VARIABILITY OF THE POROSITY OF CEREAL GRAIN LAYER UNDER THE INFLUENCE OF STATIC LOADING

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INTRODUCTION

The optimization of the processes of drying and storage to a large degree depends on the porosity of grain layer, the value of which is determined by the shape of grains, their geometrical dimentions, the state of their surfaces and their mutual positioning in the layer [3, 4].

Increase of contamination, increase of moisture, and, at the filling of containers, the phenomenon of self-sorting and the increase of the height of layer are the main factors influencing the decrease of porosity. If the elimination of the first three factors is not now a greater problem, it seems purposefull, for economic reasons, to increase the height of the column of grain stored in silos [1, 6].

In connection with this it seemed right to undertake investigations on the determination of the influence of static loading on the porosity of cereal grain layer.

METHODOLOGY OF INVESTIGATIONS

The object of the investigations was grain of 4 chosen varieties of the basic types of cereals coming from the harvest of 1975 in the Experimental Station of Evaluation of Varieties is Czesławice (Lublin district). In the initial stage of the experiment, with the help of a pressure porometer, we determined the state of the initial porosity, that is the porosity of a loosely heaped layer of grain [5]. Then we passed on to recording the course of changes of the normal strain (operating on the layer of grain in the measurement cylinder) in function of the volumetric deformation of this layer (Fig. 1).

The process of static loading was realized on the universal resistance apparatus Instron model 1253 at a constant deformation rate $V_{\Delta l} =$ 10 mm/min. The character of the course of the curve at compressing the

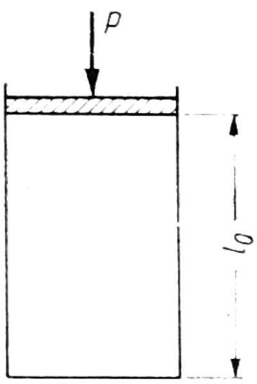

Fig. 1. Diagram of the measuring system

grain layer obtained from the recorder of the machine is equivalent to the curves of compression for other loose media, like among others soils [2].

The investigation material subjected to loadings diminished the state of its porosity by gradual compacting. In order to analyse the influence of loadings on the change of porosity of grain layer it was necessary to determine first the relation between the volumetric deformation and the porosity of the investigated layer of grain. Therefore the following considerations on the change of the air content in the measurement cylinder filled with grain were made (Fig. 2), at the assumption that

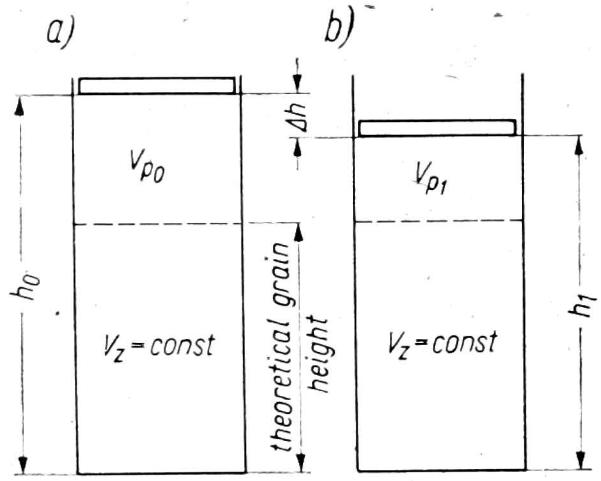

Fig. 2. Diagram of the measuring system: *a* — before loading, *b* — after the loading of grain mass

the volume of grain does not change in the process of compressing (V_z = const).

The porosity of grain layer in loose state is expressed by the formula:

$$P_o = \frac{V_{po}}{V_z + V_{po}},$$

where:

V_{po} — volume of air (cm^3),
V_z — volume of grain = const (cm^3).

After the loading the porosity will be

$$P_i = \frac{V_{pi}}{V_z + V_{pi}}, \quad (1)$$

where:

V_{pi} — volume of air in the intergrain spaces after loading (cm^3).

In turn

$$V_{pi} = V_{po} - V_{\varepsilon},$$

where:

V_{ε} — volume of air displaced by the piston in the process of compressing.

Assuming a constant intersection of the sample and considering that $\varepsilon = h/h_0$, where h_0 — equivalent to the initial height of the sample of grain, the following relation was obtained:

$$P_0 = \frac{P_o - \varepsilon}{1 - \varepsilon}. \quad (2)$$

Hence it follows that the basis for the determination of the loaded layer of grain is the knowledge of the deformation of the column of grain — ε and the initial porosity — P_o.

Then for every value of loading (at a determined step of compressing equal $2 \cdot 10^5$ N/m² in the range 0—$80 \cdot 10^5$ N/m²) corresponding to a certain deformation was assigned a value of porosity determined from formula [2], obtaining a set of points of co-ordinates (σ_i — P_i). This the course of the change of porosity in function of static loadings of grain layer was obtained.

DISCUSSION OF THE RESULTS

The relation $P = P(\sigma)$ was described, with the help of numerical methods, by an equation of the type:

$$P(\sigma) = \begin{cases} P_o \exp a\sigma^2 + b\sigma & \sigma \leqslant 10 \cdot 10^5 \text{ N/m}^2 \\ d \exp s \cdot \sigma & \sigma > 10 \cdot 10^5 \text{ N/m}^2 \end{cases} \quad (3)$$

The obtained coefficients P_0, a, b, d, and s for the investigated varieties are presented in Table 1. Graphic illustration of the considered relation is presented in Figures: Fig. 3 — for winter wheat, Fig. 4 — for spring wheat, Fig. 5 — for rye, Fig. 6 — for barley, Fig. 7 — for oats.

Table 1

Compilation of the values of parameters of the equation $P = P(\sigma)$ for chosen varieties of cereals

Type of cereal	Variety	P_0	a	b	s	d
Winter wheat	Aurora	44 50	0.0015	—0.0277	—0.0052	41.41
	Kaukaz	45.15	0.0017	—0.0298	—0.0059	42.12
	Grana	44.95	0.0021	—0.0346	—0.0069	42.24
Spring wheat	Kolibri	45.75	0.0019	—0.0337	—0.0059	41.86
	Carola	49.70	0.0016	—0.0337	—0.0081	45.18
	Urbanka	46.50	0.0028	—0.0505	—0.0119	41.72
Rye	Dańkowskie Nowe	48.40	0.0021	—0.0397	—0.0075	43.27
	Dańkowskie Złote	47.25	0.0018	—0.0376	—0.0080	42.30
	Pancerne	50.30	0.0022	—0.0447	—0.0086	43.83
Barley	Piast	54.20	0.0025	—0.0494	—0.0075	45.81
	Elgina	51.45	0.0019	—0.0430	—0.0080	43.96
Oats	Flämingsweiss	68.25	0.0006	—0.0515	—0.0118	48.99
	Romulus	67.00	0.0015	—0.0660	—0.0125	45.63

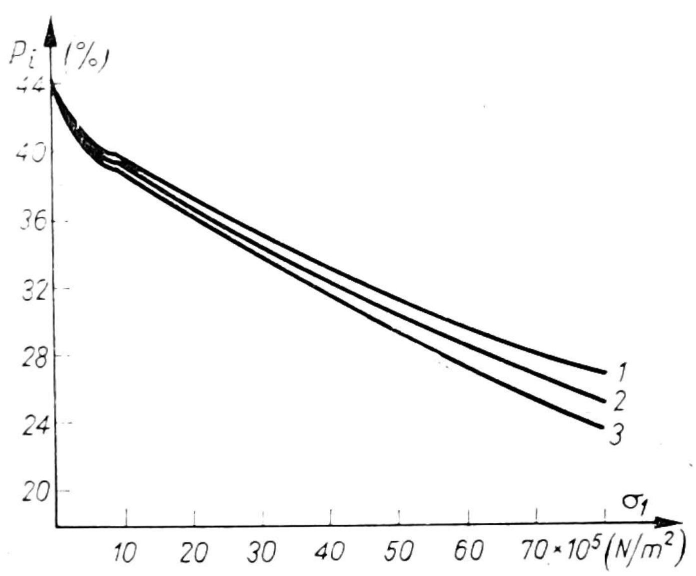

Fig. 3. Change of the grain mass porosity in the chosen varieties of winter wheat under the influence of increased static loadings: *1* — Aurora, *2* — Kaukaz, *3* — Grana

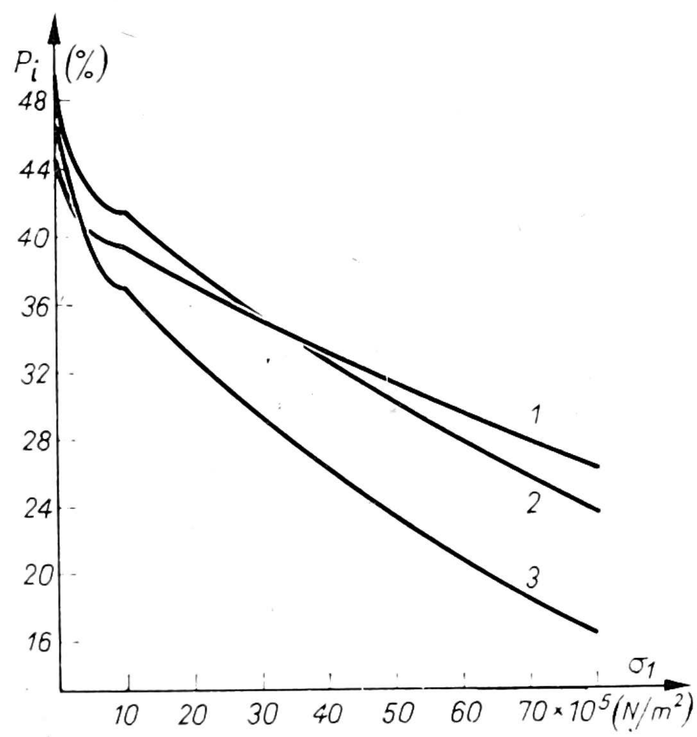

Fig. 4. Change of the grain mass porosity in the chosen varieties of spring wheat under the influence of increased static loadings: *1* — Kolibri, *2* — Carola, *3* — Urbanka

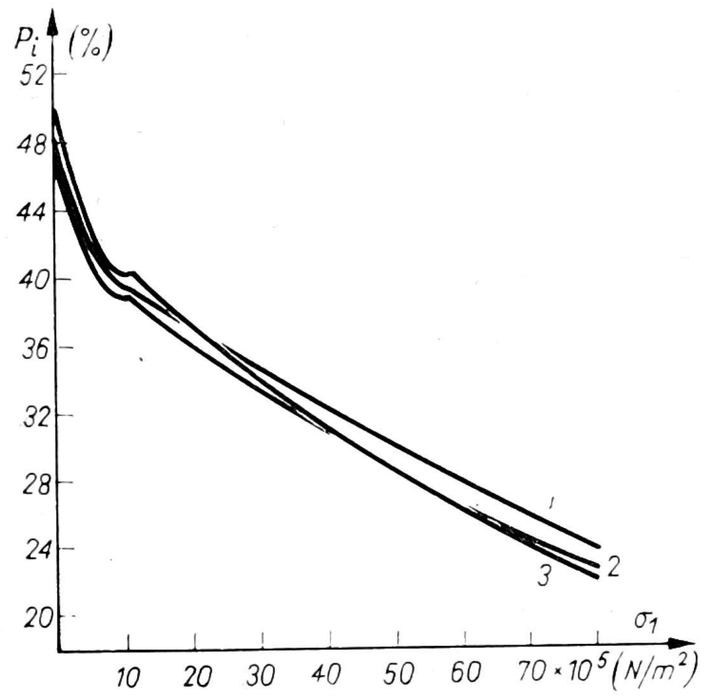

Fig. 5. Change of the grain mass porosity in the chosen varieties of rye under the influence of increased static loadings: *1* — Dańkowskie Nowe, *2* — Dańkowskie Złote, *3* — Pancerne

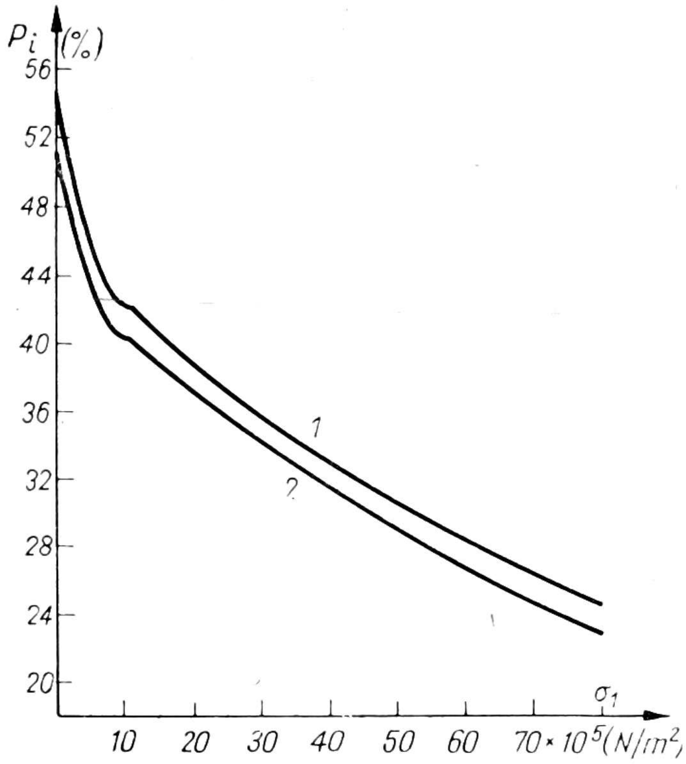

Fig. 6. Change of the grain mass porosity in the chosen varieties of spring barley under the influence of increased static loadings: *1* — Piast, *2* — Elgina

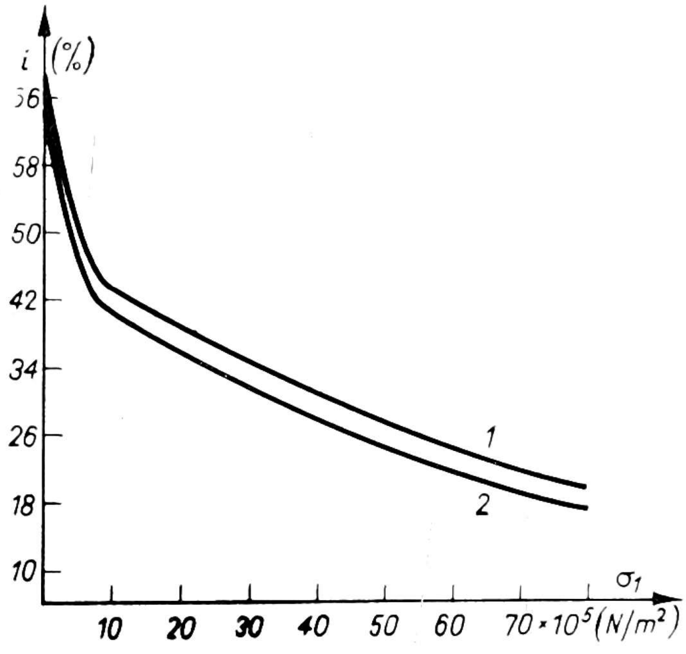

Fig. 7. Change of the grain mass porosity in the chosen varieties of oats under the influence of increased static loadings: *1* — Flämingsweiss, *2* — Romulus

The obtained shape of the curve determined the choice of a two-element describing equation:

a) the rapid drop of porosity of layer to the limit of normal strain $\sigma = 10 \cdot 10^5$ N/m²,

b) the gradual decrease of porosity in the range of strains $\sigma = 10 \cdot 10^5 - 80 \cdot 10^5$ N/m².

Although both these processes take place simultaneously, in the initial stage of compressing the process of the rapid drop of porosity is explained by the increased movement of grains tending to obtain a state of permanent equilibrium. In the parallel process dominates the phenomenon of clear compressing of particular grains.

Among the investigated varieties of cereals different ranges of variability of the porosity of loaded layer are observed. The most decreases the porosity of oats grain leyer — the loss of free intergrain spaces at the assumed level of normal strains is 50.29%. The least with winter wheat — 17.13%. It is assumed that a decisive role in so considerable a difference between these values is played by the chaffing of oats grain.

Table 2

Limit values and the loss of porosity of grain mass subjected to static loading in the range to $80 \cdot 10^5$ N/m²

Type of cereal	Variety	Initial porosity (%)	Porosity at $\sigma = 80 \cdot 10^5$ N/m² (%)	Loss of porosity
Winter wheat	Aurora	44.50	27.37	17.13
	Kaukaz	45.15	26.24	18.91
	Grana	44.95	24.31	20.64
Spring wheat	Kolibri	45.75	25.97	19.78
	Carola	49.70	23.64	26.06
	Urbanka	46.50	16.08	30.42
Rye	Dańkowskie Nowe	48.40	23.69	24.71
	Dańkowskie Złote	47.25	22.23	25.00
	Pancerne	50.30	22.03	28.27
Barley	Piast	54.20	25.06	29.14
	Elgina	31.45	23.21	28.24
Oats	Flämingsweiss	68.25	18.98	49.27
	Romulus	67.00	16.71	50.29

Table 2 presents the limit values and the loss of porosity of grain layers subjected to static loadings. On the basis of these results we can assume that the coefficient s in the theoretical equation can be an index of the degree of compactness of the loaded grain layer — the greater the porosity decrease the lower the value of the coefficient s.

Summing up we can state that higher degrees of compactness characterize those loose materials that show a higher susceptibility to the change of porosity of grain layer in the accepted range of loadings.

REFERENCES

1. Gąsiorowski H., Szebiotko K.: Współczesne metody przechowywania mokrego ziarna zbóż. Post. Nauk rol. nr 6, 1974.
2. Kisiel I., Lysik B.: Zarys reologii gruntów. Działanie obciążenia statycznego na grunt. Wyd. „Arkady", Warszawa 1966.
3. Pabis S.: Suszenie płodów rolnych. PWRiL, Warszawa 1965.
4. Szot B.: Metodyczne aspekty oceny cech fizycznych ziarna pszenicy. Rocz. Nauk rol. ser. D, t. 160, 1976.
5. Szot B., Woźniak W.: Zastosowanie porometru ciśnieniowego do oznaczania porowatości warstwy ziarna zbóż. Biuletyn IHAR nr 1—2, 1974.
6. Tomczyk S.: Magazyn ziarna i innych nasion. PWRiL, Warszawa 1970.

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ZMIENNOŚĆ POROWATOŚCI WARSTWY ZIARNA ZBÓŻ POD WPŁYWEM OBCIĄŻEŃ STATYCZNYCH

Streszczenie

Optymalizacja procesów suszarnictwa i przechowalnictwa w znacznej mierze zależy od porowatości warstwy ziarna, której wielkość uwarunkowana jest między innymi stopniem zagęszczenia nasion wynikającym ze wzajemnego ułożenia nasion w masie.

Badania wpływu obciążeń statycznych na porowatość warstwy ziarna przeprowadzono na 4 odmianach pszenicy ozimej, 3 odmianach pszenicy jarej, 3 odmianach żyta oraz 2 odmianach jęczmienia i owsa, przy użyciu porometru ciśnieniowego (pomiar porowatości) oraz maszyny wytrzymałościowej firmy „Intron" (obciążenia statyczne).

Charakter przebiegu zmiany obciążeń w funkcji odkształcenia wskazuje na wyraźne zróżnicowanie zarówno w stopniu zagęszczenia, jak i sprężystości badanych odmian zbóż.

Na podstawie uzyskanych przebiegów wyznaczono porowatość w funkcji obciążeń ciągłych od 0 do 800 N/cm^2. Spadek zawartości wolnych przestrzeni międzyziarnowych dochodzi do 50% u owsa i do 30% u pozostałych rodzajów zbóż.

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ИЗМЕНЧИВОСТЬ ПОРИСТОСТИ СЛОЯ ЗЕРНА ЗЕРНОВЫХ ПОД ВЛИЯНИЕМ СТАТИЧЕСКИХ НАГРУЗОК

Резюме

Оптимализация процессов сушки и хранения в значительной мере зависит от пористости слоя зерна, величина которой обусловлена м.пр. степенью сгущения семян, вытекающей из их расположения в массе относительно друг друга.

Исследования влияния статических нагрузок на пористость слоя зерна провели на 4 сортах озимой пшеницы, 3 сортах яровой пшеницы, 3 сортах ржи и 2 сортах ячменя и овса с применением напорного порометра (измерение пористости) и машины для исследования прочности фирмы „Инстрон" (статическая нагрузка).

Характер развития изменений нагрузок в функции деформации указывает на отчетливую дифференциацию как степени сгущения, так и упругости исследуемых сортов зерновых.

На основании полученных развитий определили пористость в функции сплошных нагрузок от 0 ыа 800 Н/см². Понижение содержания свободных межзерновых пространстве достигает 50% у овса и 30% у остальных видов зерновых.

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