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EFFECT OF DIFFERENT VARIANTS OF PRETREATMENT OF WHEAT GRAIN ON THE PARTICLE SIZE DISTRIBUTION OF FLOUR AND BRAN

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Summary. The paper presents the results of a study on the particle size distribution of flour and bran obtained as a result of milling of wheat grain with the application of vacuum impregnation and IR heating as the preliminary treatments. The grain was prepared for the milling through the combined application of vacuum impregnation at 5 and 100 kPa and of IR treatment at temperatures of 150 and 180^{o}C during 90 and 150 s in different variants. It was found that the manner of grain preparation for milling had an effect on the particle size distribution of the products of the milling process. The consecutive application of the processes of vacuum impregnation and IR heating caused a significant increase in the level of bran fraction with larger particle sizes, which may indicate effectiveness of the proposed preliminary treatment of wheat grain prior to milling.

Key words: vacuum impregnation, infrared radiation treatment, milling, wheat, particle size distribution.

INTRODUCTION

In cereal processing grain moisture is one of the fundamental criteria of estimation of its status and technological value. That parameter is of particular importance in the production of flour. Hence the production processes of various products of that industry frequently involve moistening operations. The moistening is conducted at various stages of the technological sequence: immediately after the cleaning of granular materials (prior to milling), or after milling and before various processes, mainly thermal [Jankowski 1988].

The moistening of grain causes a number of various changes. The inner structure of kernels changes. The forces binding proteins and starch are reduced, and the kernel structure gets damaged through the appearance of strains caused by the various levels of swelling of the particular components [Obuchowski et al. 1981, Skonecki i et al. 2010].

Grain moistening is one of the most important pretreatments before the proper technological processes. Contact with water is the starting point for a number of physical and chemical transformations [Maskan 2001].

Among other things, grain moistening is conducted prior to the milling of wheat and rye in order to plasticise the seed coat and to separate it from the parenchyma. Well moistened kernels are such whose whole external surface (seed coat) is uniformly moistened, irrespective of the amount by which the grain moisture has been increased [Kowalewski 1992, Dziki et al. 2004, Opielak et al. 2004, Dziki et al. 2005, Grochowicz et al. 2006].

Jurga [1997] reports that grain to be subjected to milling or husking should be characterised by moisture difference between the parenchyma and the seed coat. That difference should about 2%. Too great a difference in moisture between the seed coat and the parenchyma has an unfavourable effect on the milling properties of grain, as it causes an increase in grain elasticity and plasticity, which leads to an increase in the unit energy requirements in the course of milling.

Within the scope of this study, the grain material was moistened with the technique of vacuum impregnation which permits notable intensification of the process of mass exchange in the solid-liquid system, the consequence of which is uniform moistening of the grain in the external layers of the kernels, without wetting the parenchyma [del Valle et al. 1998, Betoret et al. 2003, Chiralt et al. 2001, Guamis et al. 1997, Gonzalez et al. 1999, Chafer et al. 2003, Fito et al. 1996, Fito et al. 2001]. However, grain subjected to vacuum impregnation is characterised by too high moisture levels, in some cases even exceeding 20%, to be directly subjected to milling. Hence the proposal to apply the technique of infrared radiation treatment (micronisation) that guarantees the possibility of obtainment of virtually any desired grain moisture level prior to the milling and ensures favourable changes in the structure of the kernels. Another advantage of the process is the fact that the times of grain exposure to infrared radiation are very short (up to 3 min), which minimises the energy consumption.

The objective of the study was to determine the effect of vacuum impregnation and IR radiation treatment on the particle size distribution of flour and bran which is one of the fundamental criteria in the evaluation of the process of milling.

PURPOSE AND METHODS

The experimental material was wheat grain cv. Koksa and Torka. The grain was moistened to several levels of initial moisture content. The milling of the grain was performed on a laboratory mill Quadrumat Junior. It is a four-roller laboratory mill with an aspiration system and a drum sifter. The milling of a grain sample using this mill corresponds to the milling parameters obtained in industrial mills. Determinations of grain material moisture prior to and after the moistening, and of the flour and bran obtained as a result of the milling, were made with the over-dry method in accordance with the standard PN-86/A-74011. Grain moistening was conducted in sealed containers. A laboratory balance with an accuracy of 10^{-2}g was used to weigh portions of 500 g of each kind of grain, the portions were placed in the containers, and then water was added in such amounts as to obtain the required levels of grain moisture. Then the containers with the grain material were sealed, shaken and placed in a refrigerator for a period of 72 hours.

Impregnation of wheat grain

The process of grain impregnation was conducted in a chamber with a volume of ca. 2 dm^3, coupled to a vacuum pump permitting the regulation of pressure win the chamber within the range of 5-100 kPa. The chamber was immersed in the water bath of an ultra-thermostat which permitted the process to be conducted under various temperature conditions. To ensure complete immersion of all kernels, they were placed in a container made of wire mesh. The level of pressure in the chamber was recorded by means of a vacuum gauge. The cover of the camber was additionally equipped with a system of valves connecting the chamber with the vacuum pump and a water reservoir. The tight sealing at the interface between the chamber and the cover was achieved by means of a gasket greased with vaseline.

After placing the vacuum chamber in the ultra-thermostat, the temperature of the process of grain moistening was set. The temperature of 15°C was applied. The water wetting the grain was at a temperature similar to that of the temperature in the chamber. The differences between those temperatures were within ±2°C. After the temperature in the chamber stabilised, a container with a weighed portion of grain material, with a weight of ca. 40 grams, was placed in it.

Next, when the hydraulic hoses were filled with water, the chamber was closed and, after opening the valve connecting with the vacuum pump, the pressure in the chamber was set. The pressure levels applied in the study were 5 kPa and 100 kPa – atmospheric pressure (control treatment). When the pressure stabilised, the valve connecting with the water reservoir was closed. Each time the grain sample was flooded with a portion of water with volume of ca. 0.2 dm^3. In the course of flooding the grain sample with water, a slight increase of the pressure in the chamber was observed as the chamber filled with the water. The control sample was moistened following a similar procedure, but under the conditions of atmospheric pressure.

When the grain sample was fully flooded, the pressure was rapidly brought up to the atmospheric pressure. Grain samples were taken immediately after the impregnation (after about 30 seconds of contact with water).

The measurement system is presented in Fig. 1.

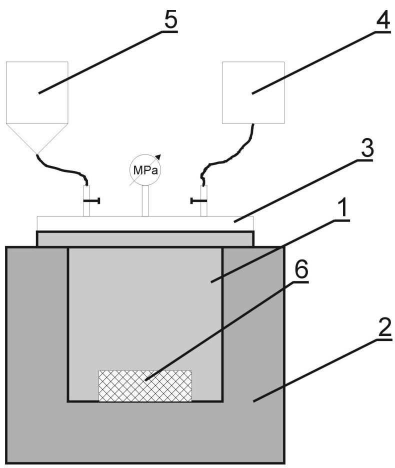

Fig. 1. Schematic of the measurement system for the study of the process of vacuum impregnation of grain: 1 – vacuum chamber, 2 – ultra-thermostat, 3 - cover, 4 – vacuum pump, 5 – water reservoir, 6 – container with grain material

Grain heating with IR radiation

The process of grain heating with IR radiation was conducted with the help of a device designed and constructed by Andrejko [2004]. The main elements of the system (Fig. 2) are frame 1, belt conveyor and a heating system with stepless temperature adjustment. The grain material is pursed into chute 3, equipped with a shutter, and then it is fed onto the belt of the conveyor (single layer). The material on the conveyor belt is moved to the heating zone 8, where it is subjected to treatment with infrared radiation. The conveyor is powered by a DC electric motor with a voltage regulator permitting smooth adjustment of the belt speed within the range from $5\times10^{-3}m\times s^{-1}$ to

7×10^{-2} m$\times$s^{-1} (the material remains in the heating zone for 15 to 200 s, respectively). The conveyor belt material is characterised by considerable resistance to high temperatures (up to 250°C) and low IR transmittance (ca. 10%). The device is equipped with two heating heads 2 (each with 4 IR radiators); the upper head, positioned above the belt, and the lower head, located beneath the belt.

For heat treatment of small grains it is sufficient to use only the upper head. When heating large seeds, e.g. those of white lupine, it is recommended that the lower head is also switched on. In such a case the belt of the conveyor should be replaced with a belt of φ = 0.1 mm copper wire, with square mesh of 1 mm side. Such a wire mesh has IR transmittance of over 90%.

IR radiation is emitted by 8 individually supplied radiators (4 in each section). Those are temperature radiators, built of ceramic material, supplied with mains power (230V), and their power rating is 400W. In their spectrum the share of visible radiation is at a level of a fraction of one percent (dark emitters). Due to their design (flat panel emitters) they provide uniform heating at all points of the surface of the conveyor belt within the heating zone. Mean temperature of the emitter surface is ca. 500°C, and the emitted wavelength is λ = 2.5-3.0 μm.

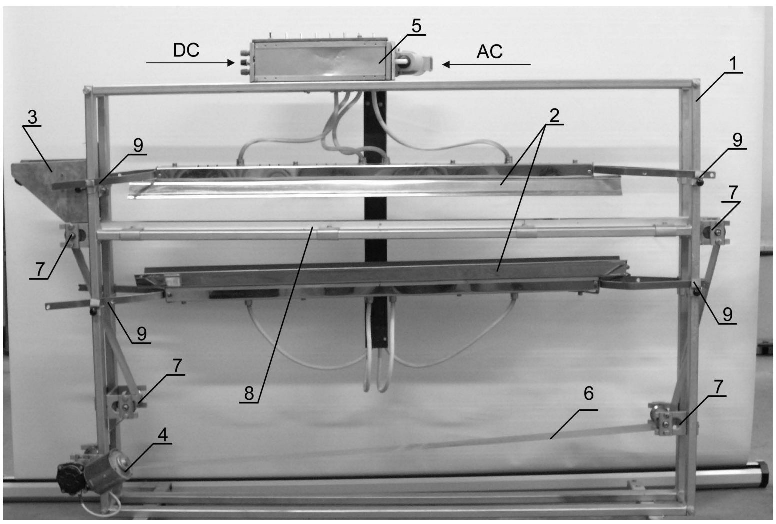

Fig. 2 Laboratory device for IR treatment of granular plant materials; 1 – frame, 2 – heating head with 4 IR radiators with individual power supply, 3 – filling chute, 4 – DC motor, 5 – control module, 6 – conveyor belt, 7 – rollers, 8 – heating zone, 9 – adjustment of heating head position

Particle size distribution determination

Flour and bran screening was performed using the Retsch vibratory sieve shaker AS 200. It is equipped with an electromagnetic drive system producing 3D throwing motions, which causes uniform distribution of the material screened over the whole sieve area. Very simple operation and short screening times with very high separation efficiency are the advantages of the sieve shaker.

The screening was conducted at vibration amplitude of 2.20 mm and measurement time of 2 minutes. The adopted parameters of sifting result from earlier studies on the effect of the parameters of the sieve shaker operation on the separation efficiency of granular mixtures. The sieves applied were Vogel sieves with elongated apertures with dimensions of 1.60x25, 1.70x25, 2.20x25, 2.50x25 and 2.80x25 mm. The weight of a screened sample was 300 g. The measurements were performed in five replications.

Moreover, sieve analysis was performed for flour and bran acquired through milling. The sifting was made using sieves with square mesh, suitable for flour and bran.

RESULTS AND DISCUSSION

The results of the analyses performed within the scope of the study are presented graphically in Figures 3-4.

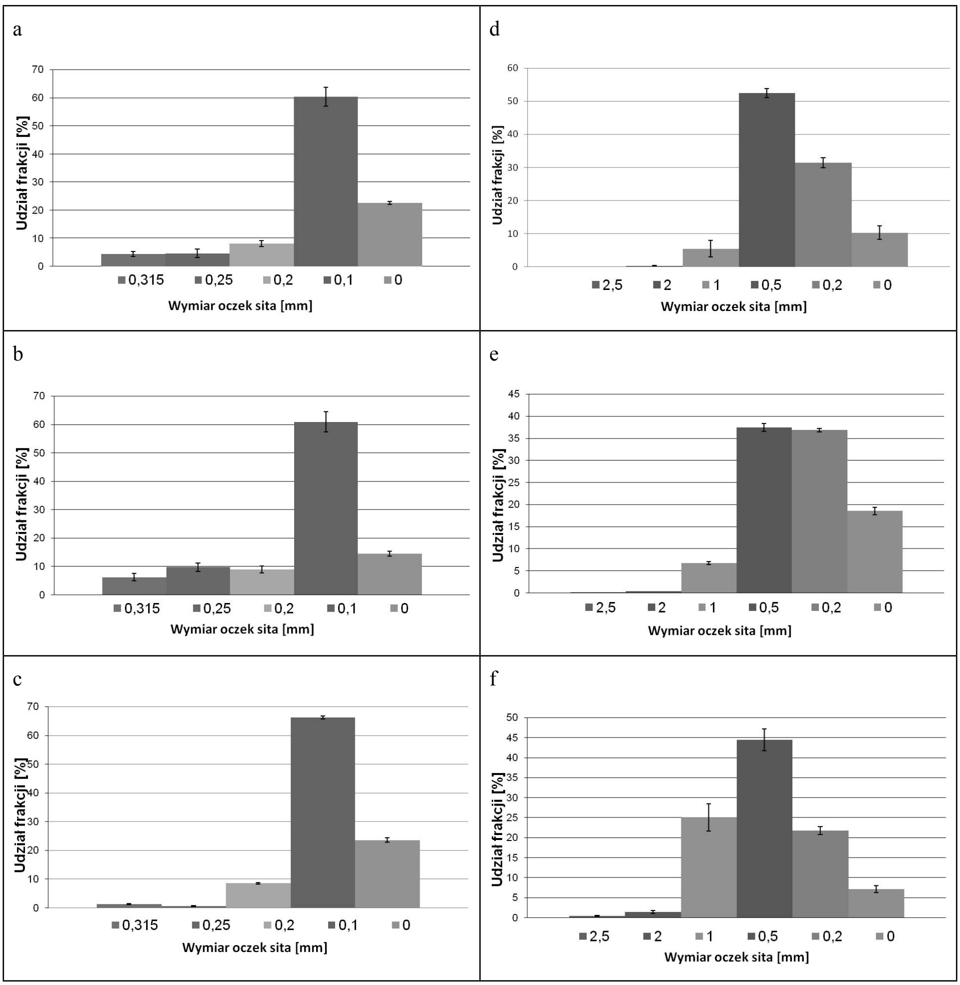

Fig. 3. Results of sieve analysis of flour and bran obtained through milling of wheat grain cv. Torka, a, b, c – flour, d, e, f – bran,
a, d – flour and bran from zero sample (control) b, e – flour and bran from grain after micronisation at 150 °C for 90 s. c, f – flour and bran from grain after impregnation at 5 kPa and micronisation at 150 °C for 150 s

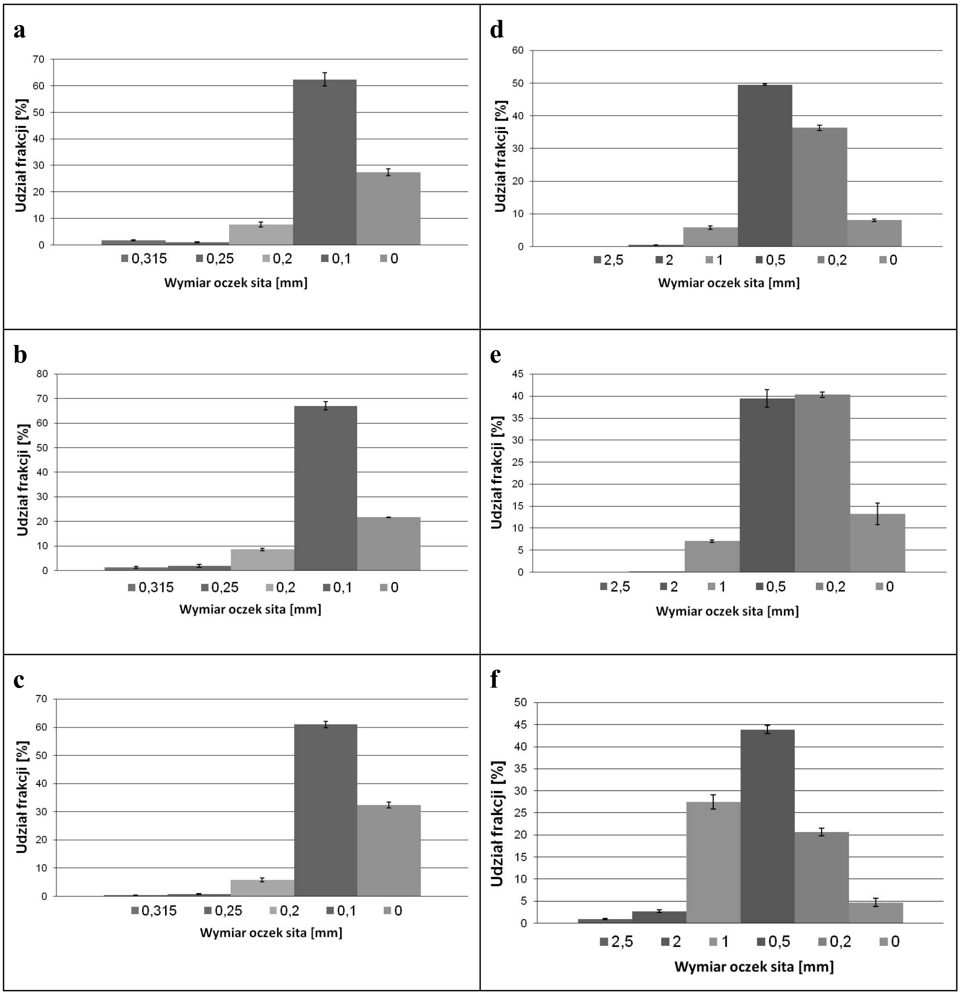

Fig. 4. Results of sieve analysis of flour and bran obtained through milling of wheat grain cv. Koksa, a, b, c – flour, d, e, f – bran,
a, d – flour and bran from zero sample (control) b, e – flour and bran from grain after micronisation at 150 °C for 90 s. c, f – flour and bran from grain after impregnation at 5 kPa and micronisation at 150 °C for 150 s

After analysing the results obtained one can note that in all cases studied the size of the bran particles produced was affected by the process of impregnation preceding the milling, causing an increase in their size. The fraction obtained on the sieve with mesh size of 1 mm was several times greater after grain impregnation at 5 kPa than in the other cases. Analysis of the particle size distribution of flour revealed that, irrespective of the preliminary treatments applied, its changes were not as pronounced as was the case with bran.

CONCLUSIONS

The study and the analysis of the results permitted the formulation of the following conclusions:

- Preliminary treatment of wheat grain consisting in the application of micronisation or impregnation and micronisation affects the particle size distribution of both the flour and the bran.
- Greater changes were observed in the case of bran. The moistening of grain, followed by short-time drying (micronisation) causes the seed cover to become elastic and not to crumble. Hence, after the application of both pretreatment processes, the mean size of bran particles increases significantly.

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WPŁYW RÓŻNYCH WARIANTÓW PRZYGOTOWANIA ZIARNA PSZENICY NA SKŁAD GRANULOMETRYCZNY MĄKI I OTRĄB

Streszczenie. W pracy zaprezentowano wyniki badań składu granulometrycznego mąki i otrąb otrzymanych w wyniku przemiału ziarna pszenicy z zastosowaniem impregnacji próżniowej i ogrzewania promieniowaniem podczerwonym jako obróbki wstępnej. Ziarno przygotowano do przemiału przez zastosowanie połączonych zabiegów impregnacji próżniowej w ciśnieniu 5 i 100 kPa oraz obróbki promieniowaniem podczerwonym w temperaturze 150 i 180 ^{o}C i czasie 90 i 150 s w różnych wariantach. Stwierdzono, że sposób przygotowania ziarna do przemiału ma wpływ na skład granulometryczny produktów przemiału. Zastosowanie kolejno po sobie następujących procesów impregnacji i ogrzewania promieniowaniem podczerwonym powodowało znaczny wzrost ilości frakcji otrąb o większych wymiarach cząstek, co może świadczyć o skuteczności proponowanej obróbki ziarna przed przemiałem.

Słowa kluczowe: impregnacja próżniowa, obróbka promieniowaniem podczerwonym, przemiał, pszenica, skład granulometryczny.