ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

2021 • 4

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

БАЯНДАМАЛАРЫ

ДОКЛАДЫ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

REPORTS

OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN

PUBLISHED SINCE JANUARY 1944

ALMATY, NAS RK

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
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БАЯНДАМАЛАРЫ **2021 • 4**

«Қазақстан Республикасы Ұлттық ғылым академиясының баяндамалары»
ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)
Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» Республикалық қоғамдық бірлестігі (Алматы қ.). Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ93VPY00025418** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *өсімдік шаруашылығы, экология және медицина саласындағы биотехнология; физикалық және химиялық ғылымдар.*
Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28; 219 бөл.; тел.: 272-13-19
http://reports-science.kz/index.php/en/archive

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

Доклады Национальной академии наук Республики Казахстан»
ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы). Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ93VPY00025418,** выданное 29.07.2020 г.
Тематическая направленность: *биотехнология в области растениеводства, экологии и медицины; физические и химические науки.*
Периодичность: 6 раз в год.
Тираж: 300 экземпляров
Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28; ком. 219; тел. 272-13-19
http://reports-science.kz/index.php/en/archive

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

REPORTS **2021 • 4**
OF NATIONAL ACADEMY OF SCIENCES OF THE
REPUBLIC OF KAZAKHSTAN

Reports of the National Academy of Sciences of the Republic of Kazakhstan.
ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty). The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ93VPY00025418,** issued 29.07.2020.
Thematic scope: *biotechnology in the field of crop research, ecology and medicine; physical and chemical sciences.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://reports-science.kz/index.php/en/archive

Address of printing house: ST «Aruna», 75, Muratbayev str., Almaty.

BIOTECHNOLOGY

REPORTS OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
ISSN 2224-5227
Volume 4, Number 338 (2021), 5 – 12 https://doi.org/10.32014/2021.2518-1483.52

UDC 664.723:631.243.3
IRSTI 68 85 35

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SUBSTANTIATION OF THE POSSIBILITY OF INCREASING THE EFFICIENCY OF DRYING OF GRAIN BY METHOD OF ACTIVE VENTILATION

Abstract: this article analyzes existing installations for active ventilation of grain (further in the article: AVG) in containers (bunkers, silos), identifies their main disadvantages. Experimental study has been carried out to assess the technological efficiency of existing installations for AVGduring stationary storage in a container. As a result of the analysis of the obtained results of the experimental study, the cause of the inhomogeneous temperature field inside the grain mound was revealed due to the uneven distribution of the air flow (working agent) in the interg rain space. When designing the air distribution channel of the installation, the need to comply with the law of conservation of mass for a continuous medium, for example, an air flow, was not taken into account. A ventilated bunker with a rational design of an installation for active ventilation of grain has been proposed. The principal difference between the bunker and the existing ones lies in the method of uniform distribution of the air flow inside the grain mound. The installation for the implementation of this method includes two channels designed for injecting air into the mound and removing the exhaust air together with the evaporated moisture when drying the grain using the active ventilation method. The law of conservation of mass is observed due to the cone-shaped design of the air distribution channels, as a result of which a uniform temperature field and humidity are created in the interg rain space of the mound.

Key words: installation, bunker, grain, storage, active ventilation, drying, humidity, temperature, intergrain space, mound of grain, air, distribution channels.

Introduction. The issue of grain storage after harvesting with an improvement of quality indicators requires the implementation of various measures depending on the type and initial condition of the grain. The most important of these measures is the AVG in the open area and in the granariestanks. The essence of AVG is to prevent overheating of the grain by cooling the self-heating mass. Wet grain mass can be dried by active ventilation with atmospheric air. AVG with warm dry air after harvesting increases the germination energy of immature grains, improves the quality of subsequent products.

The issue of improving the processes of drying and cooling is always actual topic in companies in relation to grain receiving, initial processing and storage. The interest of specialists in the AVG technology is associated with the versatility of the application of the corresponding installation along with the simplicity of their design. Increasing the intensity of ventilation of grain in the hoppers such as "Petkus" (Germany), BV (Russia) is directly related to the rationality of relate dequipment‘s working elementsdesign.

The purpose of the study: identification of the disadvantages of existing installations for the AVG, the choice of an effective method for AVG and rational design of the installation air distribution channels.

Research objectives: analysis of the essence of AVG and factors affecting the processefficiency; comparative analysis of known equipment for grain ventilation and drying; choose an effective way of grain ventilation and rational equipment design;analysis of the influence of the chosen design on the efficiency of the process.

Expected results: raises of the technological efficiency of grain storage with a decrease in cost of the processes; requirements for preventive processing of grain, are met improved the sanitary and hygienic working conditions.

Main part. Active ventilation of wet grain using atmospheric or heated air during warm dry weather limits the growth of microorganisms. As a result, the duration of stable storage of grain increases and its quality indicators improve.

The main parameters of the process of active ventilation of grain, according to which the technological mode of operation of the equipment is established, are the flow rate, the temperature of the fuel assembly and the humidity of the air flow; the height of the grain moundand the duration of ventilation.

Factors affecting the efficiency of active ventilation of grain: type of grain, initial moisture $w_{in.gr}$ (%) and temperature $T_{in.gr}{}^0C$ of grain, frequency of ventilation, air velocity υ_{air} (m/s), height of the grain mound H_{mound}, moisture w_{air} (%) and temperature $t_{air}{}^0C$ air, climatic conditions and season.Indicators of efficiency of stationary ventilation of grain in elevator silos and buildings of granaries: ripening of unripe grain; ensuring the quality of grain for the intended purpose; preparation of seeds for sowing; gas treatment of grain to prevent the viability of pests; prevention - cooling; preliminary drying of grain.

Methods of active ventilation of grain and equipment. Depending on the purpose of ventilation and the type of grain storage, appropriate types of installations are used. Known installations for warehouses with inclined and horizontal bottoms, as well as bunkers. Depending on the design features, they separate installations for stationary ventilation and floor-standing ones for grain storage rooms. Floor-standing installations are divided into stationary, mobile and telescopic.

The main disadvantage of the known methods of active ventilation of grain and related equipment is the uneven distribution of air in the intergranular space. Analyzing the features of installations for AVG, it is possible to determine the reasons for this deficiency.The methods of AVGin the mound, depending on the direction of air movement, are divided into horizontal and vertical. Floor ventilation systems for grain in warehouses and some bunker installations ventilate grain in a vertical direction. The technological efficiency of such ventilation units depends on the height of the grain moundand its initial moisture content.

The ventilated bunkers, developed by the firm "Pectus" (Germany) and type VB (Russia), are intended for storage of seed grain [1,2,3,8]. Inside the hopper there is an installation for universal use: for ventilating a self-heating mass of grain or drying wet grain. The main working elements of the installation are two cylinders with a perforated surface, between which there is a ventilated mass of grain. During ventilation, the air flow is forced into the inner cylinder. Through the openings of the side wall of the cylinder, the air flow enters the intergranular space and through the openings of the side walls of the outer cylinder, air with moisture is directed into the atmosphere. In the inner air distribution cylinder there is a piston, the position of which is adjusted by means of a winch through block. The location of the piston determines the height of the grain mound. If the hopper is not fully loaded with grain, the piston must be below the upper level of the grain. The ventilated «Pectus» hopper can be used to dry wet grain to equilibrium moisture content.For this, a heater is provided in the ventilation system to heat the air to a certain temperature. The advantages of such bunkers are simplicity of design, ease of maintenance, small footprint due to the height of the body, full mechanization and automation, adjustable height of the mound, the use of electricity due to the integrated equipment of the system for drying grain, etc.

The main drawback of ventilated bunkers is revealed as an uneven distribution of air flow in the intergranular space. The air speed decreases as it moves along the cylindrical distribution channel due to the increase in aerodynamic drag. A constant cross-section of the channel in height negatively affects the distribution of air along the height of the ventilated grain mass. This means that when choosing the design of the air distribution channel, the developers did not take into account the law of conservation of mass. The method of regulating the height of the ventilated grain layer does not completely solve the problem associated with uneven air distribution, and also increases operating costs.

According to the method of horizontal ventilation of grain in bunkers, two systems are adopted: for air injection and for suction of exhaust air with moisture released in the form of steam. Accordingly, depending on the purpose of the system, two fans are adopted, operating simultaneously.

As the results of exploratory research have shown, the duration of horizontal ventilation of the grain mound is 3...5 times less than the vertical. However, the air consumption per unit mass (1 ton) of grain is 3,0...3,5 times more, while the air heated by 2^0C. Therefore, the method of horizontal ventilation of grain is more expensive than the of vertical. The height of the grain embankment is limited depending on its initial moisture content. According to the results of the study, with a grain mound height above 1,5 m, unit costs increase sharply, and the technological efficiency of the process decreases [8].

The formulation of the ventilation problem does not exclude the possibility of undesirable processes (self-heating, caking, etc.) in the grain mass, which lead to a deterioration in the quality characteristics of the grain. As practice shows, the optimal moisture content of grain in the grain mound should not exceed 13...14%, which is the main factor of grain stability for storage. In this case, the amount of heat and carbon dioxide released in the grain mass itself and in all components of the grain mass that are harmful to the grain (with the exception of rodents and birds) is significantly reduced.

Investigation of the efficiency of the air distribution system for drying grain by means of active ventilation. On the above-ground granaries of peasant farms, floor installations are used, as stationary type SUV, telescopic type TUV. To determine the technological efficiency of floor-standing installations, a technique has been developed for conducting an experimental study. Experiments were carried out to study the process of drying grain using a floor-standing experimental installation in the form of a section based on TUV.

Experimental research technique. Figure 1 shows a diagram of the experimental setup. The tank 1 of the installation has a rectangular shape and is made of perforated steel sheet with a hole diameter of 2 mm. Dimensions of the tank: 3*3*2 m. At the bottom of the tank 1 along its axial line there are air distribution channels 3 having a conical shape with a base diameter of 200 mm, facing the opposite walls of the container. Large bases of the channels through diffuser 4 and pipelines were connected with a centrifugal fan VTS 4-70-2,5 with parameters: power 0,55 kW, air flow rate 1500 m^3/h and pressure loss 1000 Pa [6].

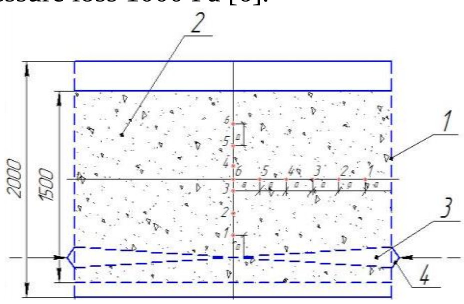


Figure 1 – Schematic of the experimental setup: 1 - perforated container; 2 - grain embankment; 3 - air distribution channels; 4 - diffuser

Product, initial parameters. A grain heap of wheat of the "Atbasar" variety was accepted with a moisture content of 25% and a temperature of 22^{0}C, the height of the grain mound in the tank is 1,5 m.

The study was carried out according to the well-known method of Institute "Grain" (Moscow) in accordance with the standards for determining the moisture content of grain SS 13586.5-2015 /RF/ [6] and the method of grain sampling SS 13586.3-2015 /RF/ [7].

According to the well-known research technique, to determine the technological parameters of the grain mound from 6 points of the grain mound along the height and, accordingly, the length of the container, a sample was taken of 6*2 = 12 times, each weighing 50 g.

The air flow velocity at the outlet of the diffuser 4 (Fig.1) was assumed to be no more than the standard value for grain ventilation - 0,02 m/s.

The procedure for conducting experiments. To measure the temperature and moisture content of the grain in the grain mound, 6 points were marked along the height and length of the embankment along the tank centerline. For this purpose, appropriate sampling holes are drilled in the tank wall. Taking into account the distance between the sampling points and the designated points of the embankment, the position of the holder of the РПО-1,6*50 sampler was adjusted in accordance with the specified depth of its penetration into the grain mound. Points in the mound for measuring grain temperature and sampling: 1,2,3,4,5 and 6 (Fig. 1).

Control and measuring devices: vertical electrocontact mercury thermometer ТПК-П; sampler РПО-1.6*50, laboratory drying cabinet СШ-4. **Parameter measurement technique**: the initial and final moisture content of grain at six points along the height of the grain moundand along the length of the air distribution channel were determined according to a well-known method [6,7]: the moisture content of samples, each weighing 50 g, was determined using an СШ-4 drying cabinet. The initial and final temperatures of the grain at the corresponding points were measured using a TPK-P electrocontact mercury thermometer.

The procedure for measuring the temperature of the grain at the characteristic points 1, 2, 3, and 6 in the mound (Fig.1). In the experimental setup, the moundwas ventilated with an air stream heated to 60^{0}C degrees using a heater for 2 hours. The grain temperatures were measured at characteristic points with an electric contact thermometer in accordance with the measurement procedure. For this, a thermometer, connected to an alternating current source with a frequency of 50 Hz, was directed to the corresponding characteristic point in the mound through the corresponding holes on the tank.

The measurement results were entered in Table 1.

Analysis and discussion of research results. Table 1 below shows the results of grain ventilation with an initial moisture content of 25%, a temperature of 22^{0}C in a perforated tank for 120 minutes at an air temperature of 60^{0}C. Figure 3 shows a graph of changes in moisture $\omega_з$ (%) and grain temperature $t_з{}^0$C at the accepted characteristic points mass of grain: 1,2,3,4,5 and 6, that is, depending on the height and width of the moundof ventilated mass of grain.The moisture content and temperature of the grain in the embankment vary depending on the direction of the air flow. The air flow gives off heat to the grains and, having cooled down, together with the evaporated moisture, is directed from the intergranular space to the outlet. When the grain is dried with heated air at 60°C, the surface moisture of the grain evaporates and the grain moisture gradually decreases.

The moisture and temperature of the grain varies greatly in the vertical direction in accordance with the direction of the air flow. For example, when the embankment is ventilated from bottom to top at characteristic points along the vertical №1 and №6 (Fig. 2), the humidity is 16% and 25%, the temperature is 33 and 28°C (curves 1 and 2 are characteristic points along the vertical).The moisture and temperature of the grain horizontally change slightly. Since at the characteristic points on the horizontal lines №1 and №6 the humidity is 17% and 18%, the temperature is 33°C and 28°C (in Fig. 2, curves 3,4 refer to the characteristic points along the horizontal).

Table 1 - The results of drying wheat grain at an initial moisture content of 25%, a temperature of 22^{0}C by the method of active ventilation (drying time 120 min, air temperature 60^{0}C)

Results		Characteristic points 1 ... 6 in the grain mound					
		1	2	3	4	5	6
Grain moisture, %	By the height of the grain mound	16	17,4	18	22	23	25
	Along the length of the grain mound	18	18	18	18	19	20
Grain temperature, t^{o}C	By the height of the grain mound	Characteristic points 1 ... 6 in the grain mound					
		33	32	30	26	24	28
	By the width of the grain mound	30	30	30	29	28	28

The air flow injected into the grain mound from the floor air distribution channel of the tank in the vertical direction is unevenly distributed in the intergranular space. Moving upwards, the grain drying efficiency gradually decreases. The conical design of the horizontal duct allows uniform distribution of the air flow in the horizontal direction. Since along the horizontal axis of the container (width of the mound), the moisture content and temperature of the grain change insignificantly.In the vertical direction, the grain temperature decreases with distance from the floor air distribution channel (4th curve, Fig. 2), and in the horizontal direction, the change in grain temperature does not exceed 2% (2nd curve).

The air flow injected into the grain mound from the floor air distribution channel of the tank in the vertical direction is unevenly distributed in the intergranular space. Moving upwards, the grain drying efficiency gradually decreases. The conical design of the horizontal duct allows uniform distribution of the air flow in the horizontal direction. Since along the horizontal axis of the container (width of the mound), the moisture content and temperature of the grain change insignificantly.In the vertical direction, the grain temperature decreases with distance from the floor air distribution channel (4th curve, Fig. 2), and in the horizontal direction, the change in grain temperature does not exceed 2% (2nd curve).

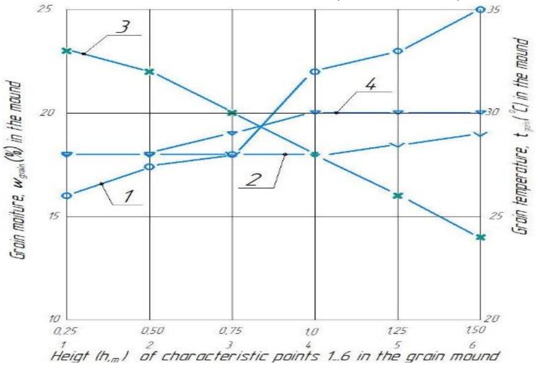


Figure 2 – Dependence of humidity ω_{grain} (%) and temperature t^{0}C of wheat grain on the height (1,2) and width of the mound (3,4) of the grain mound during drying by active ventilation: 1,2 - vertically, 3,4 – horizontally

The results of the study confirm the main disadvantage of floor-standing units for ventilation of grain such as SUV, MUV, TUV, as an uneven distribution of air flow in the intergrainer space. Since according to the table of research results (table 1), graphical dependences of humidity ω_3 (%) and temperature t^0C of wheat grain on the height (1,2) and width of the mound (3,4) of the grain mound were plotted when drying active ventilation: 1,2 - vertically, and, 3, 4 - horizontally.

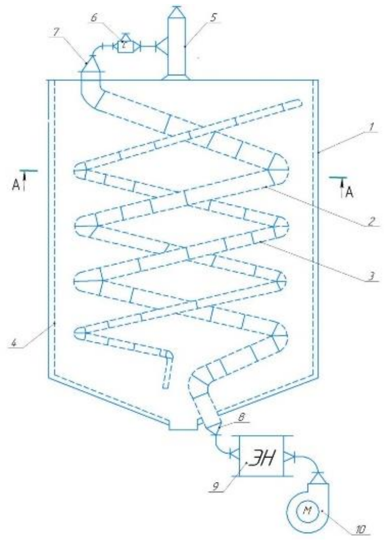
The obtained dependences of humidity ω_3 (%) and temperature t^0C of wheat on the height and width of the grain embankment (m) during drying with the help of active ventilation made it possible to make sure of the low manufacturability of existing floor-standing installations (telescopic TUV, mobile MUV and stationary SUV), associated with uneven distribution of air flows in the intergrainer space of a grain mound.Only due to the cone-shaped design of the air distribution channels in telescopic units of the TUV type, the requirement for air distribution is almost met. However, in this variant, the requirements for the distribution of air flow in the intergranular space are met along the width of the grain mound (along the transverse axis), along which the air distribution channels of the installation are located.

Active ventilation or drying of grain in the hopper at stationary mode. Uneven distribution of air flow in the intergrainerly space significantly reduces the technological efficiency of installations for active ventilation of grain. Analyzing the results of the study, we came to the conclusion that when choosing the design of the air distribution channels, the designers did not take the physical laws of motion of a continuous medium as a basis for creating the installation.

The mass conservation law when the air flow moves through the channel of a particular system is expressed in the following form:$V_{air}= F_1 \nu_1= F_2 \nu_2= \ldots= F_n\nu_n$, if a $F_1, F_2 \ldots F_n$ - the 1,2 ... n-th of the channel cross-sections along its length; $\nu_1, \nu_2 \ldots \nu_n$ - air velocities in the 1,2 ... n-th of the channel cross-sections corresponding sections of 1,2 ... nth channel sections ($F_1, F_2 \ldots F_n$).

Fig. 3 shows a diagram of a ventilated bunker, which differs in the design features of the air distribution channels. The main purpose of the hopper is to dry freshly harvested grain and periodically active ventilation of the seed during storage.The hopper for AVG consists of two containers designed as a "pipe in a pipe": a body 1 with a solid construction, inside which there is a mesh container 4. For ventilation or drying of the mound in the bunker, there are two air distribution channels 2,3 of a tapered shape and a telescopic structure.

The hopper for active ventilation of grain consists of two containers designed as a "pipe in a pipe": a body with a solid construction, inside which there is a mesh container. For ventilation or drying of the mound in the bunker, there are two air distribution channels of a tapered shape and a telescopic structure. In connection with the expedient application of the law of conservation of mass when choosing a design, the air distribution ducts are made with a variable cross-section in the direction of air movement in accordance with the purpose of the ducts. Since, in the direction of the air flow, the channel 3 (Fig. 3) for air distribution in the intergrain space is made with a decreasing cross-section, and the channel 2 for sucking air with moisture - with an increasing cross-section. Therefore, the air distribution channels have a conical shape with a varying cross-section in direction of movement of continuous media and are located opposite each other in the form of two spirals in space (Fig.3).



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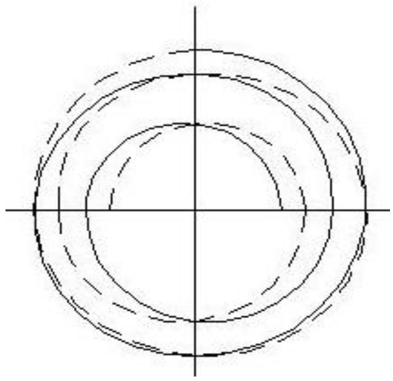

b

Figure 3. Ventilated bunker: a) bunker layout:1 - case; 2 - suction channel; 3 - air distribution channel; 4 - perforated container; 5 - exhaust fan; 6 - capacitor; 7 - suction-, 8 - discharge branch pipes; 9 - electric heater; 10 - blower fan. b) the direction of the spiral lay of the air distribution channels

Purpose of the channels (Fig. 3): injection - for air flow distribution in the intergrain space of the mound; suction channel - to remove to remove on moisture with the air stream from the intergrain space of the mound. The telescopic design of the air distribution channels allows you to adjust their position depending on the grain level in the hopper by changing the length using a special longitudinal rod. Depending on the purpose, the pressure (discharge) and suction channels are connected to the ventilation system with the help of branch pipe at one end, at the other end of the channels is blunt (closed). The distance between the channels is set depending on the moisture content of the grain, if necessary, it can be adjusted.

The use of the installation (Fig. 3) increases the technological efficiency of the processes of active ventilation of grain during storage, drying of grain during reception, reduces operating costs, due to which the cost of storing grain will be significantly reduced. The chosen design of the air distribution channels of the unit for the ventilated bunker increases the technological efficiency of ventilation due to the uniform distribution of the air flow in the intergrain space. Drying of the newly harvested wet grain when it is received by the method of active ventilation, elimination of self-heating of the grain embankment during storage, aeration and fumigation increase the nutritional properties of the grain and disinfect it, allows unripe seeds to ripen. In this regard, it is advisable to use a new design of a ventilated hopper for processing and storing seeds, drying newly harvested grain.

Conclusion. An analytical review was carried out of the known floor-standing units for ventilation of grain in the vertical direction such as SUV, PUV and TUV for horizontal ventilation of grain in the premises of grain warehouses and bunker installations for vertical ventilation of grain in bunkers such as "Pectus" and VB. As a result of exploratory research, the main and essential reason for their low technological efficiency was revealed. In scientific and practical terms, an experimental study was carried out, as a result of which the reason for the uneven distribution of the air flow in the intergrainer space of the mound during ventilation was confirmed.The use of floor-standing units for active vertical ventilation of the grain embankment is accompanied by high operating costs and low technological efficiency. The air flow injected into the grain mound from the floor air distribution channel of the tank in the vertical direction is unevenly distributed in the intergranular space. Moving upwards, the grain drying efficiency gradually decreases. The conical design of the horizontal duct allows uniform distribution of the air flow only in the horizontal direction. Since along the horizontal axis of the container (width of the mound), the moisture content and temperature of the grain change insignificantly. In the vertical direction, the grain temperature decreases with distance from the floor air distribution channel (4th curve, Fig.3), and in the horizontal direction, the change in grain temperature does not exceed 2% (2nd curve).

As a result of experimental studies, the reason for the main disadvantage of telescopic floor installations of the TUV type was revealed - the low technological efficiency of grain ventilation. The air flow along the height of the grain mound is unevenly distributed in the intergrain space. Consequently, when designing ventilated bunkers and floor storage facilities, the regularity of movement and preservation of a continuous medium was not taken into account. The energy intensity of the ventilated bunker depends on the pressure losses, which must be experimentally established as the dependence of the aerodynamic resistance of the intergrain space of the grain on the height (thickness) of the grain mound.

In the proposed ventilated bunker, it is possible to carry out grain drying by means of active ventilation of the grain bulk. As a result of an analytical review and search research, the factors influencing the technological efficiency of grain drying by ventilation were identified. A rational design of a bunker installation for grain ventilation has been chosen. The unit is located inside the mesh tank of the bunker and consists of two mesh spiral channels of a conical shape, one of which is designed for uniform distribution of the air flow in the intergrain space, and the other for removing air from the intergrain space along with the evaporated moisture. The introduction into production of the adopted technical solutions for the choice of an effective method of ventilation of the grain mound and the rational design of the installation for its implementation increases the technological efficiency and reduces the unit costs of storing the grain mound in floor rooms and in bunkers.

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ДӘНДІ ЖЕЛДЕТУ ТИІМДІЛІГІН АРТТЫРУ МҮМКІНДІКТЕРІН НЕГІЗДЕУ

Аннотация: мақалада құрылымы белгілі желдетілетін шанақтар мен астықты едендік белсенді желдету қондырғыларының кемшіліктерін негіздеу және қондырғылардың ауа таратқыш каналдарының тиімді құрылымын іріктеу арқылы үймедегі астықты белсенді желдету процесінің технологиялық тиімділігін көтеру мәселесі қарастырылған. Сиымдылықтардағы (шанақтар, силостар) астықты белсенді желдету тәсілдеріне талдау жүргізіліп, дән массасын еден үстінде және сиымдылықтарда белсенді желдетуге арналған қондырғылардың құрылымдарына байланысты принциптік кемшілігі анықталды. Дәнді тұрақты сақтауға арналған белгілі желдетілетін шанақтар мен астықты едендік белсенді желдету қондырғыларының технологиялық тиімділігін бағалау үшін эксперименттік зерттеу жүргізілді. Эксперименттік зерттеу нәтижелерін талдау негізінде дән үймесінің ішінде әркелкі температуралық өріс пайда болуы себебі жарияланды. Үймедегі дәнді желдету тиімділігінің төмендігі ауа ағынының (жұмысшы агент) дәнаралық кеңістікке бірқалыпты таралмауына байланысты. Желдетілетін шанақтардың сәйкес қолданымды қондырғыларының ауа тарату каналдарының пішіні цилиндрлік болуы, ауа ағынының үймедегі дәнаралық кеңістікте бірқалыпты таралмауының басты себебі болып табылады. Желдету қондырғысының ауа тарату каналының тиімді құрылымын іріктеу барысында тұтас орта, мысалы, ауа ағыны үшін зат массасының сақтау заңдылығы басшылыққа алынбаған. Дәнді белсенді желдету қондырғысының құрылымы тиімді іріктелген желдету шанағы ұсынылды. Бұл желдету шанағының белгілі құрылымдардан принциптік ерекшелігі дән үймесінде ауа ағынын бірқалыпты тарату тәсіліне негізделген. Шанақ ішінде дәнді белсенді желдету қондырғысы ауа ағынығ үйме ішіне айдауға және желдету тәсілімен дәнді кептіру қарастырылған жағдайда буланған ылғалды ауамен бірге сорып әкетуге арналған екі каналдан тұрады. Ауа тарату каналдарының құрылымын ұзындығы бойынша кеңістіктегі спираль түрінде орындау нәтижесінде буланған ылғалдың дәннің шеткі қабаттарында салқындап конденсациялануының алдын алады. Зат массасының сақталу заңдылығы ауа тарату каналдарының конустық пішіні есебінен орындалып, нәтижесінде дәнаралық кеңістікте біркелкі температуралық өріс пайда болып, бірқалыпты ылғалдылық сақталады.

Түйін сөздер: қондырғы, шанақ, астық, сақтау, белсенді желдету, кептіру, ылғалдылық, температура, дәнаралық кеңістік, дән үймесі, ауа, тарату каналдары.

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ОБОСНОВАНИЕ ВОЗМОЖНОСТИ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ВЕНТИЛИРОВАНИЯ ЗЕРНА В НАСЫПИ

Аннотация: рассмотрен вопрос повышения технологической эффективности процесса активного ветилирования зерна в насыпи путем обоснования недостатков существующих вентилируемых бункеров и напольных установок для вентилирования зерна и выбора рациональной конструкции воздухораспределительных каналов. Сделан анализ по способам активного вентилирования зернистых продуктов в емкостях (бункерах, силосах) и выявлен существенный недостаток в конструкции установок для вентилирования зерна при напольном и бункерном хранении. Проведено экспериментальное исследования для оценки технологической эффективности существующих установок для активного вентилирования зерна в насыпи при стационарном хранении. В результате анализа полученных результатов экспериментального исследования была выявлена причина неоднородного температурного поля внутри зерновой насыпи. Причина низкой эффективности процесса вентилирования зерна в насыпи связана с неравномерным распределением воздушного потока (рабочего агента) в межзерновом пространстве. В известных вентилируемых

бункерах с установкой соответствующего назначения воздухораспределительные каналы имеют цилиндрическую форму, что является существенной причиной неравномерного распределения воздушного потока в межзерновом пространстве насыпи. При выборе рациональной конструкции воздухораспределительного канала установки не учитывалась необходимость соблюдения закона сохранения массы для сплошной среды, например, воздушного потока. Предложен вентилируемый бункер с рациональной конструкцией установки для активного вентилирования зерна. Принципиальное отличие этого бункера от существующих заключается в способе равномерного распределения воздушного потока внутри зерновой насыпи. Установка для активного вентилирования зерна в бункере включает два канала, предназначенные для нагнетания воздуха в насыпь и удаления отработанного воздуха вместе с испарившейся влагой при сушке зерна способом активного вентилирования. Выполнение конструкции воздушных каналов по их длине в виде пространственной спирали устраняет конденсацию испаряемой влаги в наружных слоях зерновой насыпи. Закон сохранения массы соблюдается за счет конусообразной конструкции воздухораспределительных каналов, в результате чего в межзерновом пространстве насыпи создается однородное температурное поле и влажность.

Ключевые слова: установка, бункер, зерно, хранение, активная вентиляция, сушка, влажность, температура, межзерновое пространство, насыпь зерна, воздух, каналы распределения.

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www:nauka-nanrk.kz

ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

http://reports-science.kz/index.php/en/archive

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *В.С. Зикирбаевой*

Подписано в печать 15.08.2021.
Формат 60х881/8. Бумага офсетная. Печать - ризограф.
8,5 п.л. Тираж 300. Заказ 4.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19