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TEMPERATURE DISTRIBUTION IN SEED MASS STORED IN A METALLIC SILO IMMEDIATELY AFTER HARVEST

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Key words: silos, grain storage, temperatures, solar radiation.

Abstract

The aim of the study was to determine temperature distribution in seed mass stored in a metallic silo BIN60 (4.5 m in diameter). The silo was loaded with wheat grain, var. Elena, immediately after harvest on August 25, 2001. Temperatures were recorded at four points located on the silo radius, within a month after silo filling, i.e. until September 25, 2001. The maximum grain temperatures were determined on the basis of the results of measurements. The highest temperature inside the silo (42.9°C) was recorded on August 26, 2001 at a distance of 0.05 m from the silo wall. Such a high temperature can negatively affect the quality of stored grain. It is a direct consequence of a high rate of solar radiation energy. High temperatures of seeds made it necessary to analyze the rate of solar radiation affecting the silo blanket within the period of seed temperature measurement. The data on total daily insolation in the investigation area were provided by the Meteorological Station in Tomaszkowo. They were used for calculating the balance of solar radiation energy in W/m^2, applying the Black's formula modified by Brunt. Then temperature distribution in seed mass and solar radiation energy were compared. The above results allowed to draw practical conclusions on the limitation of the negative effect of seed mass overheating during storage in metallic silos. Both the location of silo batteries in a proper position in relation to the incidence angle of solar radiation and the use of insulating and protective layers covering silos blankets are recommended.

ROZKŁAD TEMPERATUR W MASIE NASION SKŁADOWANYCH W SILOSIE METALOWYM BEZPOŚREDNIO PO ZBIORZE

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S ł o w a k l u c z o w e: silosy, przechowywanie nasion, temperatury, promieniowanie słoneczne.

S t r e s z c z e n i e

Celem badań było wyznaczenie rozkładu temperatur w masie nasion w metalowym silosie BIN60 o średnicy 4,5 m. Silos załadowano pszenicą odmiany Elena, bezpośrednio po zbiorze 25.08.2001 r. Po zasypie, przez okres miesiąca, do 25.09.2001 r. prowadzono rejestrację temperatur w 4 punktach leżących na promieniu silosu. Z uzyskanych wyników pomiarów wyznaczono maksymalne temperatury ziarna. Najwyższą temperaturę 42,9°C zanotowano 26.08.2001 r. wewnątrz silosu w odległości 0,05 m od ściany silosu. Tak wysoka temperatura ma niekorzystny wpływ na jakość przechowywanego materiału. Wiąże się ona z wysoką energią promieniowania słonecznego. Wysokie temperatury nasion zmusiły do analizy wielkości promieniowania słonecznego oddziałującego na płaszcz silosu w okresie pomiarów rozkładu temperatur nasion. Ze stacji meteorologicznej w Tomaszkowie otrzymano wyniki dobowych sum usłonecznienia na obszarze prowadzonych badań. Na podstawie tych wyników ze wzoru Blacka w postaci zmodyfikowanej, podanej przez Brunta, obliczono saldo energii promieniowania słonecznego w W/m^2. Następnie porównano rozkłady temperatur masy nasion i energii promieniowania. Powyższe wyniki analizy pozwalają na wyciągniecie wniosków dotyczących zmniejszenia niekorzystnego przegrzania masy nasiennej przechowywanej w metalowych silosach zbożowych. Zaleca się stosowanie odpowiedniego usytuowania baterii silosów w odniesieniu do kierunku padania promieni słonecznych oraz odpowiednich warstw izolacyjnych i ochronnych pokrywających płaszcz silosów.

Introduction

The political transformations taking place in Poland at the end of 1980s included also significant changes in all national economy branches, especially agriculture, whose share in the gross national product was 8%, compared with 3% today (Central Statistical Office 1990, 2004). Changes in the agricultural structure made farmers specialize in particular production sectors. This concerned first of all plant production intensification and effective grain management. The farms which specialize in grain production were confronted with the problem of grain storage. Grain is usually stored in farm buildings adapted for this purpose, or metallic silos.

The physical and biological processes taking place after combine harvesting, during grain drying and storage, have a considerable effect on the biological value and eating quality of grain (GÓRECKI, GRZESIUK 2002). Therefore, three stands for testing cylindrical drying silos were constructed at the

Department of Agricultural Process Engineering, University of Warmia and Mazury in Olsztyn (BOWSZYS 1994):

- a silo with a radial ventilation system, funnel grain inlet chute, capacity 40 m^3,
- a silo with a vertical ventilation system, funnel grain inlet chute, capacity 37.3 m^3,
- a silo with a vertical ventilation system, capacity 70 m^3.

The above silos are equipped with appropriate apparatus and adapted for conducting complex studies on:

- rate and resistance of drying air flow,
- non-uniform airflow in seed mass,
- seed self-sorting and segregation,
- temperature distribution in seeds dried and stored in silos,
- biological changes in stored grain.

It is very important to maintain a proper temperature and humidity inside the silo during grain storage, as these factors affect the development of microorganisms influencing the quality of seed material and the eating value of grain (BOWSZYS, MAJCHRZAK 2002). Increased temperatures (above 20^{o}C) (KOSTECKI 1992, MAJCHRZAK 2002) are conducive to the development of fungi, especially *Penicillum* spp and *Rhizopus nigricans*, which cause mold and seed self-heating, thus deteriorating grain quality.

The objective of the present study was to determine temperature distribution in wheat grain stored in a silo immediately after harvest, as dependent upon solar radiation balance.

Material and Methods

The experimental material was wheat grain, var. Elena, with moisture content 13.5%. After combine harvesting wheat grain was pre-cleaned and dried in a platform drier. The silo was filled with grain to a height of 2.8 m.

The object of studies was a cylindrical silo, 4.5 m in diameter, with a flat perforated bottom (Fig. 1), located in the area owned by the Experimental Station in Tomaszkowo. The silo blanket, 4.85 m in height, is made of 1.5 mm tinned sheet.

Over the experimental period, i.e. from August 25, 2001 to September 25, 2001, temperature was measured at a height of 1.2 m at one external and three internal points of the silo (Fig. 1). The measuring points were located at the following distances from the silo wall:

- outside – 0.05 m,
- inside – 0.05 m – B_{23},
- inside – 0.75 m – B_{22},
- inside 1.5 m – B_{21}.

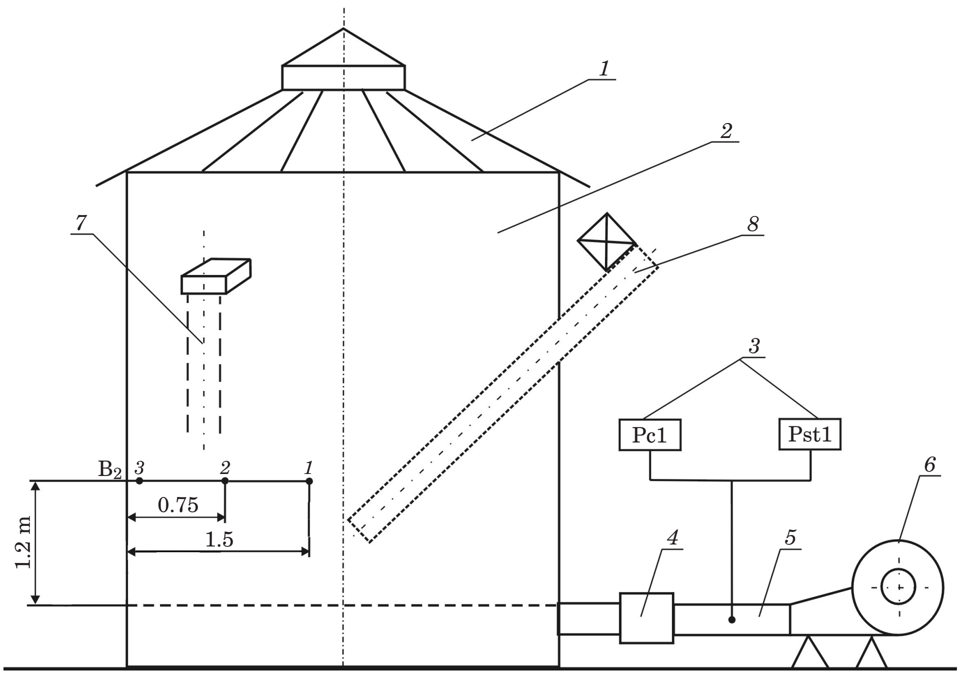

Fig. 1. Elevator with a vertical ventilator: *1* – roof, *2* – elevator, *3* – manometers, *4* – reheater, *5* – pipeline, *6* – ventilator, *7* – pipeline, *8* – worm conveyor, B_{23}, B_{22}, B_{13} – points of temperature measurement

Temperature was measured with a four-channel RDT recorder, registering 1398 measurements. The recorder can transmit the data to the computer on a daily basis. Temperatures at all measuring points were recorded at one-hour intervals for 30 days. Temperature measurement accuracy was 0.1°C.

Solar radiation balance was determined from the following formula:

$$R_n = R_k - R_l \qquad (1)$$

R_k – short-wave radiation balance (W/m^2),
R_l – long-wave radiation balance (W/m^2).

The short-wave radiation balance was calculated according to the Black's formula:

$$R_k = (1-\alpha)R_0(0{,}22 + 0{,}54u) \qquad (2)$$

R_0 – total radiation at the atmospheric boundary (W/m^2),
u – relative insolation,
á – albedo.

Albedo coefficient was *á*=0.50 (KAPUŚCIŃSKI 2000).

The long-wave radiation balance was calculated according to the Brunt's formula:

$$R_t = -5{,}68 \cdot 10^{-8}(t+273)^4(0{,}56-0{,}08\sqrt{e})(0{,}1+0{,}9u) \qquad (3)$$

R_t – long-wave radiation balance (W/m^2),
t – air temperature, degrees Celsius,
e – water vapor pressure, hPa,
u – relative insolation.

The coefficients in formulas 2 and 3 were adopted according to tables (KAPUŚCIŃSKI 2000). The radiation R_n decides about the final thermal effect on the silo surface. The values of cloudiness, air temperature and water vapor pressure were provided by the Meteorological Station in Tomaszkowo, belonging to the Department of Meteorology and Climatology, University of Warmia and Mazury in Olsztyn. The correlation between solar radiation balance and temperature inside the silo was also determined (OKTABA 1971).

Results

Figure 2 presents the results of air temperature measurements taken outside and inside the silo with wheat grain, at points $B_{21,}$ $B_{23,}$ B_{33}. Inside the seed mass, at point B_{21} temperature was decreasing from the initial value of 29.9°C to 18.7°C, according to the equation y=5E–05x^2–0.0542x+32.452 (R^2=0.9859). 0.75 m from the silo wall, at point B_{22}, the initial temperature was 29.6°C, to decrease to 17.7°C after 30 days, according to the equation y=4E–05x^2–0.052x+31.83 (R^2=0.9857). Heat exchange between the surroundings and wheat grain inside the silo was slow, which can be explained by a low coefficient of thermal conduction of wheat *ë*=0.137 W/mK (PABIS 1992).

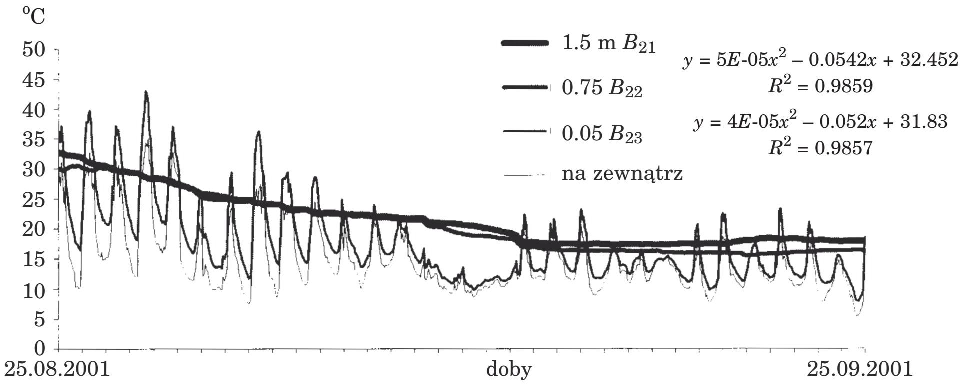

Fig. 2. Changes in grain temperature during the period of storage in an elevator

The highest daily temperature fluctuations (Fig. 2), correlated with solar radiation balance (Fig. 3), were observed in the near-wall zone, and varied from 19°C to 42.9°C on the second day of storage, when solar radiation rate was 27 344 W/m^2. Particular attention should be also paid to temperatures and solar radiation balance on the seventh day of storage – temperatures ranged from 14.7 to 36.2°C, and solar energy rate was 23 289 W/m^2.

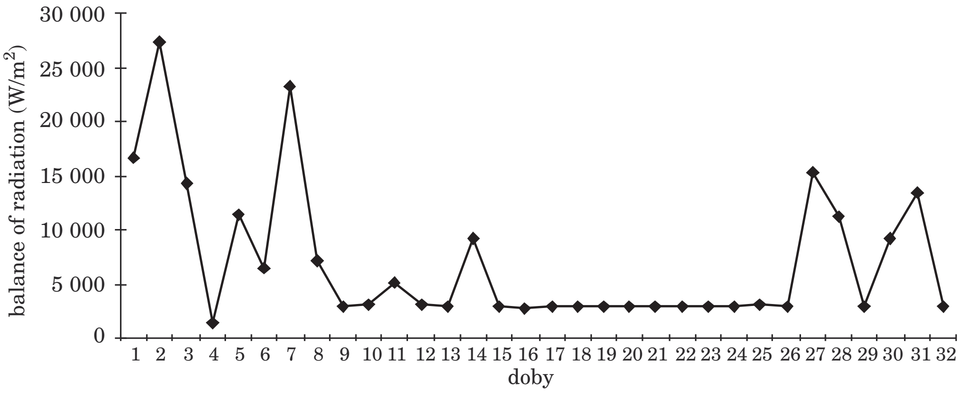

Fig. 3. Balance of radiation during the period of storage in a grain elevator

The data obtained show that the highest temperature values and fluctuations can be recorded at silo walls, so the grain placed there is affected by inadequate storage conditions to the greatest degree, which may deteriorate its biological value and eating quality.

Conclusions

1. The results of measurements indicate that high temperatures having a negative effect on grain quality were noted at the silo wall.

2. This suggests that silo blankets should to insulated, to protect grain against considerable temperature rise and fluctuations resulting from a high rate of solar radiation energy.

3. The silos produced in Poland are made of tinned sheet, so producers should coat their cylindrical parts with paints (materials) reflecting solar radiation, so as to decrease the temperature inside the silo during grain storage.

4. The location of silo batteries in a proper position in relation to the incidence angle of solar radiation (east-west) should be taken into account while designing grain elevators.

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