№ 3 (130) / 2025

Техніка, енергетика, транспорт АПК

Vol. 130, № 3 / 2025

UDC 631.561.6
DOI: 10.37128/2520-6168-2025-3-4

# ANALYSIS OF TECHNICAL AND TECHNOLOGICAL EQUIPMENT FOR DETERMINING IMPURITIES IN SEED RAW MATERIALS

**Stanislav MELNYK**, postgraduate student
Dnipro State Agrarian and Economic University

**МЕЛЬНИК Станіслав Михайлович**, аспірант
Дніпровський державний аграрно економічний університет

*The article is dedicated to the development of technology and equipment for the reuse of waste and stimulation of its transformation into raw materials for other industries. The problems of laboratory determination of oil and grain impurities in grain are analyzed, and a set of impurity properties requiring further investigation is defined. Samples of laboratory equipment from leading manufacturers are reviewed, the main criteria of interaction between raw materials and the working environment are formulated, and the directions for the development of separation equipment are substantiated. It is shown that grain waste mixtures are characterized by stochasticity and the emergence of properties under conditions of an unstable working environment, which is manifested through fluctuations of airflow parameters, turbulence, and complex aerodynamic phenomena. These features require not only preliminary identification of fraction properties but also the implementation of measures for stabilizing the working environment during analysis. Based on the performed analysis, a laboratory sorting machine with vertical pneumatic separation is substantiated as the most rational solution. The proposed equipment should be equipped with automated control systems, an adaptive vibrating feeder with adjustable amplitude and frequency, a raw material deaerator, aspiration and dedusting units, antistatic inspection windows, and protective elements against reverse airflows. The main design concept is based on aggregation and modularity, which ensures adaptability to various types of raw materials and research tasks. A system of criteria for evaluating laboratory grain analyzers is proposed, including the availability of separation methods, absence of grain injury, possibility of process intensification, fractionation capability, automation level, and network integration. The implementation of the proposed solutions enables reduction of analysis time, improvement of accuracy and repeatability of results, and expansion of functional capabilities of laboratory equipment in grain processing and waste utilization technologies.*

***Key words**: laboratory, waste, oil impurity, grain impurity, separation, equipment, design.*
***Table. 2. Ref. 31.***

## 1. Problem formulation

Technological innovations in the food industry cover a number of solutions, which can include technical and technological support for resource-saving technologies and technical and technological support for the use of waste as a resource source. The problem of waste use in the food industry requires solutions in the context of studying the properties inherent in waste. The main goal is to implement the principles of sustainable development and rational use of resources, which formed the basis of the concept of the "circular economy" as an economic model. The concept is based on the reuse and stimulation of the transformation of one industry by-product into raw materials for another industry [1, pp. 93-98]. Ukraine has joined the trend, and the conditions of the crisis stimulate new approaches and acceleration of the processes of digital transformation of the production and processing of agricultural raw materials.

On the way to implementing new approaches, problems have emerged that need to be resolved. Ukraine is an agrarian country that grows a significant amount of grain and oilseed crops, has achieved significant success in increasing yields [2], [3], [4], and also generates a significant amount of waste in agriculture. For example, the oilseed processing industry generates 4% of the main seed waste and 17% of sunflower husk. It is known that the oil impurity in the main seed waste is about 45%, and the oil admixture in the husk is 4-6%, although studies show the percentage of oil admixture in the husk up to 12%.


Article received 24.10.2025. Article accepted 08.12.2025. Article published 25.12.2025.

Oil and grain admixtures are suitable for the production of food and feed products by their technological and biochemical indicators, but insufficient study of the physical and mechanical properties inherent in waste and products of intermediate grain processing, the lack of waste sampling methods, waste sample preparation methods, the lack of laboratory means of determining the number of waste fractions that can be used to manufacture products, as well as the lack of multi-criteria means of technical and technological equipment for processing waste into finished products, hinder technological innovations.

List of main problems: there is a gap in the study of the properties inherent in waste and products of intermediate grain processing, lack of methods for preparing samples of garbage and waste that ensure sample representativeness, lack of technical and technological means for laboratory determination of the percentage of oil/grain admixture and multi-criteria means of technical and technological equipment for processing waste into finished products.

## 2. Analysis of recent research and publications

The State Standards of Ukraine for Grain and Seeds and the International Requirements [5] for Grains in terms of Sample Selection and Preparation have two areas of application: general requirements that apply to both grain and seeds in terms of sample selection and preparation, as well as standards that take into account the specifics of individual grains and seeds.

According to the DSTU 4138-2002 standard [6], the amount of waste and oil/grain impurities is determined for all crops that can be used for the production of food and feed products. According to the DSTU 8837:2019 [7], DSTU 3768-2019 [8], DSTU 3769-98 [9], DSTU 4524-2006 [10] and others, the percentage of waste and oil/grain impurities is determined, which takes into account the specificity of the seed mixture of an individual agricultural crop.

The standards for all crops recommend a manual method of analysis for the content of garbage / oil impurity, and as an auxiliary means to reduce the time of analysis, a sieve manual method or a method using a mechanical scatterer is recommended. In case of need for an arbitration determination of the content of garbage / oil impurity, the standards recommend only a manual method of analysis.

To determine the amount of oil / grain impurities, there is still no recommended technical and technological means of laboratory determination of oil impurity.

As for the products of intermediate processing of cereals, there are several standards that regulate the method of determining oil / grain impurity. For example, DSTU 7123:2009 [11] recommends determining quality indicators at least once a month or in the event of replacing a batch of raw materials, which does not allow using the analysis results in Automated Process Control Systems (APCS). There is also no method for determining the quality indicator "Oil impurity content". The standard recommends determining the mass fraction of fat and extractive substances in absolutely dry matter. Such an indicator cannot be used in the technological process of oil extraction for a significant time to determine the percentage of oil in the husk and the large discrepancy in the percentage of oil, which is introduced by botanical and sorption oiliness, as well as the presence of a large amount of wax, aldehydes, phosphatides and a number of other substances soluble in petroleum solvents, which distort the real amount of oil impurity in the waste.

The recommended methods of sampling and preparation of samples used for compound feed are not valid in Ukraine. It was determined experimentally that the methods of sampling and preparation of samples used for sampling sunflower, rapeseed, compound feed are not representative when used for sampling waste. Thus, at an oil extraction enterprise in Ukraine, experiments were conducted to determine the percentage of oil impurity by the methods recommended for sampling sunflower and by the method of determination using an experimental sorting machine for extracting oil impurity from sunflower husks [12]. The oil impurity was sorted for 24 hours by a sorting machine and accumulated in big bags, after which it was weighed. Spot samples were taken by the method of cutting the husk flow every hour and the obtained samples were mixed to obtain a daily sample with subsequent quartering. By manual disassembly in the laboratory of the enterprise, the percentage of oil impurity determined was 2.0%, and the experimental sorting machine isolated 6.0%.

In recent years, significant research has been conducted on the indicators inherent in grain processing waste [12, p.31-34]. Indicators that can be used in the development of equipment for sorting oil extraction waste were obtained [13]. The researchers analyzed the properties inherent in fractions of sunflower oilseeds, technical means of post-harvest processing. The results of research on pneumatic sieve and pneumatic gravity separators allow for further improvement of the technological efficiency of the devices. Analysis of the technical equipment of post-harvest processing of sunflower seeds and theoretical studies of the process of separation of air-separated impurities, the results of laboratory and field studies of experimental devices allow for the practical application of the results of the research [14].

The scientific foundations of technical and technological support for waste-free processing of grain raw materials into food products and feed have been developed [15], [16] and examples of technical support for processing grain raw materials into food products and feed have been provided (cylindrical trier for preparing grain components, plant for manufacturing feed pellets, disperser-homogenizer, expander), as well as new technologies for processing solid raw materials into products and feed.

But the main properties of the waste mixture submitted for sorting have not yet been studied. Sunflower oilseeds are a mixture of fractions, the composition of which is given in DSTU 7011-2009 [17]: crushed; eaten by pests; sprouted; damaged; immature; seeds caught by frost; completely or partially collapsed, shriveled; damaged by herbivorous bugs; the sizes of the fractions of which are smaller than the sizes of the main grain. Grain fragments have various sizes, but the overwhelming number of oil impurity fractions have a common characteristic - this is density. Thus, sunflower waste, sunflower litter have a number of particles of longitudinal dimensions, have branching of the particle body. In the process of sorting, the particles of the mixture are compacted and form conglomerates, which is characterized by an increase in the internal resistance of the mixture, an increase in the shear resistance index, uncertainty of the angle of natural slope, etc. Conglomerates prevent stratification (de-laminating) of the mixture, especially of small-sized particles of the mixture. As determined by experiments according to the DSTU 7123:2009 method [11], the mass fraction of fat and extractive substances in absolutely dry matter is almost 10% due to the dense fraction with dimensions of 0.2-1.0 mm, which remains in the mixture and is not sorted, but which can be used for the needs of product manufacturing.

When sorting garbage with an increased amount of moisture, the quality of sorting decreases. First, moisture leads to an increase in morphometric indicators, density, midsection, critical speed, etc. Second, moisture in garbage is a factor that stimulates the hydrolysis of carbohydrates in garbage and fruit shell. Hydrolysis products have the property of gluing together individual particles of the mixture.

The fruit and seed shell of the kernel of oil crops is an active sorbent of oil (triglycerides), which have the property of polymerizing, have adhesion to the components of the mixture that is subjected to sorting. The property of triglycerides to polymerize is used in the manufacture of drying oils as a solvent and hardener for oil paint.

Moisture, carbohydrate hydrolysis products and triglyceride polymerization products lead to gluing of mixture particles, leads to caking of the mixture, lump formation, blocks the sorting process and requires additional scientific research into the phenomena of stratification, emergentity, the influence of fluctuations in the working environment [18] (vibration, air pulsations, internal and boundary tribological properties, etc.) and the development of the latest technical and technological means, modernization of equipment for grinding and deauneration of settled raw materials.

## 3. The purpose of the article

Based on the study of the current state of the problem of determining the percentage of oil/grain impurities in raw materials, to propose possible solutions for the technical and technological support of laboratory determination.

## 4. Results and discussion

Analysis and classification of existing laboratory equipment can be determined depending on the method of interaction of the working environment with raw materials:

• equipment using one method of interaction of the raw materials to be sorted and the working environment to determine a separate indicator of grain quality;

• equipment using several sequential methods of interaction of the raw materials to be sorted and the working environment to determine one separate or several indicators of grain quality;

• high-tech analytical laboratory equipment for the simultaneous determination of several indicators of grain quality.

Analysis of literary sources indicates a large number of laboratory mechanical equipment that calculates the means of technical and technological support for sorting of grain, waste and intermediate products of processing. But from the study of the state of the art of sorting equipment and the achievements of fundamental research, it is possible to propose several methods of intensification of sorting processes and improvement of its quality. Such methods include the Magnus, Coanda, Karman effects.

The Magnus effect is a physical phenomenon that occurs when a grain moves through an air stream and rotates. As a result, a transverse force is created that acts perpendicular to the direction of the flow. This force is directed from the side where the direction of rotation coincides with the direction of the flow to the side where these directions are opposite. This phenomenon can be used to split the flight paths of oil impurity fractions.

The Coanda effect is a physical phenomenon that consists in the fact that the air stream flowing out of the nozzle tends to deviate towards the wall. If a solid wall is located near the stream, the cross-section of the secondary flow decreases on the side of the solid wall. This leads to the jet being deflected towards the wall under the action of atmospheric pressure until the jet touches the wall. This phenomenon can also be used to split the flight paths of oil impurity fractions.

Karman effect, vortex trail, chains of vortices observed when air flows around elongated cylindrical bodies (or other linearly elongated profiles that flow around them poorly) with a longitudinal axis perpendicular to the direction of motion of the continuous medium. The separation of vortices occurs on both sides of the body in turn; after separation, the vortices form two chains behind the body, the direction of rotation of the vortices in one chain is opposite to the direction of rotation in the other. The Karman effect can be used to design a deaerator for loosening a settled mixture of oil impurities.

WESTRUP LA-HT [19]. Gravity spiral separator Small-scale spiral separator LA-HT is designed to separate round seeds of one diameter from round seeds of another diameter using gravity. It is used for fractionation of seeds by density, it is possible to adjust to the required grain diameter. It has very limited application, for spherical grains, grain injury is present, additional adjustment is very limited and depends on a number of independent environmental factors (air humidity, presence of condensate, oiliness of seeds, initial injury, dust dispersion, tribometric indicators of grains, etc.).

WESTRUP LA-BG BELT GRADER [20]. Laboratory belt grader separator for separating round seeds from flat seeds - for example, primrose seeds from begonia seeds. LA-BG BELT GRADER separator is designed to separate round seeds from flat seeds by morphometric criteria. It makes sense to use when there is a pair of seeds of maximum size: flat and spherical size. Limited use for seeds of transitional shape (sunflower seeds, wheat). Lack of automation, limited interface.

HALDRUP LT-15 [21], LT-20, LT-21, LT-35 offers a number of models of laboratory air threshers/sorters for laboratory determination of impurities during harvesting and for assessing the quality of combine operation when harvesting grain heaps. The equipment provides a fine threshing process without macro- and micro-trauma of the grain. The presence of only air cleaning, the possibility of additional settings for corn, sunflower, sorghum. The absence of the possibility of fractionation, process automation and local network interface.

CHOPIN Technologies ROTACHOC offers a spreader, to which a set of sieves with a diameter of 25, 40, and 50 cm is attached, and upon additional request of users, sieves are made with holes of any diameter. The spreader is able to provide 2 speeds of rotation of the sieve package, installation of three sieve sets simultaneously, additional functions such as vertical shaking of sieve sets and rectilinear reciprocating movement of sieve sets. Presence of seed trauma, limited local network interface and lack of automation.

PFEUFFER GmbH MLN Sample Cleaner [22]. The cleaning process largely corresponds to the process of a conventional cleaning machine. The process is carried out using sieves and aspiration. The separator determines the proportion of impurities (coarse particles, fine particles, aspiration discharges) and fine grains. High seed trauma, complex procedure for resetting (sieve replacement), limited automation of the process.

PFEUFFER GmbH SLN Sample Cleaner offers a sieve separator. Number of sieves 3, all sieves with rectangular holes, fully automatic cleaning with a defecator and aspiration. The separator is equipped with sieve sorting with cleaning balls. High seed injury, complex procedure for reconfiguration (replacement of sieves).

PFEUFFER GmbH Auto Sample Cleaner (ASC), Automatic separator equipped with aspiration, deauner - loosener and cleaning of sieves with balls. Available touch screen display, built-in printer and local network interface. High seed injury, complex procedure for reconfiguration (replacement of sieves).

CHOPIN Technologies NSP [23] - Laboratory sieve separator using flat sieves and aspiration. High seed injury, complex procedure for reconfiguration (replacement of sieves). Limited automation and interface.

REITER Seed Processing GmbH & Co. Its laboratory equipment [24] positions it as laboratory aspirators of the RPA-120, RPA-500, RPA-600, RPA-1500 type, although it can be attributed to aerodynamic sorting machines. The separator is equipped with a vibrating feeder with a drive control system, large antistatic windows made of impact-resistant glass for visual inspection, an air valve with 2 pneumatic covers, an exhaust air dust removal system. High seed damage.

RIELA RF-14 Pre-Cleaner [25] The sieve-drum aspiration separator with a conical sieve has a design specific to laboratory equipment, which imitates the company's separators. The grain mixture is pre-cleaned and aspirated. High seed damage, complex reconfiguration procedure (replacement of sieves). Limited automation.

HUICHUAN Heavy Industry, Live magnetic separator [26]. Equipped with a leather-covered magnetic drum connected via a vibrating feeder. Magnetic field strength 1800-6000Gs. Designed for all types of grain. No sub-settings, automation and LAN interface.

MCC Lilliput Laboratory magnetic separator [27]. Laboratory magnetic separator. The seed mixture is pre-mixed with a fine-grained ferromagnetic powder and during the subsequent sorting process is magnetized to the magnet together with the grain. Designed for a limited type of grain, without sub-settings, automation and local network interface.

SOLLAU LSV Laboratory high intensity magnetic separator [28]. The LSV laboratory high-intensity magnetic separator is mainly used in laboratory conditions for the separation of magnetic and paramagnetic particles, bulk materials. Limited use for the separation of paramagnetic materials, limited use for the separation of diamagnetic materials due to the laboriousness of cleaning from metal debris. Limited automation.

WESTRUP LA-T Laboratory trier [29] is designed for sorting grain of different lengths. Has a high technological efficiency of removing long particles, Limited automation.

HALDRUP DC-20 [30] Densimetric sorting and cleaning column. Densimetric cleaning and sorting column. Equipped with an electronically controlled feeder, cleaning in a vertical air stream, a fan with adjustable feed. The densimetric column is a unit of pneumatic, air, aerodynamic and aspiration blocks. Possibility of fine sorting

OLISLAB 1100. Laboratory scatterer (RLU-1) [31]. The company "Olis", Ukraine, manufactures scatterers for sieve analysis and fractionation of grains.

***Table 1***

***Equipment and methods of interaction of grains with the working environment***

| Mechanical laboratory sorting machines | Methods of interaction of grain with the working environment | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | flat-screen | drum-screen | air | pneumatic | aerodynamic | aspiration | gravity | trier | magnetic | magnetic-powder | grader |
| Westrup LA-HT | | | | | | | ● | | | | |
| Westrup LA-BG | | | | | | | | | | | ● |
| HALDRUP LT-15 | | | ● | | | ● | | | | | |
| CHOPIN Rotachoc | ● | | | | | | | | | | |
| «OLIS» RLU-1 | ● | | | | | | | | | | |
| PFEUFFER MLN | ● | | | | | ● | | | | | |
| PFEUFFER SLN | ● | | | | | ● | | | | | |
| PFEUFFER ASC | ● | | | | | ● | | | | | |
| CHOPIN NSP | ● | | | | | ● | | | | | |
| REITER RPA-120 | | | | | | ● | | | | | |
| RIELA RF-14 | | ● | | | | ● | | | | | |
| HUICHUAN HI | | | | | | ● | | | ● | | |
| MCC Lilliput | | | | | | | | | | ● | |
| SOLLAU LSV | | | | | | | | | ● | | |
| HALDRUP DC-20 | | | ● | ● | ● | ● | | | | | |
| WESTRUP LA-T | | | | | | ● | | ● | | | |
| SORTMASH CC-002-05 | | | ● | ● | ● | ● | ● | | | | |

*Source: developed by the author*

Experimental laboratory equipment SORTMASH CC-002-05 [12] has a number of advantages. Among them are versatility, the use of vibropneumatic, air, aerodynamic, aspiration methods of separation, additional methods of process intensification, the possibility of additional settings, the possibility of fractionation, process automation, the available local network interface. The disadvantages include the limited sorting of mineral impurities, the presence of traumatization of some types of grain. But the presence of disadvantages does not limit the scope of application, since the oil impurity, for the sorting of which the analyzer is being developed, is already a completely traumatized raw material. As for the mineral impurity, its amount is within the initial requirements for the main raw material, the granulometric composition is improved by the dispersing equipment of the following technological processes (rolling, pressing, crushers, conditioners). The presence of a mineral component for some types of domestic animals and poultry is a vital component (for example, a certain amount of mineral stones is always present in the stomach of a bird).

Table 1 shows the ways of interaction of grain and waste with the working environment, from which it is possible to conclude that the best result can be achieved when sorting waste using an upward air flow and the maximum number of ways of interaction of raw materials and the working environment.

To assess the possibilities of using existing laboratory equipment in the laboratory analysis of grain and their waste oil/grain impurities, it is possible to use a list of criteria that are not exhaustive (Table 2). The criterion "universality" determines the possibilities of using equipment for analyzing grain of several crops, i.e., not one crop.

***Table 2***

***Criteria for evaluating the use of laboratory equipment for waste analysis***

| Mechanical laboratory sorting machines | Evaluation criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | versatility | availability of separation methods | absence of traumatism | additional methods | additional setting | fractionation process | automation | local network interface | notes |
| Westrup LA-HT | | | | | | ● | | | |
| Westrup LA-BG | | | | | ● | ● | | | |
| HALDRUP LT-15 | | ● | ● | | | | | | |
| CHOPIN Rotachoc | ● | | | | ● | | | ● | |
| «OLIS» RLU-1 | ● | | | | ● | | | | |
| PFEUFFER MLN | ● | ● | | | | | | | |
| PFEUFFER SLN | ● | ● | | ● | ● | ● | | ● | |
| PFEUFFER ASC | ● | | | ● | ● | | ● | ● | |
| CHOPIN NSP | ● | ● | | | | | | | |
| REITER RPA-120 | ● | ● | | | | | ● | ● | |
| RIELA RF-14 | | ● | | | | | | | |
| HUICHUAN HI | | | | ● | | ● | | | |
| MCC Lilliput | | | | ● | | ● | | | |
| SOLLAU LSV | | | | ● | | ● | | | |
| HALDRUP DC-20 | ● | ● | | ● | ● | ● | ● | ● | |
| WESTRUP LA-T | | ● | ● | | | ● | | | |
| SORTMASH CC-002-05 | ● | ● | | ● | ● | ● | ● | ● | |

*Source: developed by the author*

The presence of several implemented methods of separation and interaction of raw materials with the working environment should be determined by the criterion "availability of separation methods". Given the special effectiveness of using the link of separation methods in the design of a laboratory analyzer, Table 1 provides an additional analysis of the number of methods used in the design of laboratory machines. When assessing by the criterion of “absence of injury”, the percentage of grain that was injured during the analysis is determined, and the injury should not exceed the normative percentage of the standard indicator. If there are additional methods of intensification of the sorting process in the design of the analyzer (vibration, cleaning of working bodies, pneumatic treatment, aspiration treatment, etc.), the indicator “additional methods” is determined. In the analysis process, it is necessary in some cases to carry out “additional adjustment”, for example, to compensate for fluctuations in the working environment or fractional composition of raw materials. In production conditions, the task often arises to carry out “fractionation” of the grain mixture according to one or more criteria, the assessment of which is provided by laboratory equipment with available capabilities. Reducing the time for laboratory analysis and conducting analytical processing of the result corresponds to arranging laboratory equipment according to the criteria of “process automation” and the presence of a “local network interface”.

## 5. Conclusion

A feature of grain waste mixtures is the stochasticity and emergence of its indicators. The variability of waste is complemented by the uncertainty of the working environment. Thus, when sorting by air flow, fluctuations in pressure, temperature, flow velocity, turbulence, aerodynamic phenomena of Magnus, Karman, Coande and others require preliminary determination not only of the indicators of raw material fractions, but also determination of changes in properties (emergence) of the mixture, as well as implementation of measures to stabilize the working environment.

Analysis of the advantages of each of the designs of mechanical laboratory sorting machines proves that the following solutions should be implemented for the proposed laboratory sorting machine: sorting should be automated and in a vertical ascending air flow with the connection of pneumatic, air, aerodynamic and aspiration blocks, which allows to achieve the tasks of cleaning grain from clogging to the greatest extent;the laboratory machine must be equipped with a vibrating feeder with the ability to control the amplitude and frequency of oscillations; the air flow generator must be equipped with an electronic control unit; the laboratory machine must be equipped with a deauner – a raw material loosener; the machine must be equipped with antistatic windows for visual inspection, an air valve to prevent reverse air flows, an exhaust air dedusting system; the main design directions should be aggregation and/or modularity.

## References

1. Zvarych, I. Ya. (2019). Implementation of the EU action plan in the sphere of circular economy. *Scientific Bulletin of Uzhhorod National University. International Economic Relations and World Economy, 25*(1), 93–98. Uzhhorod. [in Ukrainian].
2. Polyakov, O. I., & Shcherbak, A. D. (2022). Sunflower productivity under the influence of mineral fertilizers and growth regulators. *Scientific and Technical Bulletin of the Institute of Oilseeds of the NAAS, 33*, 111–122. DOI: https://doi.org/10.36710/IOC-2022-33-11 [in Ukrainian].
3. A national record for sunflower yield has been set. (2025, October 25). URL: https://agropravda.com/news/agrobiznes-life/13350-ustanovlen-nacionalnyj-rekord-urozhajnosti-podsolnechnika [in Ukrainian].
4. Tyvonchuk, Ya. A., & Dubinina, M. V. (2024). Assessment of sunflower seed production in Ukraine. In *Food security of Ukraine in the context of war and post-war recovery: Global and national dimensions* (pp. 292–294). Mykolaiv National Agrarian University. DOI: https://doi.org/10.31521/978-617-7149-78-0-95 [in Ukrainian].
5. International Seed Testing Association. (2025, November 1). *International rules for seed testing*. URL: https://www.seedtest.org/en/international-rules-for-seed-testing-rubric-3.html [in English].
6. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (2002). *Seeds of agricultural crops. Methods for determining quality (DSTU 4138-2002).* Kyiv. [in Ukrainian].
7. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (2019). *Oilseeds. Methods for determining waste and oil impurities (DSTU 8837:2019).* Kyiv. [in Ukrainian].

8. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (2019). *Wheat. Technical conditions (DSTU 3768:2019).* Kyiv. [in Ukrainian].
9. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (1998). *Barley. Technical conditions (DSTU 3769-98).* Kyiv. [in Ukrainian].
10. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (2006). *Buckwheat. Technical specifications (DSTU 4524:2006).* Kyiv. [in Ukrainian].
11. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (2009). *Sunflower husks. Technical specifications (DSTU 7123:2009).* Kyiv. [in Ukrainian].
12. Kudryavtsev, I. M. (2025). *Justification of the design and technological parameters of an aerodynamic separator for cleaning sunflower seed mixture waste* (PhD dissertation). Dnipro State Agrarian and Economic University. [in Ukrainian].
13. Mikhailov, E. V., Kyurchev, S. V., Kolodiy, O. S., Zadosna, N. O., Verkholantseva, V. O., Chernyshova, L. M., & Palyanychka, N. O. (2019). *Technical means of post-harvest processing of sunflower seeds*. FORWARD PRESS. [in Ukrainian].
14. Shevchenko, I., & Aliiev, E. (2018). Study of the process of calibration of confectionery sunflower seeds. *Food Science and Technology, 12*(4), 135–142. [in English].
15. Aliyev, E. B. (2020). *Mechanical and technological foundations of the process of precision separation of sunflower seed material* (Doctoral dissertation). Kharkiv. [in Ukrainian].
16. Aliyev, E. B. (Ed.). (2022). *Technical and technological support for waste-free processing of grain raw materials into food products and feed*. LIRA. [in Ukrainian].
17. State Enterprise “Ukrainian Research and Training Center for Standardization, Certification and Quality”. (2009). *Sunflower. Technical specifications (DSTU 7011:2009).* Kyiv. [in Ukrainian].
18. Stepanenko, S. P., Kotov, B. I., & Kalinichenko, R. A. (2021). Study of the movement of grain material particles in a vertical channel under the influence of air flow pulsations. *Agricultural Machinery, 47*, 25–36. DOI: https://doi.org/10.36910/acm.vi47.619 [in English].
19. WESTRUP. (2025, October 31). *LA-HT spiral separator*. URL: https://www.westrup.com/small-scale-machines [in English].
20. WESTRUP. (2025, October 31). *LA-BG belt grader*. URL: https://www.westrup.com/ru/small-scale-machines [in English].
21. HALDRUP. (2025, October 31). *LT-15 laboratory thresher and cleaner*. URL: https://en.haldrup.net/haldrup-products/haldrup-lab-machines/haldrup-lt-15/ [in English].
22. PFEUFFER. (n.d.). *MLN sample cleaner*. URL: https://www.pfeuffer.com/product/mln-sample-cleaner [in English].
23. CHOPIN Technologies. (2025, October 31). *Lab separator NSP*. URL: https://agroproekt.com.ua/grain-quality/nsp [in Ukrainian].
24. REITER Seed Processing. (2025, October 31). *Laboratory precision aspirator RPA-120*. URL: https://www.reiter-sp.com [in English].
25. RIELA. (2025, October 31). *RF-14 pre-cleaner*. URL: https://riela.de/en/products/cleaning-technology [in English].
26. HUICHUAN Heavy Industry. (2025, October 31). *Live magnetic separator*. URL: https://www.huichuanmachinery.com [in English].
27. MCC. (2025, October 31). *Lilliput laboratory magnetic separator*. URL: https://www.researchgate.net/publication/338836289_Alfalfa_seed_cleaning_using_a_magnetic_separator [in English].
28. SOLLAU. (2025, October 31). *LSV laboratory high-intensity magnetic separator*. URL: https://www.sollau-cz.com/lsv-laboratory-high-intensity-magnetic-separator [in English].
29. WESTRUP. (2025, October 31). *LA-T indented cylinder*. URL: https://www.westrup.com/small-scale-machines [in English].
30. HALDRUP. (2025, October 31). *DC-20 densiometric cleaning and sorting column*. URL: https://en.haldrup.net/haldrup-products/haldrup-lab-machines/haldrup-dc-20/ [in English].
31. OLIS. (2025, October 31). *Lab separator OLISLAB 1100 (RLU-1)*. URL: https://olis.com.ua/osnashenie/ochischennya-zerna/rassev-rlu-1/ [in Ukrainian].

# АНАЛІЗ ТЕХНІЧНОГО ТА ТЕХНОЛОГІЧНОГО ОБЛАДНАННЯ ДЛЯ ВИЗНАЧЕННЯ ДОМІШОК У НАСІННЕВІЙ СИРОВИНІ

*Стаття присвячена розробці технології та обладнання для повторного використання відходів та стимулювання їх перетворення на сировину для інших галузей промисловості. Проаналізовано проблеми лабораторного визначення вмісту олії та зернових домішок у зерні, а також визначено комплекс властивостей домішок, що потребують подальшого дослідження. Розглянуто зразки лабораторного обладнання провідних виробників, сформульовано основні критерії взаємодії сировини та робочого середовища, а також обґрунтовано напрямки розвитку сепараційного обладнання. Показано, що суміші зернових відходів характеризуються стохастичністю та виникненням властивостей в умовах нестабільного робочого середовища, що проявляється через коливання параметрів повітряного потоку, турбулентність та складні аеродинамічні явища. Ці особливості вимагають не лише попередньої ідентифікації властивостей фракцій, але й впровадження заходів щодо стабілізації робочого середовища під час аналізу. На основі проведеного аналізу обґрунтовано лабораторну сортувальну машину з вертикальним пневматичним сепаруванням як найбільш раціональне рішення. Запропоноване обладнання має бути оснащене автоматизованими системами керування, адаптивним вібраційним живильником з регульованою амплітудою та частотою, деаератором сировини, аспіраційними та пилоочисними установками, антистатичними оглядовими вікнами та захисними елементами від зворотних повітряних потоків. Основна концепція проектування базується на агрегації та модульності, що забезпечує адаптивність до різних типів сировини та дослідницьких завдань. Запропоновано систему критеріїв оцінки лабораторних аналізаторів зерна, включаючи наявність методів розділення, відсутність травмування зерна, можливість інтенсифікації процесу, можливість фракціонування, рівень автоматизації та мережеву інтеграцію. Впровадження запропонованих рішень дозволяє скоротити час аналізу, підвищити точність та повторюваність результатів, а також розширити функціональні можливості лабораторного обладнання в технологіях переробки зерна та утилізації відходів.*

***Ключові слова:*** *лабораторія, відходи, олійна домішка, зернова домішка, сепарація, обладнання, конструкція.*

***Табл. 2. Літ. 31.***

### *INFORMATION ABOUT THE AUTHOR*

**Stanislav MELNYK** – postgraduate student Industrial mechanical engineering, Dnipro State Agrarian and Economic University, (St. Sergiy Efremov, 25, Dnipro, Ukraine, 49000, e-mail: stealths1978@gmail.com, https://orcid.org/ 0000-0002-8151-223X).

**МЕЛЬНИК Станіслав Михайлович** – аспірант спеціальності 133-Галузеве машинобудування, Дніпровського державного аграрно-економічного університету (вул. Сергія Єфремова, 25, м.Дніпро, Україна, 49000, e-mail: stealths1978@gmail.com, https://orcid.org/ 0000-0002-8151-223X).