The relative frequency of immersion of rye grains in liquid

A V Saitov¹, V G Farafonov² and V E Saitov¹ ²
¹Federal Agrarian Scientific Center of the North-East, 166 A, Lenin str., Kirov, 610007, Russia
²Vyatka State Agrotechnological University, 133, October ave., Kirov, 610017, Russia
E-mail: vicsait-valita@e-kirov.ru

Abstract. The grain heap of rye, in addition to high-grade grain, contains weeds and harmful impurities. Poisonous ergot sclerotia are harmful impurities. Modern grain cleaning machines do not provide the allocation of ergot sclerotia in one technological process by air flow and on sieves. Ergot sclerotia have a specific gravity lower than that of rye grain. Purification of rye seeds from ergot sclerotia by specific gravity is possible in a salt solution. To create a machine for the insulation of toxic ergot from grain, practical experiments were carried out on throwing single grains of winter rye of the Falenskaya 4 variety into a liquid with a specific gravity of \( \rho_{zh} = 1.0 \times 10^3 \); 1.09 \times 10^3; and 1.15 \times 10^3 \text{ kg/m}^3. \) Sodium salt of hydrochloric acid (NaCl) was used to create the solution. The results obtained are presented in the form of the distribution of the relative frequency of grains when immersed in a liquid from the height \( h \) of fall. It was found that 100% immersion of grains in water occurs at a height \( h \) of not less than 43 \,10^{-3} \text{ m}, and an aqueous solution of salt – 58\,10^{-3} \text{ m}. When developing a device for the isolation of ergot sclerotia by specific gravity in a salt solution, it is necessary to take into account that the grain will move in a flow and exclude the appearance of an undesirable trapping of an air bubble by a grain, which will worsen the results of separating impurities from the grain.

1 Introduction
People have been using rye grain for food preparation for a long time. Rye grain is also a valuable component for the preparation of feed for farm animals.

The grown rye crop is harvested by self-propelled combine harvesters [1-3]. The grain material in the harvesters accumulates in the hopper. In addition to grain, this grain material contains weeds and harmful impurities. Poisonous ergot sclerotia are among the harmful impurities [4-5].

At present, the separation of various impurities from the grain heap of rye is carried out by machines of preliminary, primary and secondary cleaning, mainly by air flow and on sieves [6-8].

These machines do not provide the isolation of toxic ergot sclerotia in one technological process from rye grain due to the closeness of their physical and geometric properties (windage, color, width, thickness, and length) [9-12].

Studies to improve the design and increase the efficiency of the technological process of these machines do not solve the problem noted [13-18].

Ergot sclerotia have a specific gravity lower than that of rye grain. Therefore, the release of poisonous ergot sclerotia is possible in an aqueous solution of inorganic salts. For this, you can use solutions of sodium salt of hydrochloric acid or potassium salt [19].
Accordingly, an urgent issue is the creation of a machine for the isolation of toxic ergot sclerotia from rye grain by specific gravity in an aqueous solution of salt. When developing such a device for high-quality performance of the technological process for the isolation of ergot sclerotia from rye grain, it is necessary to determine the height of the location of the outlet of the loading bunker with grain relative to the surface of the aqueous salt solution [20].

Therefore, the purpose of practical research is to determine the minimum height of the location of the outlet of the loading bunker with grain relative to the surface of the liquid in the bath of the device for separating ergot from grain material by specific gravity in a saline solution in order to ensure that the grain is overcome by surface tension forces.

2 Materials and methods
To implement the set research goal, practical experiments were carried out of throwing single grains of winter rye varieties Falenskaya 4 with a moisture content of 14% into a liquid with a specific gravity of $\rho_{zh} = 1.0 \cdot 10^3$, $1.09 \cdot 10^3$ and $1.15 \cdot 10^3$ kg/m$^3$. To change the specific gravity $\rho_{zh}$ of the liquid, sodium salt of hydrochloric acid salt (NaCl) was used. A general view of a sample of grains of winter rye variety Falenskaya 4 and sodium salt of hydrochloric acid (NaCl) in the placer is shown in figure 1.

![Figure 1](image1.png)

**Figure 1.** A general view of a sample of grains of winter rye variety Falenskaya 4 (a) and sodium salt of hydrochloric acid (NaCl) (b).

According to the geometric shape, the winter rye grains of the Falenskaya 4 variety have an elongated rounded shape. Therefore, a rye grain is considered as an elongated ellipsoid of revolution. This geometric model of a grains has major major and minor axes.

For the experiments, an experimental setup was made, which is shown in figure 2.

![Figure 2](image2.png)

**Figure 2.** Experimental setup for experiments on immersion in liquid of different specific gravity $\rho_{zh}$ of individual grains of winter rye variety Falenskaya 4 in varying the height $h$ of fall.
The setup is a vessel in the form of a bath of transparent glass. The bath has a length of 0.35 m, a width of 0.20 m and a height of 0.15 m. The internal cavity of the bath contained a volume of liquid in the amount of 9 liters.

Above the bath, metal plates were installed, which had a thickness of \(1.5 \times 10^{-3}\) m, a length of 0.28 m and a width of 0.04 m. Using a set of these metal plates, the height \(h\) of the fall of rye grains into a liquid of various specific gravity \(\rho_{zh}\) was varied. The grains in the amount of 20 pieces were installed on the surface of the upper plate and dropped into the liquid along the main minor axis (flat). For the supply of grains along the main major axis to the surface of the liquid, they were clamped with tweezers and dropped from the studied height \(h\) in the direction of this axis.

The relative frequency of immersion in water \((\rho_{zh} = 1.0 \times 10^3\) kg/m\(^3\)) and an aqueous solution of sodium salt of hydrochloric acid (NaCl) with specific gravity \(\rho_{zh} = 1.09 \times 10^3\) and \(1.15 \times 10^3\) kg/m\(^3\) of individual grains of winter rye variety Falenskaya 4 in varying the height \(h\) of the fall was determined by the expression (%):

\[
p = \frac{n_2}{n_1} \cdot 100\tag{1}
\]

Where \(n_1\) – the number of individual grains entering the liquid, pc.;

\(n_2\) – the number of grains that are drowned in liquid, pc.;

To record reliably obtained experimental data, the temperature of the liquid and outside air in the laboratory was maintained at 20 °C. The experiments were carried out in triplicate. The experimental data were processed using a SAMSUNG NP-R540H personal computer using the Microsoft Excel 2013 office documentation package for statistical data processing. The resulting dependencies are presented using the CorelDRAW 12 vector graphics editor.

3 Results and Discussion

The distributions of the relative frequency \(p\) of grains of winter rye variety Falenskaya 4 when immersed in a liquid of different specific gravity \(\rho_{zh}\) along the main minor axis (flat) from the height \(h\) of fall are shown in figure 3.

It follows from the figure that grains when falling from a height of \(h \leq 13.0 \times 10^{-3}\) m along the main minor axis (flat) onto the water surface \((\rho_{zh} = 1.0 \times 10^3\) kg/m\(^3\)), do not sink in it. This is due to the fact that they cannot overcome the force \(R_2\) of the surface tension of water. At a fall height \(h\) of 16.0, 19.0, and 22.0 \(\times 10^{-3}\) m, the amount of grains capable of overcoming the force \(R_2\) of the surface tension of water is 5, 10 and 22%, respectively. A further increase in the height \(h\) of the fall of grains into water increases the index of the relative frequency \(p_{1000}\) of immersion of grains, which at \(h = 37.0 \times 10^{-3}\) m is already 84%. At a height of \(h = 43.0 \times 10^{-3}\) m, all grains that are dropped from the plate begin to sink in the water.

When grains arrive along the main minor axis (flat) from a height of \(h \leq 19.0 \times 10^{-3}\) m to the surface of an aqueous solution of salt with a specific gravity of \(\rho_{zh} = 1.09 \times 10^3\) kg/m\(^3\), they do not sink in it due to the fact that they do not have sufficient kinetic energy to overcome the force \(R_2\) of the surface tension of the solution. At a height of \(h = 19.0; 22.0\) and \(25.0 \times 10^{-3}\) m, the index of the relative frequency \(p_{1090}\) of immersion of grains is 5, 8 and 15%, respectively. At a height of \(h = 34.0 \times 10^{-3}\) m, the relative frequency \(p_{1090}\) of immersion of grains in a salt solution is 47%, and at a height of \(h = 46.0 \times 10^{-3}\) m, the \(p_{1090}\) index already increases to 90%. With a drop height \(h = 52.0 \times 10^{-3}\) m, all grains that are dropped from the plate begin to sink in this salt solution.

When grains arrive along the main minor axis (flat) onto the surface of an aqueous salt solution with a specific gravity of \(\rho_{zh} = 1.15 \times 10^3\) kg/m\(^3\) from a height of \(h \leq 19.0 \times 10^{-3}\) m, the force \(R_2\) of the surface tension of the liquid is not overcome by them. An increase in the height \(h\) of the fall of caryopses from \(22.0 \times 10^{-3}\) m to \(55.0 \times 10^{-3}\) m determines their relative frequency \(p_{1150}\) of immersion in an aqueous salt solution from 20% to 95%, respectively. The minimum immersion height \(h\) of all dropped grains in this liquid is \(58.0 \times 10^{-3}\) m.
\( \rho_{zh} = 1.0 \cdot 10^3 \text{ kg/m}^3 \);
\( \rho_{zh} = 1.09 \cdot 10^3 \text{ kg/m}^3 \);
\( \rho_{zh} = 1.15 \cdot 10^3 \text{ kg/m}^3 \)

**Figure 3.** Distributions of the relative frequency \( p \) of grains of winter rye variety Falenskaya 4 when immersed in liquid along the main minor axis (flat) from the height \( h \) of fall.

The distributions of the relative frequency \( p \) of immersion in liquid of different specific gravity \( \rho_z \) of grains of winter rye of the Falenskaya 4 variety from the height \( h \) of the fall when dropped from the plate along the main major axis are shown in figure 4.

**Figure 4.** Distributions of the relative frequency \( p \) of grains of winter rye variety Falenskaya 4 when immersed in liquid along the main major axis from the height \( h \) of fall.
When grains enter the water surface along the major major axis ($\rho_{zh} = 1.0 \cdot 10^3$ kg/m$^3$) from a height of $h \leq 3.0 \cdot 10^{-3}$ m, the force $R_z$ of the surface tension of the liquid is not overcome by them. Therefore, the grains do not sink in water, but float on its surface. An increase in the height $h$ of the fall of grains from $6.0 \cdot 10^{-3}$ m to $12.0 \cdot 10^{-3}$ m determines their relative frequency $p_{1090}$ of immersion in water from 40% to 95%, respectively. At a height of $h > 15.0 \cdot 10^{-3}$ m, all the grains entering the water surface sink in it.

When falling along the main major axis from a height of $h \leq 3.0 \cdot 10^{-3}$ m into a liquid with a specific gravity of $\rho_{zh} = 1.09 \cdot 10^3$ kg/m$^3$, grains are also unable to overcome the force $R_z$ of its surface tension and their relative frequency $p_{1090} = 0\%$. An increase in the height $h$ of the fall causes an increase in the $p_{1090}$ index: at $h = 6.0 \cdot 10^{-3}$ m the $p_{1090}$ index = 30\%, at $h = 9.0 \cdot 10^{-3}$ m the $p_{1090}$ value = 70\%, at $h = 12.0 \cdot 10^{-3}$ m the $p_{1090}$ index is 85\%, with $h = 15.0 \cdot 10^{-3}$ m $p_{1090} = 95\%$ and with a height $h > 18.0 \cdot 10^{-3}$ m $p_{1090} = 100\%$.

When grains enter the surface of an aqueous solution of sodium salt of hydrochloric acid (NaCl) with a specific gravity of $\rho_{zh} = 1.15 \cdot 10^3$ kg/m$^3$ in the direction of the main major axis from a height of $h = 6.0 \cdot 10^{-3}$ m, their relative immersion frequency $p_{1150}$ does not exceed 20\%. An increase in the height $h$ of the fall of the grains to $18.0 \cdot 10^{-3}$ m causes already 90\% immersion in an aqueous salt solution, and 100\% immersion of the grains occurs at a fall height $h = 24.0 \cdot 10^{-3}$ m.

The results of the experiments carried out on the throwing of individual grains into a liquid of different specific gravity $\rho_{zh}$ show different drop height $h$ for their one hundred percent immersion. The immersion height $h$ of individual grains in water is less than in an aqueous salt solution. This is due to the fact that water has a lower specific gravity $\rho_{zh}$ compared to an aqueous salt solution and, accordingly, a lower surface tension coefficient than an aqueous salt solution. Therefore, in order to overcome the surface tension of an aqueous salt solution, the grains must have a large kinetic energy. For this, the grains must fall into an aqueous salt solution from a greater height $h$.

In the machine for the isolation of toxic ergot sclerotia from rye grain, the transfer of grain material into an aqueous salt solution will occur in the form of a stream. In this case, undesirable entrapment of an air bubble by the grain is possible, which will worsen the results of separating impurities from the grain. Accordingly, further research is necessary to assess the loss of $P_z$ in the waste of seeds that floated to the surface with air bubbles.

4. Conclusion

Thus, as a result of practical experiments, it was found that one hundred percent immersion of single grains along the main major axis into water with a specific gravity of $\rho_{zh} = 1.0 \cdot 10^3$ kg/m$^3$ occurs at a fall height $h$ of at least $15.0 \cdot 10^{-3}$ m, and when arriving from a height $h$ not less than $43.0 \cdot 10^{-3}$ m in the direction of the main minor axis (flat), all grains are also immersed in this liquid. When grains enter the surface of an aqueous solution of sodium salt of hydrochloric acid (NaCl) with a specific gravity of $\rho_{zh} = 1.09 \cdot 10^3$ and $1.15 \cdot 10^3$ kg/m$^3$ along the main minor axis (flat), their one hundred percent immersion is carried out at a drop height $h$ of at least $52.0 \cdot 10^{-3}$ and $58.0 \cdot 10^{-3}$ m, respectively, and at a height $h$ of falling into these salt solutions of at least $18.0 \cdot 10^{-3}$ and $24.0 \cdot 10^{-3}$, respectively, in the direction of the main major axis, all grains are also immersed. The experiments performed are consistent with theoretical studies [21].

When developing a device for the isolation of toxic ergot sclerotia, the movement of grain into an aqueous solution of inorganic salt will occur in a continuous stream. In this case, it is necessary to take into account the undesirable capture of an air bubble by full-fledged grains and their floating on the surface of an aqueous salt solution, which can be disposed of as waste.

References

[1] Orobinsky V I, Gievsky A M, Baskakov I V and Chernyshov A V 2018 Seed refinement in the harvesting and post-harvesting process. Advances in Engineering Research 870-874
[2] Aldoshin N and Didmanidze O 2018 Harvesting Lupinus albus axial rotary combine harvesters. Research in Agricultural Engineering 64(4) 209-214
[3] Aldoshin N, Didmanidze O, Lylin N and Mosyakov M 2019 Work improvement of air-and-
screen cleaner of combine harvester. Engineering for Rural Development: Proceedings of 18th International Scientific Conference (Latvia University of Life Sciences and Technologies, Faculty of Engineering) 18, 100-104

[4] Schekleina L M 2019 The influence of weather factors on certain periods of development of the fungus Slavicep spurpurea (Fr.) Tul and the level of ergot erosion in the Kirov region. Agricultural science of the Euro-North-East 20(2), 134-143

[5] Sheshegova T K, Schekleina L M, Zhelifonova V P, Antipova T V, Baskunov B P and Kozlovsky A G 2019 The resistance of rye varieties to ergot and the content of ergot alkaloids in sclerotia claviceps purpurea in the conditions of the Kirov region. Mycology and phytopathology 53(3), 177-182

[6] Volkhonov M S, Zimin I B and Ostrovsky Yu N 2020 Analysis of the state of preliminary cleaning of grain in farms of the north-western region of the Russian Federation and prospects for improvement. Bulletin of the Kazan State Agrarian University 2(58), 82-86

[7] Burkov A I, Glushkov A L and Lazykin V A 2019 Comparative studies of the effectiveness of the functioning of the pneumatic separation channels of the fractional pneumatic separator of seeds. Bulletin of the Voronezh State Agrarian University 3(62), 26-31

[8] Kharitonov M K, Gievsky A M, Orobinsky V I, Chernyshov A V and Baskakov I V 2020 Improving the efficiency of sieve cleaning of grain cleaning machines. Bulletin of the Voronezh State Agrarian University 1(64), 19-27

[9] Orobinsky V I, Tarasenko A P, Gievsky A M, Chernyshov A V and Baskakov I V 2018 Improving the mechanization of high-quality seed production. Advances in Engineering Research 849-852

[10] Badretdinov I, Mudarisov S, Tuktarov M, Dick E and Arslanbekova S 2019 Mathematical modeling of the grain material separation in the pneumatic system of the grain-cleaning machine. Journal of Applied Engineering Science 4(17), 529-534

[11] Gievsky A M, Gulevsky V A and Orobinsky V I 2019 Ways to increase the performance of universal grain cleaning machines. Bulletin of the Federal State Educational Establishment of Higher Professional Education "Moscow State Agroengineering University named after VP Goryachkin 3(85), 12-16

[12] Savinyh P, Sychugov Y, Kazakov V and Ivanovs S 2018 Development and theoretical studies of grain cleaning machine for fractional technology of flattening forage grain. Engineering for Rural Development: 17th International Scientific Conference Engineering for Rural Development, Proceedings, 124-130

[13] Gievsky A M, Orobinsky V I, Tarasenko A P, Chernyshov A V and Kurilov D O 2018 Substantiation of basic scheme of grain cleaning machine for preparation of agricultural crops seeds. IOP Conference Series: Materials Science and Engineering 327, 042035

[14] Orobinsky V I, Gievsky A M, Tarasenko A P and Chernyshov A V 2019 Study of strength and sowing qualities of seeds of winter wheat with fractional technology of post-harvest grain processing. Bulletin of the Voronezh State Agrarian University 62(3), 13-18

[15] Andreev V L 2019 Calculation of the effective separation of light impurities in the inertial jalousie-countercurrent dust collector. IOP Conference Series: Materials Science and Engineering International Workshop «Advanced Technologies in Material Science, Mechanical and Automation Engineering» 32097

[16] Ermoliev Yu I, Doroshenko A A and Belov S V 2016 Simulation of the process of separation of chopped straw in a pneumatic separator with three pneumatic channels. Bulletin of the Don State Technical University 85(2), 59-68

[17] Orobinsky V I, Gievsky A M, Tarasenko A P, Chernyshov A V and Baskakov I V 2019 A study of the effectiveness of cleaning heaps of spring wheat for seed purposes with an air-sieve separator. Bulletin of the Voronezh State Agrarian University 61(2), 34-42

[18] Kharitonov M K, Gievsky A M, Orobinsky V I, Chernyshov A V and Baskakov I V 2020 Studying the design and operational parameters of the sieve module of the grain cleaning...
machine. *IOP Conference Series: Earth and Environmental Science* 012021

[19] Saitov V E, Farafonov V G and Saitov A V 2019 Experimental substantiation of the effective height of a grain falling by a stream of liquid in an ergot release device. *IOP Conference Series: Earth and Environmental Science* 341 (012123) 1-6

[20] Saitov A, Gatullin R and Saitov V 2019 A machine for separating ergot from rye seeds. *Patent RF*, no. 2689470

[21] Sysuev V A, Saitov V E, Farafonov V G, Suvorov A N and Saitov A V 2017 Theoretical Background of Calculating of the Parameters of the Device for Grain Cleaning from Ergot Sclerotia. *Russian Agricultural Sciences* 3 273-276