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# PURIFICATION AND SEPARATION OF LOOSE MATERIALS IN A PNEUMATIC SYSTEM WITH VERTICAL AIR STREAM

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**Summary**. The paper presents an influence of air stream flow rates in a modified separator with vertical air stream on purification and separation of selected grain mixture. An analysis of the obtained data on vertical air stream flow intensity revealed great variability of grain separation and purification efficiency. It was found that both air stream intensity and the way and rate of mixture supply into the working area of the separator had the largest influence on the course and efficiency of particular mixture components separation (particularly of light substances). It was observed that precise regulation of air stream flow and its wide variability range allowed for an achievement of very good results of purification and separation of the studied grain mixture. The obtained effects resulted in a positive evaluation of the proposed construction of laboratory separator with vertical air stream for efficient separation of particular components of grain mixture.

**Key words:** contaminated winter wheat grain, pneumatic separator with vertical air stream, purification and separation efficiency, constructional changes evaluation.

## INTRODUCTION

At present, a spectrum of technological processes of preparation and processing of the cereal raw materials and other grains (including herbal) require many specific procedures including purification or separation into particular size fractions [Grochowicz 1995, Wodziński 2003, Dmitrewski et al. 1981]. Separation of grain mixtures and other loose materials of biological origin is one of the key technological operations that are most often applied in cereal and fodder industries. Subsequent processes as well as final product's quality (seeding material, purity of flour, groats, cereal flakes etc.) depend on those procedures' efficiency [Olszewski 1995, Grochowicz et al. 1995, Czarnecki et al. 2000, Konopko 1995, Molenda et al. 2003]. During separation of any grain mixture, several physical properties differences between general material directed to purification and separation, and mixture constituents (contaminants) can be utilized [Wawer 2000, Schmidt.1997, Panasiewicz 1999]. In the case of pneumatic separation, the air stream (vertical, diagonal or horizontal) is the fundamental feature, and aerodynamic properties of particular grain mixture's components are the separating factor. Among aerodynamic properties, the course and efficiency of pneumatic separation depend on the critical air stream flow rate $u_k$ (floating) of particles and the aerodynamic resistance coefficient and volatility coefficient are the most important [Modrzewski et al. 2004, Kozłowski 2000, Panasiewicz 1995]. It should be emphasized that separation processes in agricultural and foodstuff industries are much more complicated than in other industry branches, because biologically diversified material can occur in the former. These materials are characterized by great variability and low reproducibility (even within the same grain variety or species) of many physical properties [Mączka et al. 2004, Mieszkalski et al. 1999, Grochowicz 1995, Schmidt 1997, Wodziński 2003]. Interdisciplinary nature of physical traits of particular mixture's constituents at different technical and technological parameters of pneumatic separation process gave rise to the present study.

## THE AIM OF STUDY

The study was aimed at an evaluation of the influence of applied parameters of air flow rate in modified construction of separator with vertical air stream on purification and separation processes of selected grain mixtures.

Studies referred to proposed constructional changes of laboratory device and its efficiency of purification and separation of contaminated wheat, barley, and rye grains.

Detailed experiments included:

- Designing and constructing the study stand for laboratory pneumatic separator taking into account continuous control of air stream flow intensity and material supply into the working area,
- Selecting grain mixtures and evaluating the type and level of their refinement,
- Preparing raw materials for study, including examining their general physical properties, measuring the process parameters and evaluating the separation efficiency in vertical air stream,
- Statistical processing of the achieved study results.

## MATERIAL AND METHODS

Contaminated (after combine-harvester harvest) wheat grain was used for study. The contamination level was 8% (±0.5%), moisture content 14% (±0,5). Studies were carried out for 1 kg samples. Determination of general physical properties was made in accordance to obligatory Polish Norms. The stream flow rate was measured using electronic anemometer. The range of applied air stream flow rates was $V_p$ = 6, 7, 8, 9, 10, 11, and 12 m·s$^{-1}$. Setting a given air stream flow rate was made using VF61-7R544 type frequency converter. The transporter band velocity was 5 m·s$^{-1}$. All measurements were realized in five replications.

In order to evaluate the efficiency of pneumatic process of studied grain mixture separation, two indices were applied: separation efficiency (*η*) that can also be used to assess the device efficiency:

$$\eta = \frac{b_1}{b_o} \cdot 100 \,, \tag{1}$$

where: $\eta$ – separation efficiency, %;
$b_o$ – total weight of contaminants in initial material possible to separate in pneumatic separator, kg;
$b_1$ – weight of contaminants separated from initial material in pneumatic separator, kg;

and the separation precision coefficient (*z*) that characterizes the losses resulting from separating part of valuable grains along with the wastes:

$$z = \frac{a_2}{a_2 + b_2} \cdot 100 \, . \tag{2}$$

where: $z$ – precision coefficient, %;

$b_2$ – amount of light fraction separated in air stream, kg;

$a_2$ – amount of heavier fraction separated altogether with light fraction, kg.

## EXPERIMENTAL STAND

Studies upon the influence of the applied parameters of air stream flow rates on purification and separation processes of selected grain mixtures were carried out using new type of pneumatic separator with vertical air stream (Fig. 1). After switching the separator on and setting the assumed technical and technological parameters, samples from supplying basket were transported by band transporter, and then reloaded into the working area of air stream. After separation, particular fractions were weighed. Granulometric composition of separated fractions was divided into the following groups: fraction I – 0-0,2 mm; fraction II -2,0-2,5 mm; fraction III – 2,5-3,15 mm; fraction IV – 3,15-4,0 mm.

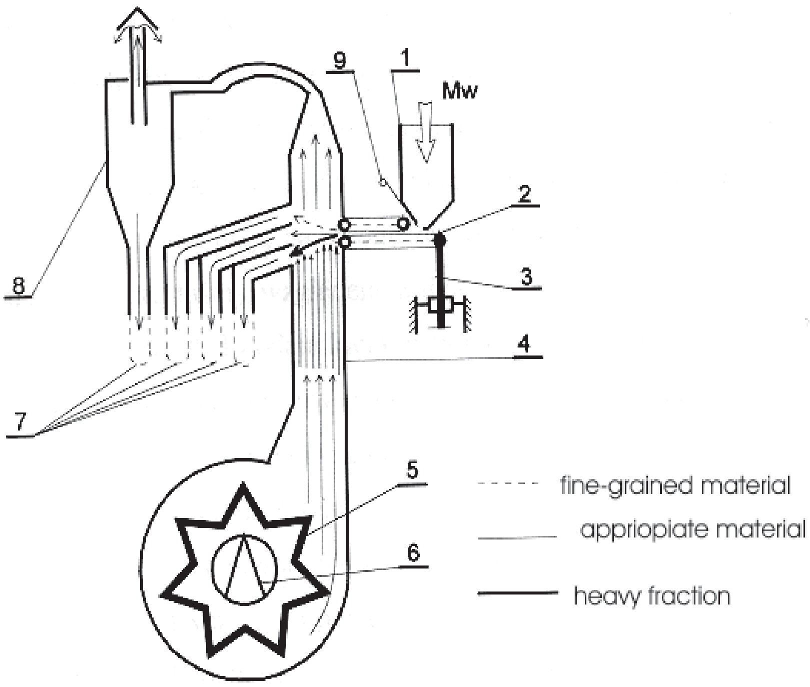


Fig. 1. Scheme of pneumatic separator with vertical air stream flow and double-band transporting supplier: 1 – supplying basket, 2 – band transporter, 3 – regulation screw for changing the angle of material supplying, 4 – cylindrical working channel, 5 – ventilator, 6 – flange shielding the sucking channel, 7 – troughs, 8 – cyclone, 9 – shutter for controlling the amount of material supplied to transporter

## RESULTS

A large number and variety of separation traits give theoretical premises of any selection for planned biologically-origin grain mixture purification or separation process. However, in order to set similar to optimum purification and separation conditions, a method should be chosen which ensures an efficient and fast processing. Therefore, a proper purification method selection taking into account both device construction and applied technical and technological parameters of the whole process is very important. Detailed knowledge on principal physical properties of a grain mixture and its particular components (contaminants) should be also kept in mind (Table 1).

Table 1. Physical properties of grain mixture (wheat) used in the study

| Grain mixture | Moisture content [%w. b.] | 1000-grain weight [g] | Shaken density [kg·m$^{-3}$] | Loose density [kg·m$^{-3}$] | Angle of repose [˚] | Angle of slide [˚] |
|---|---|---|---|---|---|---|
| Contaminated wheat grain | 14,1 | 32,1 | 791,3 | 700,2 | 17,5 | 31.6 |

Detailed results on the course and efficiency of purification and separation of contaminated wheat grain estimated as average percentage of grain mixture in particular outlet channels, i.e. on a net in channels 1, 2, 3, and cyclone are presented in Fig. 2.

An analysis of the achieved results indicates a close dependence between vertical air stream intensity and the amount of separated particular fractions (components) of grain mixture accumulated in outlet channels. The heaviest grain fractions were separated in the largest amounts in channels K1 and K2; such an effect was present for all the ranges of the applied air stream flow rates. The most efficient separation (purification) of grain accumulated in these channels occurred in the case of $V_p$ = 9-11 m·s$^{-1}$ air stream flow rate. An efficient effect was achieved of heavy particles "overthrowing" through air stream interaction area at such rates of vertical air stream flows (Fig. 2).

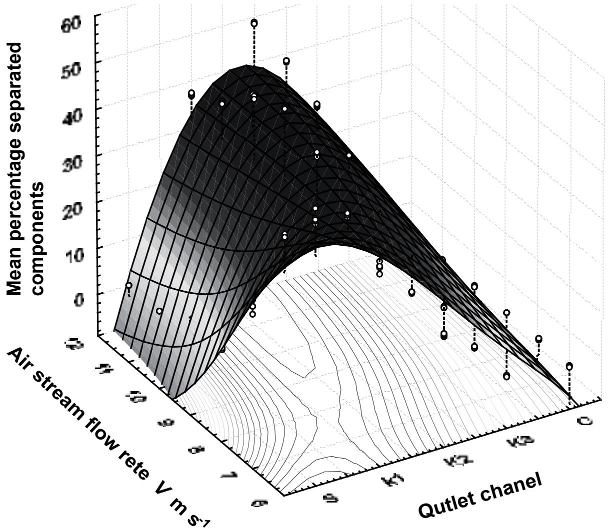


Fig. 2. Mean percentage of separated components of grain mixture in particular outlet channels depending on vertical air stream flow rate

At higher rates, removing larger amounts of light fraction (fine and dust contamination) separated in channel K3 and cyclone was recorded. From the point of view of purification efficiency it is a positive phenomenon, however, it should be stressed that high rates of air stream can blow away slightly heavier particles that mix with wastes and are considered as a loss of purified grain. On the basis of granulometric composition analysis and assuming fraction 0-0,2 mm as contamination, values of separation efficiency index (*η*) and separation precision coefficient (*z*) were calculated (Fig. 3).

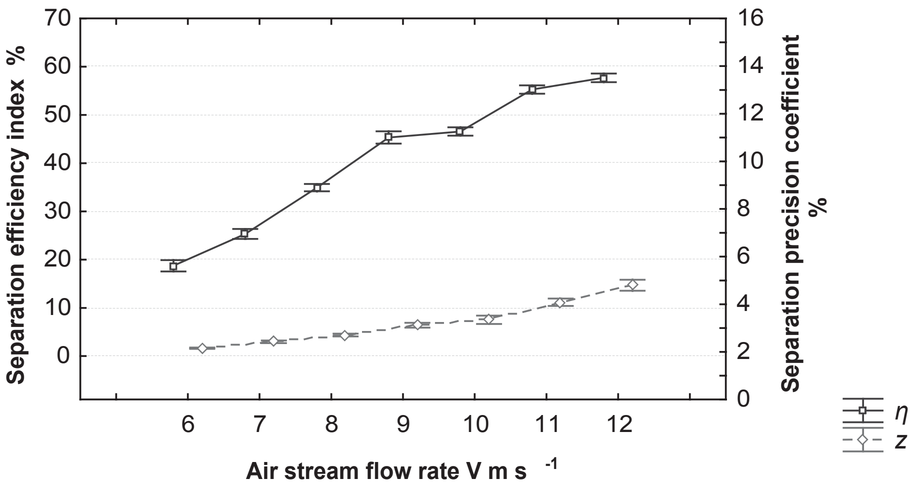


Fig. 3. Changes of separation efficiency index *(η )* and separation precision coefficient *(z)* depending on vertical air stream flow rate

An analysis of the above-mentioned indices values revealed that the best purification and separation results were achieved at air stream flow rates within the range of $V_p$ = 9-11 m·s$^{-1}$. At such intensities, the highest values of *(η)* were recorded, which amounted to 45,3% (for $V_p$ = 9 m ·s$^{-1}$), 47,1% (for $V_p$ = 10 m· s$^{-1}$), and 55,2% (for = $V_p$ 11 m ·s$^{-1}$). It should be emphasized that the highest values of *(η)* and *(z)* were achieved at air stream flow rate $V_p$ = 12 m ·s$^{-1}$, although relatively high separation efficiency of 60% for that type of pneumatic separator led to relatively large losses of heavy grain that was blown away and separated by air stream in cyclone.

It confirms that an achievement of high indices describing grain mixture purification and separation processes is not always practically and economically reasonable.

## CONCLUSIONS

1. An analysis of the achieved study results referring to varied vertical air stream flow rates revealed a wide range of wheat grain separation and purification efficiencies.

2. It was found that both air stream intensity and the way and rate of mixture supply into the separator's working area had the largest influence on the course and efficiency of particular components separation (including mainly light contaminants).

3. Precise regulation of air stream flow rate and wide range of its differentiation allowed for an achievement of very good results referring to purification and separation of the studied grain

mixture. The best effects and efficiency assessed by means of indices *(η)* and *(z)* were achieved for $V_p$ = 9-11 m·s$^{-1}$ air stream flow rates.

4. The proposed construction of laboratory pneumatic separator with vertical air stream was positively assessed, because it allows for an efficient separation and isolation of particular components of grain mixture in the form of contaminated wheat grain.

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