Comparative evaluation of the operation of a combine harvester with an additional sieve with adjustable holes for sunflower harvesting

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Abstract. The cost of production of sunflower is determined by the number of operations for its cultivation as well as the manufacturing charges for them. The extraneous matter content of the hopper sunflower heap is the factor that can increase the cost of sunflower production. In connection with that, it is advisable to reach the minimum values of the extraneous matter content in the hopper heap during sunflower harvesting. The article substantiates the design of the sieve with additional holes which is installed as an additional cleaning stage in the combine harvester. Adjustable sieve holes have a shape similar to the longitudinal shape of oilseeds. The area of the sieve hole can be adjusted depending on the type or variety of sunflower, which will significantly reduce the extraneous matter content in the hopper heap. To analyze the sieve performance, a check sample was made which was installed as an additional cleaning stage on the "Niva" SK-5-M-1 and "Vector 410" grain combine harvesters. The analysis is presented of the extraneous matter content in the hopper heap with the use of an additional sieve with a different area of adjustable holes and without it.

1. Introduction
To reduce the cost of post-harvest treatment of sunflower heap, it is expedient to carry out high-quality cleaning of the heap during the combine harvester operation. To achieve that, it is necessary to increase the number of sieves in accordance with the technical capabilities of the combine harvester. Moreover, additional sieves should be developed, taking into account the geometric parameters of the crop to be harvested. It is obvious that the existing designs of lipped screens are focused on cleaning of grains of cereals, which in comparison with sunflower oilseeds have smaller sizes and another shape [1]. By size sunflower seeds are divided into edible, “intermediate” and oil-bearing varieties. Edible sunflower seeds have an average length of 11-23 mm, width of 7.5–12 mm. Oil-bearing sunflower seeds are smaller than edible ones and their average length is 7-13 mm, width 4-7 mm. “Intermediate” sunflower seeds by size are between edible and oil-bearing sunflower seeds [2,3]. It follows that in order to improve the quality of sunflower heap cleaning, it is rational to develop a sieve with adjustable holes, the shape of which would copy the shape of the longitudinal section of the oilseeds. It is expedient to carry out a production
test of check samples of sieves with adjustable holes in comparison with production sieves for
determining their performance efficiency.

2. Materials and methods
The technological process of cleaning the sunflower heap with the additional sieve with adjustable holes
(diameter – 12 mm; rate of displacement of the holes relative to each other (adjustment) – 2 mm) was
studied.

The tests were carried out using “Niva” SK-5-M-1 and “Vector 410” combine harvesters in Russia,
in the Balashovsky district of the Saratov region at the private agricultural enterprise “The Head of the
Farm Zaikin E. B.” from 20th September till 10th of October 2018 on the sunflower variety “Saratovsky 20”,
with a yield of 1.1 t/ha, at a moisture content of oilseeds 8 %, heads height – 115 cm, plant height
– 140 cm, the extraneous matter content in the heap fed to the cleaning sieves was 12%, with the heap
feed on cleaning sieves 1.5-3 kg/s and the air flow rate of 1.5-3 m/s.

It is obvious that the additional sieve with adjustable holes will be installed under the lower sieve
pan of the combine harvester (figure 1) [4].

**Figure 1.** Scheme of cleaning of the combine harvester having the sieve with adjustable
holes: 1 – delivery board; 2 – finger comb; 3 – straw walkers sections; 4 – upper sieve
pan; 5 – lower sieve pan; 6 – sieve with adjustable holes; 7 – fan.

The design of the sieve with adjustable holes is as follows: this is a frame 1, on which a bolt joint
fixes a support 9 with an adjuster screw 10, coupled with a Г-shaped plate 7 by an adjuster nut, and that
allows displacing the lower movable sieve 6 relative to the upper sieve 4 forming adjustable holes
(figure 2).

**Figure 2.** Sieve with adjustable holes: 1 – sieve frame; 2 – guide slot; 3 – mounting
brackets; 4 – upper fixed sieve; 5 – corrugated tubes; 6 – lower movable sieve; 7 – Г-
shaped plate; 8 – adjuster nut; 9 – adjuster screw support; 10 – adjuster screw.
Changing the shape of adjustable holes due to the displacement of the lower fixed sieve, it is possible to achieve conformance of the holes to the shape of the longitudinal section of the oilseeds, depending on the variety to be harvested [2].

Since all oilseeds are slightly different in their geometric parameters (height, width, thickness), then the shape of a conventional oilseed will be taken as the longitudinal section of the ellipse centered on the origin (figure 3) [5].

\[
\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1, \tag{1}
\]

where \(a\) and \(b\) are the semi-axes of the ellipse, mm.

![Figure 3. Geometry of sunflower oilseeds.](image)

The area of the longitudinal section of the ellipse is:

\[
S_e = \pi ab, \quad m^2 \tag{2}
\]

The coefficient \(\tau\) was defined as the ratio of the width of the adjustable hole to its length (figure 4):

\[
\tau = \frac{s}{l}, \tag{3}
\]

where \(s, l\) are respectively the width and the length of the adjustable hole, mm.

![Figure 4. Geometric dimensions of the adjustable hole: \(a\) – hole of the upper fixed sieve, mm; \(b\) – hole of the lower movable sieve, mm.](image)
Let us present the technological process of separation through the adjustable sieve holes by the ratio between the parameters of the feed and pass of the sunflower heap and the fall of oilseeds off the sieve [6]. Moreover, pass is considered to be a part of the oilseeds passed through the adjustable holes; fall off is the part of the oilseeds blown off the sieve by the airflow of the fan (figure 5) [7]:

\[ q = q_1 + Q_1 = q_2 + Q_2 + q_3 + Q_3, \]  

where \( q \) – feed of sunflower heap to the sieve with adjustable holes, kg/s; \( q_1 \) – oilseeds content in the sunflower heap fed to the sieve, kg/s; \( Q_1 \) – extraneous matter in the sunflower heap fed to the sieve, kg/s; \( q_2 \) – number of seeds passed through the sieve, kg/s; \( Q_2 \) – extraneous matter passed through the sieve, kg/s; \( q_3 \) – number of oilseeds blown off the sieve, kg/s; \( Q_3 \) – extraneous matter blown off the sieve, kg/s.

![Figure 5. Technological process of cleaning the sunflower heap by a sieve with adjustable holes: 1 – extraneous matter passed through the sieve; 2 – oilseeds fed to the sieve; 3 – airflow; 4 – oilseeds passed through the sieve.](image)

**3. Results and discussion**

In accordance with the stated theoretical prerequisites, a sample of the additional sieve with adjustable holes was made (figure 6).

![Figure 6. Check sample of the additional sieve with adjustable holes.](image)
The sample was mounted under the lower sieve of the combine harvester (figure 7).

Figure 7. Mounting of the sieve with adjustable holes: 1 – upper sieve; 2 – lower sieve; 3 – arm bracket for mounting the sieve with adjustable holes; 4 – sieve with adjustable holes; 5 – bottom of the housing of the lower sieve pan; 6 – wind board of the fan.

For regulating the additional sieve with adjustable holes, three versions of displacement of the holes relative to each other were specified (figure 8).

Figure 8. Versions of displacement of the hole of the additional sieve with adjustable holes.
From the analysis it follows that for performing laboratory experiments and obtaining 4 values of the coefficient $\tau$, it is necessary to displace the movable sieve relative to the fixed one by 2.0 mm pitch. In this case, the values of the coefficient $\tau$ determined by the formula (3) are as follows:

1) $\tau = \frac{12}{12} = 1$;  
2) $\tau = \frac{10}{11.83} = 0.85$;  
3) $\tau = \frac{8}{11.31} = 0.70$;  
4) $\tau = \frac{6}{10.39} = 0.58$.

When the coefficient $\tau$ decreases, the area of the adjustable hole reduces.

The results of the performance of the additional sieve with adjustable holes were compared with the performance of grain combine harvesters “Niva” SK-5-M-1 and “Vector 410”, equipped only with production cleaning sieves. During the tests, it was found that under the same operating modes, cleaning of the sunflower heap with the additional sieve with adjustable holes is more effective (figures 9-10).

**Figure 9.** Dependences of the extraneous matter content in hopper sunflower heap in a combine harvester $Q_2$ on the feed of sunflower heap $q$ ($q^*$), kg/s and the air flow velocity $v_{\text{air}}$, m/s at a coefficient of displacement of the holes $\tau = 0.85$; $q$ – feed of the heap for cleaning with the additional sieve with adjustable holes; $q^*$ – feed of the heap to the production cleaning sieves of the combine harvester Niva SK-5-M-1.

**Figure 10.** Dependences of the extraneous matter content in hopper sunflower heap in a combine harvester $Q_2$ on the feed of sunflower heap $q$ ($q^*$), kg/s and the air flow velocity $v_{\text{air}}$, m/s at a coefficient of displacement of the holes $\tau = 0.7$; $q$ – feed of the heap for cleaning with the additional sieve with adjustable holes; $q^*$ – feed of the heap to the production cleaning sieves of the combine harvester “Vector 410”.
Thus, when using the additional sieve with adjustable holes with the feed of sunflower heap $q = 1.5$ kg/s and the air flow rate $v_{\text{air}} = 1.5$ m/s, extraneous matter content in sunflower heap was 4.2%, with production sieves it was 5.9% [8]. It is obvious that with the increase of $v_{\text{air}}$ there is a decrease in the extraneous matter content $Q_2$. Thus, when reaching $v_{\text{air}} = 2.5$ m/s, while feeding $q = 2.5$ kg/s, the extraneous matter content is reduced and it is 3.7% when using the additional sieve with adjustable holes. With the same parameters but without this sieve, the extraneous matter content $Q_2 = 5.1\%$. Note that with an increase in the feed $q (q^*)$, the extraneous matter content $Q_2$ increases in both cases. This is explained by the increase in the density of the heap flow. The minimum extraneous matter content at $\tau = 0.85$ using the additional sieve with adjustable holes is achieved at $q = 1.5$ kg/s and $v_{\text{air}} = 3.0$ m/s. In this case $Q_2 = 2.7\%$ and while using only the production sieves $Q_2 = 4.8\%$.

Let us consider the extraneous matter content during the operation of the “Vector 410” combine harvester. With that, the area of the sieve hole will be reduced to the value of $\tau = 0.7$ mm (figure 10). Presumably, the quality of cleaning should be improved.

In this case, when using the additional sieve with adjustable holes with feed of sunflower heap $q = 1.5$ kg/s and the air flow rate $v_{\text{air}} = 1.5$ m/s, the extraneous matter content in the sunflower heap was 4.0%; with production sieves it was 5.4%, and that can be explained by another modification of the combine [9]. Note that with increasing of $v_{\text{air}}$ there is a decrease in extraneous matter content $Q_2$. At $v_{\text{air}} = 2.5$ m/s, when feed $q = 2.5$ kg/s the extraneous matter content is 3.6% when using the additional sieve with adjustable holes. With the same parameters, but without this sieve, extraneous matter content $Q_2 = 5.0\%$ [10]. The minimum extraneous matter content at $\tau = 0.7$ using the additional sieve with adjustable holes is achieved at $q = 1.5$ kg/s and $v_{\text{air}} = 3.0$ m/s. In this case $Q_2 = 2.3\%$, due to a decrease in the size of the sieve hole ($\tau = 0.7$). With the use of production sieves without additional stage of cleaning, the extraneous matter content $Q_2 = 4.2\%$.

4. Conclusion
The studies show a significant reduction of extraneous matter in the hopper heap of a combine harvester through the use of the additional sieve with adjustable holes. In comparison with the combine cleaning without an additional sieve with adjustable holes, the content of extraneous matter is reduced by 38-42%. This is achieved by the shape of the adjustable hole, which displays the longitudinal section of the oilseeds, as well as the ability to reduce the shape depending on the type or variety of sunflower.

It is specified that with a decrease in the coefficient of displacement of the holes from 0.85 to 0.7, which means a reduction in the area of the adjustable hole, the extraneous matter content is reduced within 2.4–15.7% of the initial value.

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