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EFFECT OF CONDITIONS OF CONFINED COMPRESSION ON PROPERTIES OF WHEAT AGGLOMERATES

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Key words: confined compression, agglomerate properties, wheat

Polish wheat cultivar Sakwa was used in compression experiments. Ground wheat samples were compacted applying compression chambers of different diameter, at pressure ranging from 50 to 170 MPa. The agglomerates obtained in the experiments were subjected to the quality assessment. Density and mechanical resistance of the agglomerates was determined for different compression conditions, *i.e.* sample mass, die diameter, and pressure applied.

NOMENCLATURE

d – chamber diameter (mm); $L`_c$ – specific compression work (J/g); m – mass of compacted sample (g); P – loading pressure (MPa); R^2 – determination coefficient; σ – strength of agglomerate (N/cm); ρ_k – density of agglomerate directly after compression (g/cm^3); ρ_{k1} – density of agglomerate after 24 h (g/cm^3).

INTRODUCTION

The main objective of the granulation process is to obtain feedstuffs in the form of agglomerates at appropriate dimensions and required durability. One of the main research directions relates to material density changes under various compression conditions [Aydin *et al*., 1997; Hejft, 2002; Laskowski & Skonecki, 1995; O'Dogherty, 1989; Tabil & Sokhansanj, 1997]. Determination of magnitude of interactions between physical properties of materials processed and compression parameters, as well as interpretation of the phenomena accompanying to the state and density changes in material undergoing compression, constitute still an important research problem. Research works on the subject addressed, among others, the moisture of selected leguminous seeds, *i.e.*, faba bean, pea, lupine, and vetch [Laskowski & Skonecki, 1997], and grain of cereals, *i.e.*, barley, oat, wheat, and rye [Laskowski & Skonecki, 1999], material temperature [Laskowski & Skonecki, 2000], the amount of material in the die that undergoes compaction, as well as die diameter [Laskowski & Skonecki, 2004], in view of the processing course, and material ability to agglomeration assessment. In the present study, relevancy of some compaction conditions to the properties of final agglomerates is investigated.

MATERIAL AND METHODS

Polish wheat cv. Sakwa was used in the compression experiments. The grains were crushed on a hammer mill at 3 mm screen mesh size. Mean particle size of the ground material was determined according to the Polish Standard [PN-89/R-64798] applying sieve analysis method. The following sieve apertures were used: 2.5, 1.6, 1, 0.8, 0.63, 0.5, 0.4, 0.315, and 0.2. Average particle size was equal to 0.93 mm.

The compression tests were made at 14±0.2% of material moisture content (wet basis). In the experiments, the procedure described by Laskowski & Skonecki [2001a] was followed. Small material samples were compacted with the help of Zwick Z020 universal machine applying a 20 kN load cell. Changes of compression loads in relation to the piston displacement were registered with testXpert, original Zwick software. The compression assembly, as presented in Figure 1, was used in the study.

Three compression chambers differing in diameter,, *i.e.* 12, 15, 18 mm, were filled with ground wheat samples of mass varying from 2 to 10 g, dependently on the chamber used. The samples were compacted at the constant compression rate equal to 10 mm/min, for five distinct compression pressure levels, *i.e.*, 50, 80, 110, 140, 170 MPa. The experiments were carried out in three repetitions for each configuration as presented in Table 1.

TABLE 1. Conditions of compression experiments.

Die diameter d (mm)	Sample mass m (g)	Loading pressure P (MPa)
12	2, 3, 4, 5	50, 80, 110, 140, 170
15	4, 5, 6, 7, 8	50, 80, 110
18	5, 6, 7, 8, 9, 10	50, 80

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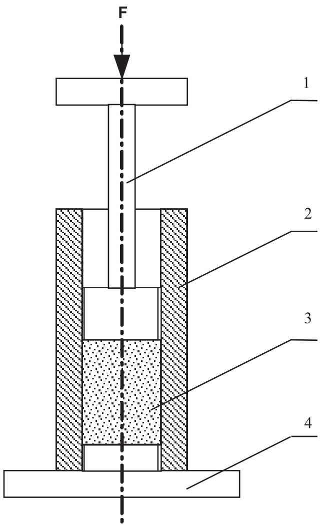

FIGURE 1. Scheme of the compression assembly: 1 – piston, 2 – cylinder, 3 – compressed material, 4 – bottom stand.

Density of the obtained agglomerates was determined directly after compaction (ρ_k), and after 24 h (ρ_{k1}). They were afterwards subjected to the mechanical testing in compression. The agglomerates in lying position were compressed until rupture occurred. This method is used frequently [Laskowski, 1989; Melcion & Delort, 1981]. The force at rupture in relation to the length of agglomerate denoted here as agglomerate strength was computed. Additionally, the specific compression work was defined as the quotient of the compression work (area under load-displacement curve), and the compacted sample mass on the basis of recorded characteristics for each individual test.

The experiment results were statistically analysed with Statistica software, ver. 5.0 (Statsoft Inc.). For the compression with 12 mm chamber diameter, multiple regression relations between agglomerate properties, compression work and sample mass as well as loading pressure were developed. For the two other chambers the effect of pressure was not analysed. Significant differences for mean values were tested at α=0.05.

RESULTS AND DISCUSSION

Some relationships, that describe the influence of sample mass and applied compression pressure on the defined above parameters, for different diameter chambers were presented in Figures 2 to 6. Tables 2 and 3 include the developed regression equations.

The density of agglomerates ρ_k and ρ_{k1} increased with the sample mass, as well as with the loading pressure (Figures 2, 3 and 4). The lower density of agglomerates after 24 h of storage ($\rho_k > \rho_{k1}$), shows their tendency to expand. For this time period, as shown by Laskowski & Skonecki [2001b], the agglomerate achieved its final density. The verification of the statistical hypothesis on the existence of significant differences, within samples differing with the mass of compacted wheat, for average agglomerate densities ρ_k and ρ_{k1}, confirmed the significant influence of the compacted material mass on these factors, which for the different dies was presented in Table 4.

TABLE 2. Regression equations describing relationships between ρ_k, ρ_{k1}, σ, L`C, and mass of compacted sample m, and loading pressure P, for the 12 mm chamber diameter.

Chamber diameter d (mm)	Equation form	Determination coefficient R^2
12	$\rho_k = 0.013\ m + 0.0006\ P + 1.14$	0.772
	$\rho_{k1} = 0.007\ m + 0.0006\ P + 1.1$	0.846
	$\sigma = 2.8\ m + 0.12\ P - 0.05$	0.562
	$L`_C = -0.45\ m + 0.06\ P + 4.18$	0.956

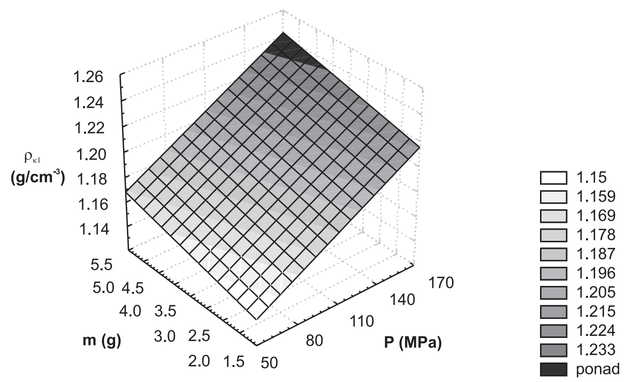

FIGURE 2. Density of the agglomerate after 24 h of storage time ρ_{k1}, in relation to the mass of compacted sample m, and loading pressure P (12 mm diameter chamber).

Strength of the agglomerates increased in relation to the mass of compacted sample (Figure 5). The highest strength, about 52.23 N/cm was obtained for the agglomerates when compressed in 18 mm chamber diameter, 80 MPa of loading pressure, and sample mass of 10 g; and the lowest of about 4.18 N/cm, under conditions of 18 mm of die diameter, 50 MPa of pressure, and 5 g sample.

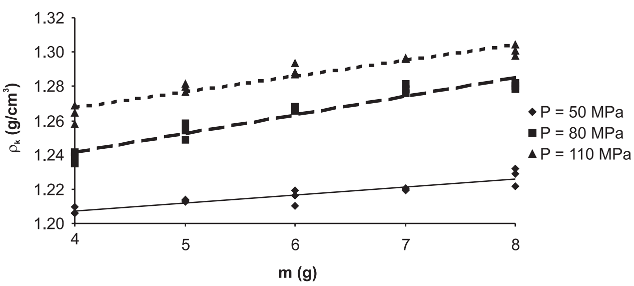

FIGURE 3. Density of the agglomerate ρ_k, in relation to the mass of compacted sample m, at different loading pressures P (15 mm diameter chamber).

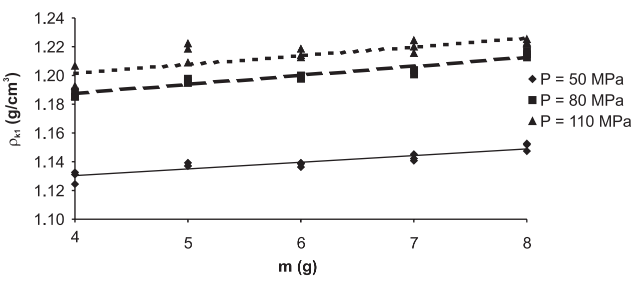

FIGURE 4. Density of the agglomerate ρ_{k1} after 24 h of storage time, in relation to the mass of compacted sample m, at different loading pressures P (at 15 mm diameter chamber).

TABLE 3. Regression equations describing the relationships between ρ_k, ρ_{k1}, σ, L`C, and the mass of compacted sample m, for the 15 and 18 mm chamber diameters.

Chamber diameter D (mm)	Loading pressure P (MPa)	Equation form	Determination coefficient R^2
15	50	$\rho_k = 0.009\ m + 1.2$	0.908
		$\rho_{k1} = 0.05\ m + 1.1$	0.850
		$\sigma = 3.65\ m - 6.6$	0.931
		$L`_C = -0.115\ m + 6.55$	0.807
	80	$\rho_k = 0.011\ m + 1.2$	0.923
		$\rho_{k1} = 0.006\ m + 1.16$	0.912
		$\sigma = 4.1\ m + 2.6$	0.786
		$L`_C = -0.21\ m + 9.6$	0.747
	110	$\rho_k = 0.005\ m + 1.19$	0.836
		$\rho_{k1} = 0.006\ m + 1.18$	0.587
		$\sigma = 5.6\ m - 3.8$	0.862
		$L`_C = -0.38\ m + 12.7$	0.853
18	50	$\rho_k = 0.002\ m + 1.2$	0.922
		$\rho_{k1} = 0.01\ m + 1.06$	0.948
		$\sigma = 5.3\ m - 22.03$	0.924
		$L`_C = -0.08\ m + 6.19$	0.753
	80	$\rho_k = 0.003\ m + 1.3$	0.887
		$\rho_{k1} = 0.009\ m + 1.14$	0.931
		$\sigma = 6.99\ m - 18.15$	0.924
		$L`_C = -0.28\ m + 10.8$	0.858

TABLE 4. Mean values of agglomeration parameters in relations to the mass of compacted sample, and the chamber characteristic.

Sample mass M (g)	Parameter			
	ρ_k (g/cm)	ρ_{k1} (g/cm)	σ (N/cm)	$L`_c$ (J/g)
Chamber diameter 12 mm				
2	1.227 (a)	1.181 (a)	15.636 (a)	10.630 (a)
3	1.259 (b)	1.189 (ab)	21.109 (b)	9.601 (b)
4	1.269 (b)	1.197 (bc)	25.952 (c)	9.079 (c)
5	1.268 (b)	1.201 (c)	23.359 (bc)	9.316 (bc)
Chamber diameter 15 mm				
4	1.236 (a)	1.170 (a)	15.138 (a)	8.724 (a)
5	1.249 (b)	1.183 (ab)	19.760 (a)	8.437 (ab)
6	1.257 (bc)	1.184 (ab)	24.893 (b)	8.068 (bc)
7	1.265 (cd)	1.188 (b)	26.063 (b)	8.011 (c)
8	1.269 (d)	1.196 (b)	34.148 (c)	7.772 (c)
Chamber diameter 18 mm				
5	1.250 (a)	1.147 (a)	10.930 (a)	7.691 (a)
6	1.253 (ab)	1.161 (b)	15.589 (b)	7.462 (ab)
7	1.255 (bc)	1.169 (c)	20.246 (c)	7.261 (bc)
8	1.256 (cd)	1.186 (d)	35.832 (de)	6.878 (cd)
9	1.258 (d)	1.191 (de)	33.690 (d)	6.809 (d)
10	1.263 (e)	1.196 (e)	39.532 (e)	6.904 (cd)

The average comparisons showed some significant differences in relation to the compacted mass, which can be observed in Table 4.

The specific compression work ($L`_c$) ranged from 5.2 to 15.3 J/g, for the whole range of the compression conditions used in the study. An exemplary relation between this work and the material sample mass m is plotted in Figure 6. The relation had generally linear character for all the pressure levels applied, and a slight decrease of the work might be observed with an increase of the compacted mass. Some homogenous groups were noticed as well (Table 4).

CONCLUSIONS

The properties of the wheat agglomerates obtained in the confined compression tests depended on mass of compacted material, loading pressure and chamber diameter. Decrease of specific compression work, and increase of density and strength of agglomerates for larger mass samples undergoing compaction were observed. Increased loading pressures cause an increase in agglomerate density and strength.

The presented research results might be useful for the development of the method for the compression ability assessment of biological materials.

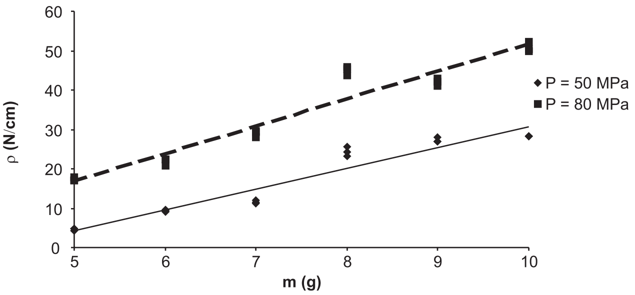

FIGURE 5. Strength of the agglomerate σ in relation to the mass of compacted sample m, at different loading pressures P (18 mm diameter chamber).

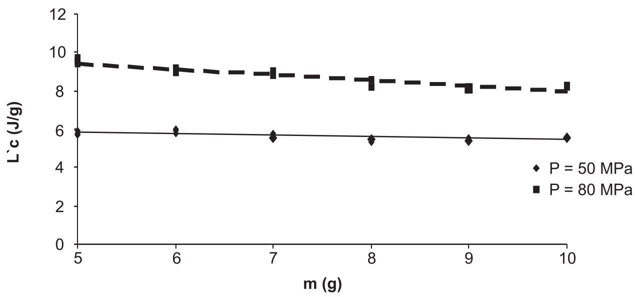

FIGURE 6. Specific compression work L`c, in relation to the mass of compacted sample m, at different loading pressures P (18 mm diameter chamber).

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WPŁYW PARAMETRÓW ZAGĘSZCZANIA NA WŁAŚCIWOŚCI AGLOMERATU ZIARNA PSZENICY

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Materiał badawczy stanowiły ziarna pszenicy odmiany „Sakwa". Rozdrobnione próbki pszenicy poddano zagęszczaniu przy stosowaniu matryc o różnych średnicach komory i maksymalnych nacisków w zakresie od 50 do 170 MPa. Uzyskane z eksperymentów aglomeraty poddano ocenie jakościowej. Badania wskazały, że gęstość i twardość aglomeratu zależy od warunków zagęszczania: masy próbki, średnicy komory i stosowanego nacisku.