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Application of roof shaped and double cone inserts in mixing of granular elements in the flow process

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A b s t r a c t. The paper presents the results of mixing elements of aftercrops, such as vetches and lupine, which differ as far as the dimensions and diameter of seeds are concerned. The research was conducted with the use of a laboratory mixer model for funnel flow system. The silos were equipped with inserts of RSI and double cone types. The research was conducted in four series, two runs with RSI inserts of two different diameters, a run with the double cone insert and, a run without application of any supporting elements. The assessment of quality of the mixture was carried out with the use of computer analysis of image acquisition. The results were analysed using one-way analysis of variance. The obtained results of the Fisher Test enable to reject the zero hypothesis and determine the impact of the elements used based on graphic interpretation. A significant influence of the double cone insert for improvement of the quality of mixture and greater stabilization of the mixing process supported with additional elements were noted. However, mixing without application of the inserts is characterized with violent run of the process in consecutive stages of mixing.

K e y w o r d s: granular material, funnel flow system, one-way analysis of variance, computer image analysis, RSI and double cone system inserts

INTRODUCTION

Due to the fact of complexity of stress conditions in a silo, dependant on the material characteristics, container shape and other factors, three different flow patterns have been observed: mass, chimney-like and mixed (Fig. 1a, b). In practice, attention is paid to two basic flow mechanisms while emptying the container: mass flow and funnel flow (Fig. 1 a, b). During mass flow, the material in the container moves downwards in a way comparable to out-flowing liquid with the free surface of the material being almost flat. Whereas, in the case of funnel flow, the material moves downward in a vertical column (core) above the output slot with the upper layer of the material creating a conical funnel, on the surface of which the material slides into the chimney. The remaining granular material maintains so-called stagnation. The layer of the material that was poured initially leaves the silo as the last one. The mechanism of funnel flow has been used as a mixing method for granular material (Błasiński *et al.*, 2001; Schlick *et al*., 1996).

The mixing process in a flow mixer is frequently used in the farming, food, cement and pharmaceutical industries (Grochowicz, 1999). The paper presents the results of mixing non-homogenous two element granular structure (vetches and lupine) constituting a mixture of stubble aftercrops.

Mixing homogenous systems in a funnel flow system enables to obtain good quality mixture in an efficient and inexpensive way (Tukiendorf, 2003). Whereas, in the case of mixing elements with varying characteristics, such as density or diameter, the mixer shall not fulfil its function completely. In practice, it is suggested to use supporting devices. In the reported project, two types of such supporting devices

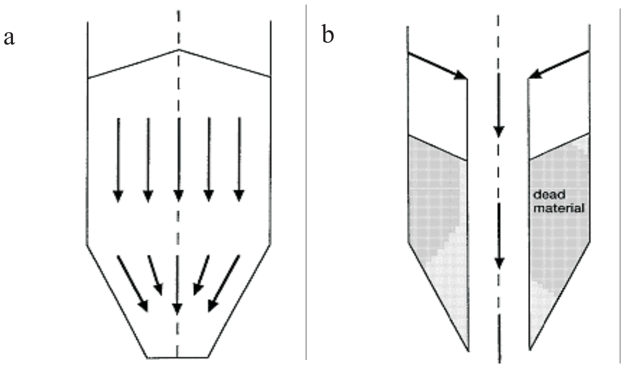

Fig. 1. Basic types of granular material flow from a silo: a – mass flow, b – funnel flow (Spencer and Hill, 2001).

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were used: a roof shaped insert (RSI) and a double cone insert. Application of the mentioned inserts influences not only the flow of the material from a silo but also eliminates disadvantageous results of dynamic overpressure impact inside a silo. The RSI and double cone inserts have an impact on segregation elimination. Application of moulders in the output phase, which changes the direction of particle flow, additionally increases the mixing process. An important parameter that has an effect on the final results is the shape and size of the insert (Enstad, 1998; Tukiendorf, 2002). The cost of installation of such a device is a good deal lower than the cost of overhaul or modernization of mixing equipment.

The aim of the research was to asses and compare the impact of application of roof shaped insert and double cone inserts on the quality of a two-element granular mixture while mixing with the use of the flow method.

MATERIALS AND METHODS

The mixing process was conduced using a laboratory flow mixer (Fig. 2a, b). The mixer consisted of two identical silos as far as the size is concerned: height of the cylindrical part – 200 mm, inner diameter – 150 mm. Each of the silos performed dumping and receiving functions. Appropriate design of the silos ensured funnel flow mechanism. The containers had particular construction consisting of 10 removable parts, allowing observation of elements location on various levels. The mixing process was carried out in 10 consecutive flows.

Stubble aftercrop of vetches and lupine underwent the mixing process. The granular elements were characterized as follows: seed dimension ratio d_1/d_2 = 0.97, and density ratio ρ_1/ρ_2 = 1.55. Volume ratio of the mixed components amounted to 1:9.

Two types of supporting inserts were used in the research:

1. Roof shaped inserts (Fig. 3) with an identical cone angle of α = 120° and different diameters of bases, d_1 = 5 cm and d_2 = 7 cm. Such inserts were placed in the upper part of each silo.

2. A double cone insert (Fig. 4) with the dimensions of: angle β = 110°, cone diameter d = 30 mm, cone height h = 60 mm. The insert was placed in the lower part of each silo.

Along with the mixing process, analysis of granular mixture quality was conducted. Computer image analysis was applied. A digital picture of each cross-section of the mixer was taken in the consecutive (1 to 10) phases of the mixing process. Further on, in the process of the following analytic procedures: pixelization, upper threshold binarization, the image was transformed into a binary form producing a combination of two values: 0 for pale seeds and 1 for dark seeds. The obtained values were used to calculate distribution variance as a measure of location of the key element on the cross-section of the agitator. The analysis was run on three mixer levels: lower (ring 1), middle (ring 5) and upper (ring 10).

a

b

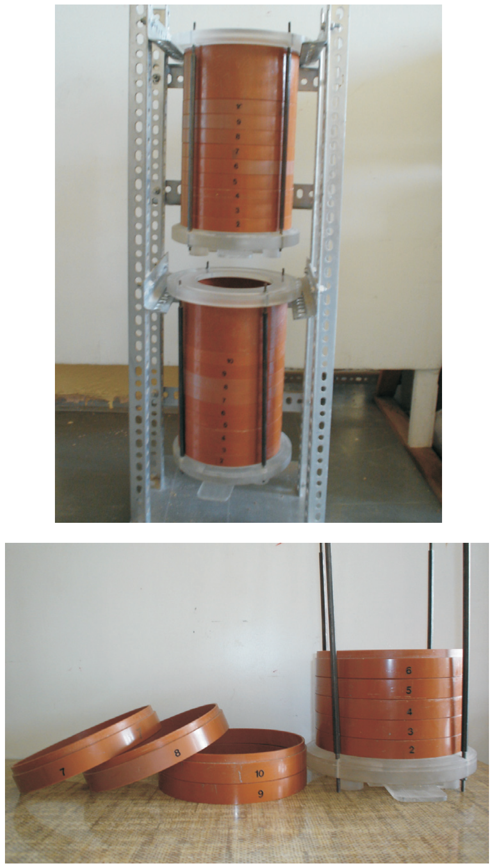

Fig. 2. Flow mixer: a – view of the whole equipment, b – modular design of the silo (own study).

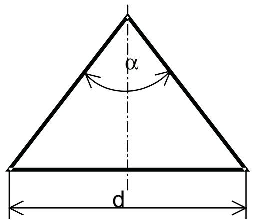

Fig. 3. Roof shaped insert elements diagram (own study).

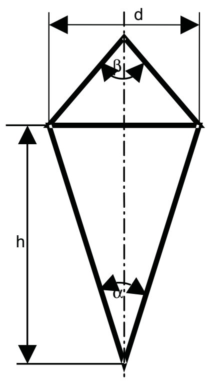

Fig. 4. Double cone insert elements diagram (own study).

The obtained results were analysed with the use of computer software in order to point out differences between average results for four series of research. One-way analysis of variance was applied, resulting in the level of significance at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The results of the statistical analysis F (Fisher-Snedocor test) were entered into tables (Table 1), followed by graphical interpretation of the data (Fig. 5a, b, c). The statistical comparison was conducted for the results of the element distribution variance for the consecutive steps one to ten, depending on the mixing method used (with the Roof Shaped Insert, with the double cone insert, without any insert) on three levels of the agitator (lower, middle, and upper part of the device).

Based on the results of one-way analysis of variance presented in Table 1, the conclusion was drawn that for each of the researched cross-sections (first, fifth and tenth) with low level of significance the zero hypothesis about the equality of average variance of the tracers distribution may be rejected. For each group the p value is mach smaller than 0.05. It was proved that mixing with the application of the RSI and double cone inserts and without the application was characterised by a different course of the process and a different final effect. The character of the influence of application of the individual elements can be concluded about on the basis of created graphs (Fig. 5) and score-sheet (Table 2).

Table 1. Results of the Fisher test for particular cross-sections of the mixer for all four research series

Cross-section of the agitator	Fisher test	Level of the significance
First	20.86315	0.001630
Fifth	7.896661	0.002632
Tenth	4.768589	0.002505

Table 2. Median of the distribution variance of the tracer for individual cross sections of the agitator in four series of research

Series of research / cross section of the agitator	Section		
	first	fith	tenth
Without the insert	0.123	0.211	0.155
Insert RSI – 7 cm	0.219	0.221	0.210
Insert RSI – 5 cm	0.218	0.226	0.192
Double cone insert	0.103	0.125	0.140

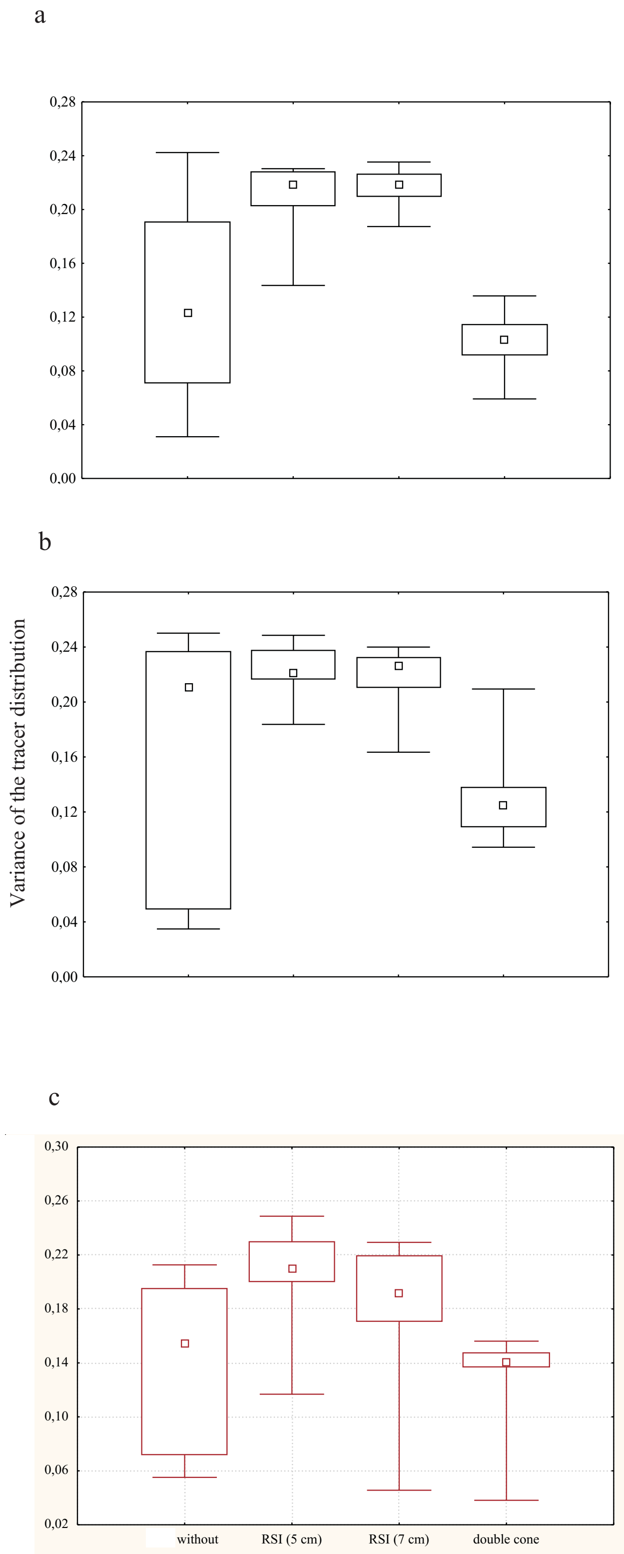

Fig. 5. Graphical interpretation of variance analysis for: a – the first; b – the fifth; and c – the tenth cross-sections of the agitator; small squares – median, rectangles – 25-75%.

Juxtaposing the results for the examined groups, presented in drawings (Fig. 5) illustrates the resultant statistically significant differences between the averages. Further, the particular graphs point out to a significant impact of the double cone insert on granular structure quality, which is reflected in the lowest variance of the tracers distribution that is an attempt at ideal order of the elements. Juxtaposing average variances of the tracer distribution for individual series of research in Table 2 confirmed the presented conclusions. Additionally, it is possible to notice that the RSI inserts cause getting the highest value of variance. The reason for this can be a phenomenon of accumulation of the tracer close to the walls of the agitator (so-called ring-shaped mixing) under the influence of collisions with the surface of the insert. But, supporting the mixing process with the RSI and double cone inserts leads to faster stabilization of the variance, which might be evidence of reaching an equilibrium (little scattering of gotten value in the 25-75% range), which can prove faster achieving the balance condition after which further mixing does not result in an improvement of the quality of mixture. Whereas, the mixing process without the application of the supporting devices is characterized with violent process of quality change of the mixture in time, which is reflected in the ranges of values on subsequent graphs (range of results of 25-75%).

CONCLUSIONS

1. In the process of mixing with the roof shaped and double cone inserts the stabilization of the tracers distribution variance takes places faster than in the case of mixing without the application of supporting devices.

2. In the case of supporting the mixing process with the double cone insert the best quality of granular mixture was obtained.

3. The results of the Fisher test point out to significant differences between the results of mixing for particular research series.

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