением показательным типа $f(t) = A \exp(Bt - Ct^2)$.

Address of the author

Dr Ing. Aleksander Zaremba,
Institute of Foundations of Chemistry and Food Technology, Agricultural Academy,
Al. Mickiewicza 21, 31-120 Kraków, Poland