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SELF-SEGREGATION OF MAIZE KERNELS DURING GRAVITATIONAL DISCHARGE FROM A SILO

Janusz Bowszys, Jarosław Tomczykowski

Department of Agricultural Chemistry and Environmental Protection
University of Warmia and Mazury in Olsztyn
Oczapowskiego Str. 8, 10-719 Olsztyn, Poland, e-mail: bowter@ uwm.edu.pl

Summary. The aim of the study was to find out how some additional elements inside a silo affected segregation of a grain mixture. Three types of silos, natural scale size, with a funnel for discharging stored grain were tested. Maize kernels were used as experimental material. It was demonstrated that in a silo with a central ventilation pipe the last batch of grain contained 2.8-fold more useless impurities than the average value. It is recommended to subject the final portion of discharged grain to additional cleaning in the types of silos tested.

Key words: silos, self-segregation, distribution of impurities

INTRODUCTION

Self-segregation of grain occurs when silos equipped with a conical funnel are emptied [Bowszys 2006]. In such silos a channel type of flow is most common. First to be discharged from a silo is the heaviest grain, lying close to the silo's symmetry axis and containing the fewest impurities. During the final phase of emptying a silo, grain is removed together with impurities which have gathered near the silo walls. This process is conditioned by the geometrical properties of the funnel as well as physical characteristics of grain [Mohsenin 1987, Kusińska 2003].

The purpose of the study was to find out how certain additional elements within a silo, such as a ventilation pipe or a cone, affected segregation of grain mixture.

The results imply how much of the grain needs to be additionally cleaned in order to remove impurities mixed with grain during self-segregation.

MATERIAL AND METHODS

Three types of silos of natural scale size, all identical in the main measurements (diameter, height of the coat, size of the discharge funnel) – Fig. 1 – were tested. One silo was equipped with a ventilation pipe; another one was furnished with a ventilation cone while the third silo had no ventilation system.

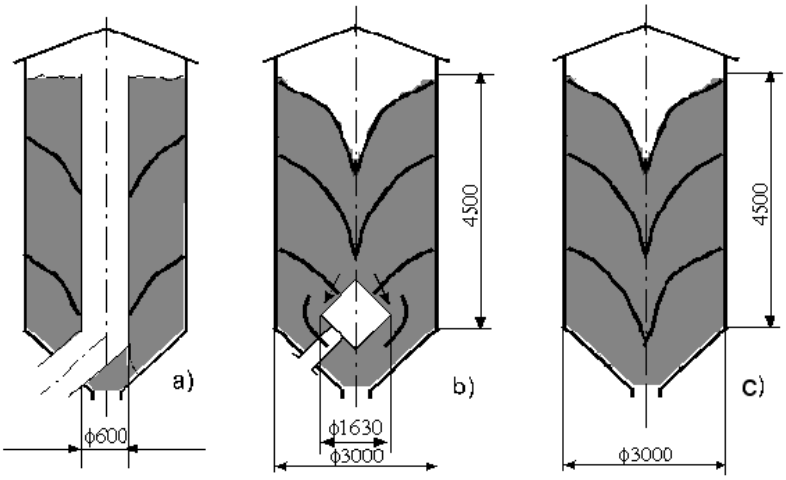

Fig. 1. Tunnel type of grain mass flow: a) in a silo with a central ventilation pipe, b) in a silo with a ventilation cone, c) in a silo without a ventilation element

The average moisture content of the maize grain was 10.1%. The silos were filled up gravitationally. During the storage the grain was not ventilated, which meant that the distribution of impurities in spaces between the grains was unaltered [Bowszys and Rogowski 1999].

The tests were performed according to own methodology. Grain samples were taken directly under the discharge pipe. The average capacity of grain discharge was 5.7 Mg h^{-1}. The first samples were collected when the grain layer height was 4.5 m; later, while the grain layer height diminished, samples were taken every 0.5 m decline. Each sample weighed 1.5 kg and was used to collect 4 smaller samples weighing 120 g. Each small sample was manually sorted into three fractions: whole grain, broken grain and useless impurities (chaff, parts of weeds). Samples were weighed on an AM-500 scales at ±0.01 g precision.

Volume of impurities was computed from the following equations:

$$X_1 = a/g \cdot 100, \% \qquad (1)$$

where:

X_1 – value of useless impurities, %
a – mass of useless impurities, g
g – analytical sample mass, g

$$X_2 = b/g \cdot 100, \% \qquad (2)$$

where:

X_2 – value of useless impurities, %
b – mass of useless impurities, g

RESULTS AND DISCUSSION

All the tested silos were identical in their external size (Fig. 1). The height of a silo coat was 5 m, the diameter was 3 m and the angle of the generator of the discharge funnel was 51.1°. The physical characteristics of grain which affect its flow from a silo are the internal friction angle and the coefficient of friction between grain and the silo wall. Maize kernels are characterised by the kinetic friction factor equal 0.33, whereas the internal friction angle is 28°. Mohsenin [1987] specified characteristics of grain mass flow from a silo depending on the internal friction angles and an incline of the discharge funnel. The correlation presented by Mohsenin suggests that the favourable effect produced by the mass of maize grain in the tested silos is excluded. It was found out that the flow of maize grain out of the tested silos was tunnel type, which is associated with the unwanted effect of grain self-segregation.

The distribution of impurities in maize grain while discharging the silos is presented in Figures 2, 3 and 4.

In the silo with a central ventilation pipe (Fig. 1a) the amount of useless impurities in the first batch of grain and at the grain layer height of 2 to 2.5 m was the smallest (8.08%). This finding confirms the tunnel type flow of grain along the central pipe. The highest percentage of useless impurities (3.8%) occurred at the height of 4.5 m, when it was 2.8-fold bigger than the average percentage of such impurities, and in the final batch it reached 2.12% (Fig. 2). The mass of grain equal to 21% of the total grain volume should be additionally cleaned.

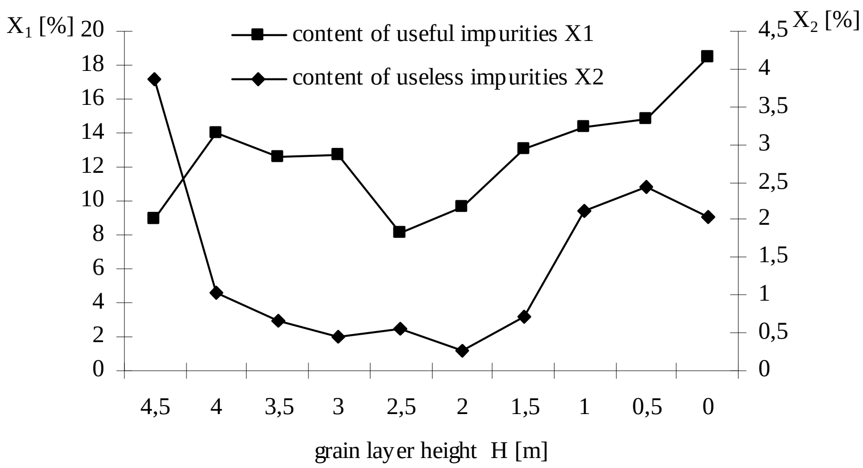

Fig. 2. Composition of impurities in maize kernels during the discharge of a silo with a radial ventilation system (with a ventilation pipe)

The analysis of the discharge process from a silo with vertical ventilation system (Fig. 3) showed that the percentage of useless impurities remained within the range of 10.27% and 13.18% during the whole process and only slightly diverted from the average value of 12.47%. The highest content of useless impurities 0.28% was in the samples collected at the grain layer height of 4.5 m and in the final phase 0.32%, whereas at the height of 3 m the percentage of useless impurities was twice as low. The batch of grain which needed further cleaning was 16% of the total amount of grain.

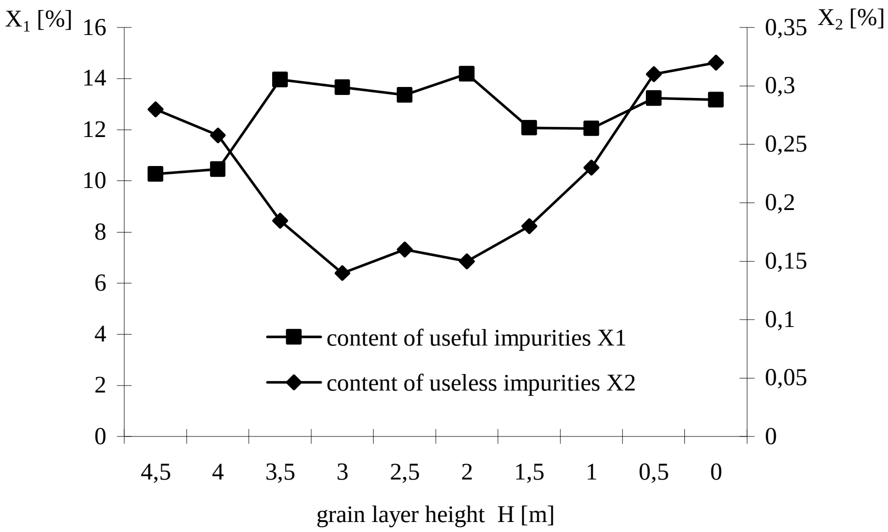

Fig. 3. Composition of impurities in maize kernels during the discharge of a silo with a vertical ventilation system (with a ventilation cone)

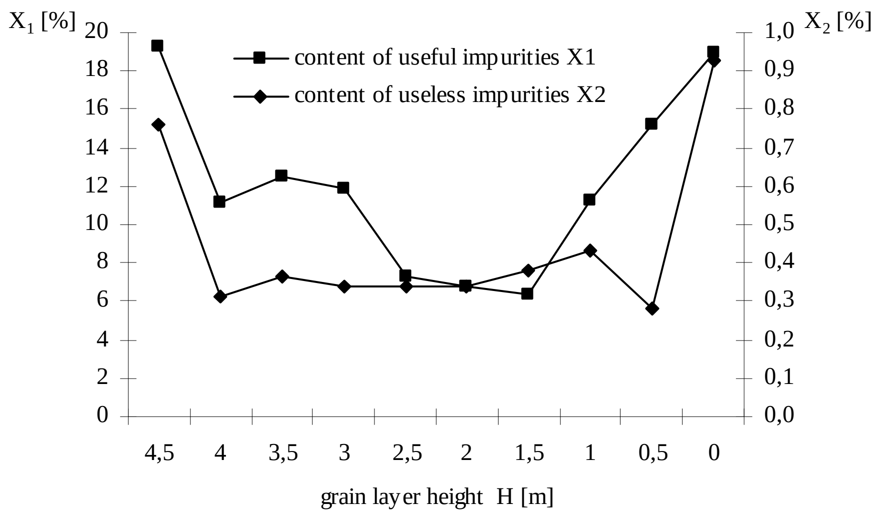

Fig. 4. Composition of impurities in maize kernels during the discharge of a silo without a ventilation system

In the silo without a ventilation system (Fig. 1c) most of useless impurities (19.24%) occurred at the height of 4.5 m and in the last batch of grain (18.91%) at the average percentage of impurities of 12.06%. When analysing the curve delineating the occurrence of useless impurities (Fig. 4) it was determined that higher quantities of impurities appeared in the initial 0.76% and the final 0.93% phase, when they were twice as high as the average value. In this silo the final batch of grain, which makes up to 13.0% of the total amount of grain, should be cleaned again.

CONCLUSIONS

1. The central pipe in a silo with a radial ventilation system causes increased segregation of useless impurities. The highest amount of useless impurities occurred in the initial and final phases of emptying the silo, when it was 2.8-fold higher than the average value.
2. In the silo furnished with a conical ventilation element, when maize grain was discharged the amount of useless impurities was uniform during the whole discharge process, only slightly diverging from the average value.
3. The highest amount of useless impurities in the silo without a ventilation element occurred in the final batch of grain, where it was 2.1-fold higher than the average value.
4. The following percentages of maize grain should be additionally cleaned after being discharged from the three types of silos: 13% in a silo without a ventilation system, 16% in a silo with a conical ventilation element and 21% in a silo with a central pipe.

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