Obtaining high-quality grain through the use of fractional technology for its cleaning

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Abstract. The article presents theoretical and experimental studies on the feasibility of using the fractionation process in post-harvest grain processing. The main signs of the separation of winter wheat heap are determined. It is established that these signs of separation have a correlation. For each thickness of the grains, a certain speed of soaring in the air channel can be set, which will allow to isolate the feed fraction not only by sieves, but also by an aspiration system. The theoretical yield fractions of the main and feed fractions were determined under various conditions. It was found that when the separation on the spike and sowing sieves is 0.8 and the air flow rate in the second suction channel is 7.0 m/s, as well as the width of the sorting sieve opening is increased from 2.0 to 2.6 mm, the yield of the main fraction decreases from 0.94 to 0.75. In general, theoretical studies have shown that to obtain high-quality seeds of winter wheat, it is necessary to install sorting sieve sheets with oblong apertures of 2.6 mm in the separators and adjust the air flow velocity in the second suction channel of 7 ... 8 m/cm.

1. Introduction
The increasing volume of grain production in our country imposes stringent requirements on post-harvest grain processing [13]. Grain-cleaning lines, the basis of which are technologically obsolete separators, can no longer cope with proper quality with all harvested crops [10]. Currently, the separation of grain heaps can be carried out according to various signs of separation and together determine the cleaning technology [1-8, 11-12]. These are most widespread separation of dimensional and aerodynamic characteristics [1, 5, 6, 7]. Fractional cleaning technology will improve the efficiency of grain cleaning units and grain quality. Its meaning is to divide the grain heap according to the most significant signs in a certain sequence. In this case, several fractions can be obtained, for example, waste, basic, feed, etc. Moreover, even one sign of separation can be used several times, but it is necessary to gradually change the operating modes of the equipment [2, 5].

To increase the efficiency of the fractionation process, the firstly one need to select such separation signs that will allow, as soon as possible, to separate the largest part of the defective grain. This will minimize the number of mechanical effects of the working bodies of grain cleaning machines on the grain, preventing its damage. Another part of the defective grain can be identified later, using other signs of separation, considering their correlation. In addition, to maintain the quality of seeds, you can use their ozone treatment [9].

Theoretical studies have shown that in the design of fractional separators, the main sign of fractionation should be the separation of the grain heap by thickness or width, which can be performed
on sorting sieves with oblong or round holes. Moreover, the descent from the sieve is the main fraction, and the passage is feed. Subsequently, defective grains, which have similar dimensional characteristics as full grains, are isolated from the main heap by means of an air stream, i.e. using the aerodynamic sign of separation.

2. Materials and methods

The experimental studies were conducted to separate the grain heap of winter wheat by speed and thickness of the grain in order to confirm the expediency of using the signs of fractionation at the Department of Agricultural Machines, Tractors, and Cars. In this case, there were sailing classifier and sieving used. Moreover, when studying the sign of grain distribution by aerodynamic properties, the air flow rate was 7.6 m / s, and when studying the sign of separation according to the thickness of the caryopsis, the width of the holes of the sorting sieve sheets was 2.4 and 2.6 mm.

3. Results and their discussion.

The separation of winter wheat grain heaps by thickness is a more preferred sign of separation than by speed of soaring. With an increase in the width of the sorting holes, the proportion of the heap entering the suction channel decreases from 0.857 to 0.726. This reduces the proportion of grain that must be allocated in the suction channel to 0,082 and 0,055. Moreover, there is a correlation noticed between the signs of separation, the speed of rotation and the thickness of the grains (Figure 1).

![Figure 1. Correlation between the average speed of soaring (Vcp) of the initial heap grains of winter wheat from their thickness (bi)](image)

Analysis of Figure 1 showed that the greater the thickness of the grain is, the higher their average speed of soaring will be. This dependence has a quadratic form. The largest grains have a soaring speed of about 9 m / s, and the smallest - about 5 m / s. Therefore, underdeveloped grains can be distinguished not only by the size of the sieves, but also by the aerodynamic properties in the aspiration system.

For a quantitative assessment of the relationship between the soaring speed and the thickness of the grains, the correlation coefficient was determined, which is presented in graphical form in Fig. 2.

Analysis of Figure 2 shows that each fraction with a certain grain thickness has a different correlation with the speed of rotation. However, one can follow the trend of an increase in the correlation coefficient with increasing sizes of the caryopsis. Therefore, for each sieve, you can determine the equivalent air velocity in the aspiration system. This will increase the completeness of the selection of feed fractions and the yield of full grain.

If we assume that the distribution of grain heap over the thickness and speed of soaring obeys the law of normal distribution, then it is possible to determine the theoretical yield fractions of the main and feed fractions. Moreover, both the lattice webs and the air flow separately. For this, there should be the rules of mathematical statistics applied.
After separation of light grain from a grain pile by an aspiration system and its separation on sorting sieve sheets, the probability of the main fraction \( P_0 \) yield will be (1)

\[
P_0 = 1 - P_{mi} - P_{OVi} - P_{mVi},
\]

where \( P_{mi} \), \( P_{OVi} \), \( P_{mVi} \) are the probabilities of the content in the initial grain pile of, respectively, small, large and lightweight grains.

\( i \) - grains of \( i \) class in thickness.

\( j \) - grains of \( j \) class by speed of soaring.

Given the completeness of the selection of fractions and determination of the desired probabilities, we obtain (2)

\[
P_0 = (1 - P_{mi}^T \cdot \epsilon_b^k) \cdot \text{e}_b^k - (1 - P_{mi}^T \cdot \epsilon_b^k) \cdot \text{e}_b^k \cdot P_{OVi}^T \cdot \text{e}_V - (P_{mi}^T - P_{mi}^T \cdot \epsilon_b^k) \cdot P_{mVi}^T \cdot \text{e}_V,
\]

where \( P_{mi}^T \), \( P_{OVi}^T \), \( P_{mVi}^T \) are the theoretical probabilities of the content in the initial grain heap, respectively, of small, large and lightweight grains.

\( \epsilon_b \), \( \epsilon_b^k \), \( \epsilon_V \) - completeness of selection on the sieve mill, spike and sorting sieves.

Then the loss of full grain \( (P_{ob}^m) \) with an ear of sieve will be (3)

\[
P_{ob}^m = (1 - P_{mi}^T \cdot \epsilon_b) \cdot (1 - \epsilon_b^k).
\]

The average thickness of the grains \( (M_b) \), taking into account the completeness of the separation of the lattice sheets, is determined by the formula (4)

\[
M_b = \frac{\sum_{i=1}^{n} P_{mi} \cdot (1 - \epsilon_a) + P_{aVi} \cdot (1 - \epsilon_a) \cdot (1 - \epsilon_e) \cdot b_i + \sum_{j=1}^{n} P_{mi} + P_{aVi} \cdot (1 - \epsilon_a) \cdot b_j}{P_0},
\]

The standard deviation of the thickness of the grains \( (\sigma_b) \), considering the completeness of the separation of the lattice sheets, can be found by the formula (5)

\[
\sigma_b = \sqrt{\sum_{i=1}^{n} (\text{M}_b - M_b)^2 \cdot \frac{P_{mi}(1-\epsilon_a) + P_{aVi}(1-\epsilon_a) \cdot (1-\epsilon_e) \cdot b_i}{P_0} + \sum_{j=1}^{n} (\text{M}_b - M_b)^2 \cdot \frac{P_{mi} + P_{aVi}(1-\epsilon_a) \cdot b_j}{P_0}},
\]

The average speed of the soaring of grains \( (M_v) \) is determined by the formula (6)

\[
M_v = \frac{\sum_{i=1}^{n} P_{mi} \cdot (1 - \epsilon_a) + P_{aVi} \cdot (1 - \epsilon_a) \cdot (1 - \epsilon_e) \cdot V_j + \sum_{j=1}^{n} P_{mi} + P_{aVi} \cdot (1 - \epsilon_a) \cdot V_j}{P_0},
\]

The standard deviation of the soaring speed of the grains \( (\sigma_v) \) is found by the formula (7)

\[
\sigma_v = \sqrt{\sum_{i=1}^{n} (\text{M}_v - M_v)^2 \cdot \frac{P_{mi}(1-\epsilon_a) + P_{aVi}(1-\epsilon_a) \cdot (1-\epsilon_e) \cdot V_j}{P_0} + \sum_{j=1}^{n} (\text{M}_v - M_v)^2 \cdot \frac{P_{mi} + P_{aVi}(1-\epsilon_a) \cdot V_j}{P_0}},
\]

With the completeness of separation \( \epsilon_b = \epsilon_v = 0.8 \) and the use of sorting sieve sheets with a slit width of 2.0 ... 2.6 mm, as well as the air velocity in the second suction channel of 7.0 ... 8.5 m / s, the dependence of the yield of the main fraction has the form shown in Figure 3.
Figure 3. The influence of the opening width of the sorting sieve (Bp) and the air velocity (V) in the channel of the main fraction output (PO) at $\varepsilon_b = \varepsilon_v = 0.8$

Analysis of Figure 3 shows that when the separation is complete $\varepsilon_b = \varepsilon_v = 0.8$, the air flow velocity in the second suction channel is 7.0 m / s and the width of the slit hole of the sorting sieve is increased from 2.0 to 2.6 mm, the yield of the main fraction decreases from 0.94 to 0.75 or 1.24 times. Under the same conditions but increasing the air velocity in the pneumatic separation channel of the second aspiration to 8.5 m / s, the yield of the main fraction decreases from 0.61 to 0.53, or 1.15 times. On the other hand, when the width of the slit hole of the sorting sieve is 2.6 mm and the air velocity increase from 7.0 to 8.5 m / s, the yield of the main fraction decreases from 0.74 to 0.529, or 1.4 times. Under the same conditions, but with a smaller width of the sorting sieve opening equal to 2.0 mm, the yield of the main fraction decreases from 0.92 to 0.61 or 1.5 times.

The effect of the air flow velocity in the second suction channel and the width of the slit holes of the sorting sieve sheets on the average thickness of the grains of the main fraction with the separation $\varepsilon_b = \varepsilon_v = 0.8$ is shown in Figure 4.

The effect of the air flow velocity in the second suction channel and the width of the slit openings of the sorting sieve webs on the thickness deviation of the main fraction grain with the completeness of separation $\varepsilon_b = \varepsilon_v = 0.8$ is shown in Figure 5.

Figure 4. Influence of the air flow velocity (V) in the second aspiration channel and the width of the slit holes of the sorting sieve (Bp) on the average thickness of the grains (Mb) of the main fraction with complete separation $\varepsilon_b = \varepsilon_v = 0.8$

Figure 5. Influence of the air flow velocity (V) in the second aspiration channel and the width of the slit holes of the sorting sieve (Bp) on the standard deviation of the thickness of the grains ($\sigma_b$) of the main fraction with complete separation $\varepsilon_b = \varepsilon_v = 0.8$
Analysis of figure 4 and 5 concludes the following: in order to obtain better seed, it is preferable to use sorting sieve sheets with a larger aperture width and an average air velocity in the second suction channel in separators than to install sieves with a smaller aperture width but a greater air velocity in the pneumatic channel. For example, when the air flow rate in the second aspiration channel is 7.5 m/s and using sorting sieves with oblong holes of 2.6 mm wide, the output of the main fraction is 0.706. The average thickness of the grains is 2.9 mm, and the standard deviation is 0.21 mm. An increase in the air flow rate in the second aspiration channel to 8.5 m/s and at the same time reducing the width of the oblong holes in the sorting sieve to 2.4 mm reduce the yield of the main fraction to 0.595. In this case, there is a decrease in the average thickness of the grains to 2.892 mm with an increase in the standard deviation to 0.218 mm.

The influence of the air flow velocity in the second suction channel and the width of the slit openings of the sorting sieve webs on the average rate of rotation of the grains of the main fraction with the separation separation $\varepsilon_{b}=\varepsilon_{v}=0.8$ is shown in Figure 6.

The effect of the air flow velocity in the second suction channel and the width of the slit openings of the sorting sieve webs on the standard deviation of rotation speed of the main fractions grain with the complete separation $\varepsilon_{b}=\varepsilon_{v}=0.8$ (Figure 7).

Analysis of Figure 6 concludes the following: a change in the width of the oblong holes of the sorting sieve sheets affects the average speed of winter wheat grain less than the change in the air flow rate in the second aspiration channel. For example, with a width of oblong holes of sorting sieves equal to 2.6 mm and an increase in the air flow rate in the second suction channel from 7.0 to 8.5 m/s, the average speed of grain flow of the main crops increases from 8.985 to 9.166 m/s or 1.02 times. However, with the width of the oblong holes of sorting sieves of 2.0 mm and the same increase in air flow rate in the second suction channel from 7.0 to 8.5 m/s, the average speed of grain flow of the main crops is slightly lower, increasing from 8.798 to 9.063 m/s or 1.03 times.

Analysis of Figure 7 indicates that a certain width of the oblong holes of the sorting sieve webs corresponds to a certain air flow rate in the suction channel, which provides the minimum standard deviation of the grain flow rate of the main crop. The minimum standard deviation for the length of the oblong holes of the sorting sieve sheets 2.0 ... 2.4 mm is observed at an air flow rate in the suction channel of 7.0 ... 7.5 m/s.

A smaller standard deviation indicates a better uniformity of the grains on this basis. If considering the highest quality grain, it is necessary to use sorting sieves with a hole width of 2.6 mm. In this case,
there should be the best uniformity of winter wheat grains observed at an air flow rate in the suction channel of 7.0 ... 7.5 m / s. This is explained by the speed correlation of the grains soaring with their thickness and incompleteness of separation, both in aerodynamic properties and in thickness.

4. Conclusion
Thus, the theoretical studies indicate that to obtain high-quality seeds of winter wheat, it is necessary to install sorting sieve sheets in the separators with a width of oblong holes of 2.6 mm and an air flow velocity in the second aspiration channel in the range of 7 ... 8 m / s. Moreover, with a separation completeness of 0.8, which corresponds to the secondary cleaning of grain, the proportion of grain heap allocated to the feed fraction does not exceed 30%.

Theoretical studies have been confirmed experimentally. The use of sorting sieve sheets with a width of oblong holes of 2.6 mm in the OZF-80 fractional cleaner with an air flow rate in the second suction channel of 7.5 m / s and a productivity of 40 t / h showed that the grain quality of the main fraction is higher than when installing sieves with a hole width of 2.4 mm, the same operating mode of the pneumatic system and reduced to 20 t / h separator performance. Moreover, the loss of full grains in the feed fraction did not exceed 0.3%.

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