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Jalolitdin Pakhritdinovich Mukhitdinov
Tashkent State Technical University, Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan

Elyorbek Xasanovich Safarov
Tashkent State Technical University, Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan, E-mail: elyorbeksafarov7@gmail.com., elyorbeksafarov7@gmail.com

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REVIEWING TECHNOLOGIES AND DEVICES FOR DRYING GRAIN AND OILSEEDS

Mukhitdinov Jalolitdin Pakhritdinovich[1], Safarov Elyorbek Xasanovich[2]

[1,2]Tashkent State Technical University, Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan,
E-mail: [1]elyorbeksafarov7@gmail.com.

Abstract: *The article analyzes the operation of the most commonly used dryers for drying sunflowers and other agricultural cereals. Based on the study of drying technology and methods, the advantages and disadvantages of dryers have been analyzed, the results of comparisons of their technical indicators have been presented in tabular form. In the form of a diagram, an analysis of foreign and domestic patent data obtained over the past 10 years for the considered drying devices was presented. The choice of the most suitable installation was carried out on the basis of the compiled analytical table. In order to improve the quality, intensity, efficiency of drying and reduce the cost of the process, recommendations have been developed for a new installation that takes into account the disadvantages of the selected dryer.*
Keywords: *sunflower seeds, grain dryer overview, drying.*

Аннотация: *Дон, кунгабоқар ва бошқа қишлоқ хўжалиги маҳсулотларини қуритишда кенг қўлланиладиган қуритиш қурилмалари ишлашининг тахлили келтирилган. Қуритиш технологиялари ва усулларини ўрганиш асосида қуриткичларнинг афзаллик ва камчиликлари таҳлил қилинган, техник кўрсаткичларининг қиёслаш натижалари жадвал кўринишида кўрсатилган. Кўриб чиқилган қуритиш қурилмалари бўйича охирги 10 йилликда ҳориж ва мамлакатимизда олинган патент маълумотларнинг тахлили диаграммалар кўринишида тақдим этилган. Тузилган аналитик жадвал асосида энг маъқул бўлганин қурилма танланган. Танлаб олинган қуриткичнинг камчиликларини инобатга оладиган қуритиш сифатини, жадаллигини, унумдорлигини ошириш ҳамда қуритиш ҳаражатлари ва нархини камайтириш мақсадида янги қурилма бўйича таклифлар келтирилган.*
Таянч сўзлар: *кунгабоқар донлари, дон қуриткичлар таҳлили, қуритиш.*

Аннотация: *Проведен анализ функционирования наиболее часто используемых сушильных аппаратов для сушки зерновых, подсолнечника и других продуктов сельского хозяйства. На основе изучения технологии и способов сушки проанализированы достоинства и недостатки сушилок, в табличной форме представлены результаты сравнений их технических показателей. В виде диаграммы представлен анализ зарубежных и отечественных патентных данных, полученных за последние 10 лет на рассматриваемые сушильные устройства. Выбор наиболее подходящей установки осуществлен на основе составленной аналитической таблицы. В целях повышения качества, интенсивности, эффективности сушки и снижения себестоимости процесса разработаны рекомендации по новой установке, учитывающей недостатки выбранной сушилки.*
Ключевые слова: *семена подсолнечника, обзор зерносушилок, сушка.*

1. Introduction

Sunflower is one of the most widely grown oilseeds grown in many countries of the world [1]. Sunflower seeds contain minerals, vitamins and many useful chemical elements necessary for human health [2]. It was discovered [3] that even sunflower pods contain useful chemicals. Therefore, a lot of work has been done on sunflower cultivation, creating high-yielding varieties[4-6].

Oil-bearing sunflower seeds, after harvesting from the fields, are characterized by low flowability, high humidity, and low mechanical strength of the husk. Sunflower seed, in contrast to cereals, consists of a kernel and two shells (fruit and seed), in addition, it is distinguished by its heterogeneity in size, and therefore the difference in mass and moisture. The seeds are also distinguished by low strength of the fruit shell, moisture inertia, low thermal conductivity. [7-12].

The moisture content of harvested sunflower seeds can be from 15% to 50%. Timely drying is necessary to preserve the sunflower seeds quality and prevent irreversible physical and chemical changes in the grain [13].

The distinctive feature of freshly harvested oilseeds and, in particular, sunflower seeds is their increased instability during storage. One of the main ways to prepare oilseeds for long-term storage, which is the most important factor affecting the energy consumption and processing quality of oil-bearing seeds is drying. The purpose of drying is to process the initial raw material into an industrial material with improved biological, physical, chemical and mechanical properties [14-15]. However, the structure of sunflower seeds during drying requires distinctive thermo-humidity conditions and modes. Due to the lack of scientific or practically grounded recommendations on modes and conditions for drying sunflower seeds, grain dryers are used.

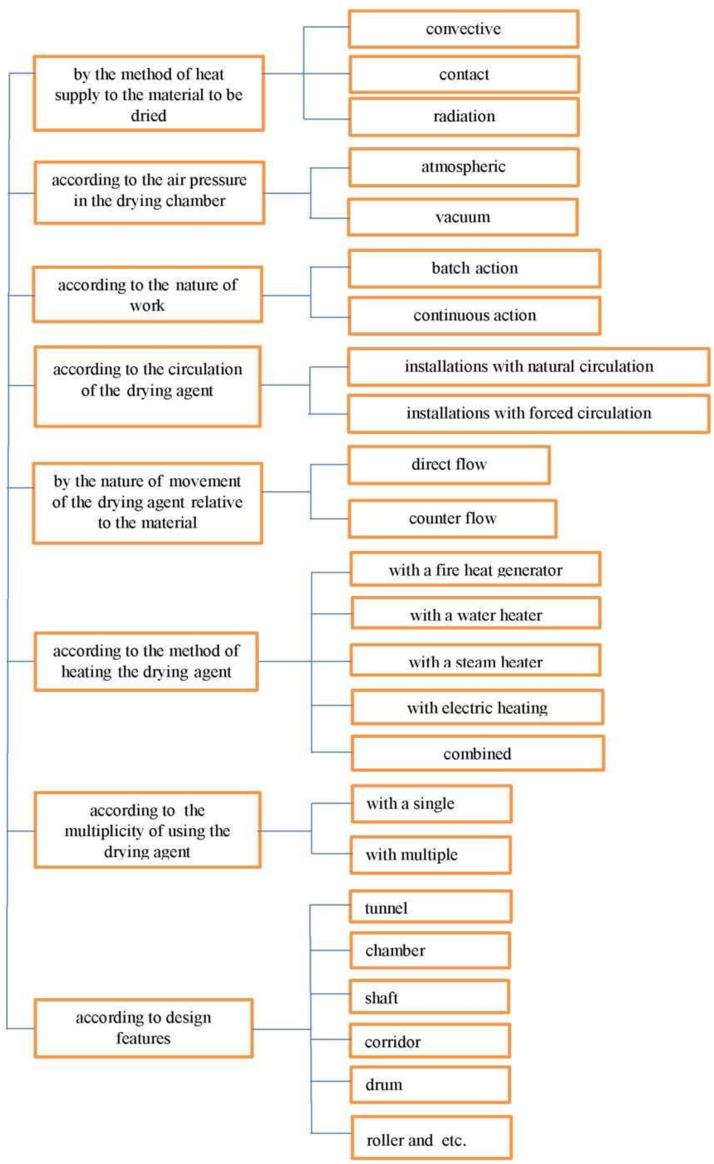

Fig. 1. ***Dryer classification.***

The uniformity of dried seeds, other things being equal, predetermines the duration of storage without self-heating and other undesirable effects [16-17]. Additional losses during storage of raw materials, which do not allow its comprehensive processing, can be attributed to weak logistics and infrastructure. Therefore, the creation of new, or modernization or processing of existing grain dryers for drying sunflower seeds in order to supply high-quality, biologically complete, environmentally friendly, capable of maintaining the organoleptic, nutritional and sowing qualities of seeds, with the rational use of fuel and energy potential is an urgent scientific problem. These indicators largely depend on the quality of heat treatment [18-19]. At the same time, the task should be solved not only to improve the quality of the final product, but also to increase the productivity of the devices, their versatility and reduce the cost of production.

A large variety of materials which are dried, requiring a detailed study of the properties of each, necessary for the proper selection of a drying plant and drying technology. Currently, there are a large number of different drying technologies and apparatuses for each of them [20], which makes a comparative analysis and, moreover, their description very difficult.

2. Main part.

Modern drying installations can be classified according to the characteristics shown in Figure 1 [21 p. 583-584, 22 p. 41-43, 23 p. 7-13].

The state of the grain layer, which affects the main patterns in the drying process in the layer, determines the main characteristic of the drying installation.

In the convective drying method, the moisture contained in the material to be dried moves from the core towards the surface of the material (moisture conductivity), washed by heated air, which transfers its heat to the material to be dried and creates a temperature gradient. Under the influence of this gradient, moisture moves in the direction of the heat flow (thermal and moisture conductivity). Regardless of the drying method, the directions of moisture movement can either coincide (thermal and moisture conductivity will intensify the evaporation process), or thermal moisture conductivity will resist the evaporation of moisture from the material [21 p. 611-613]. Only under the condition that the surface temperature of the material to be dried is less than the temperature in the core of the material, it is possible for the direction of moisture movement to coincide.

2.1. Methods and technologies for drying grains and oilseeds

1. Mine dryers.

Mine dryers vertical version (Fig. 2), where the drying process takes place in a dense, slowly descending in a gravitational field layer of seeds, flowing on its way traffic arranged in staggered order horizontal boxes, which fed and removed from the drying agent intended for drying of bulk materials [24-25.].

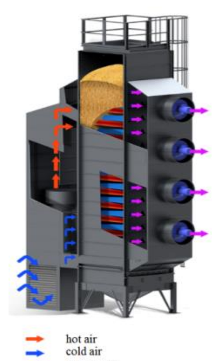

Fig. 2. ***General view of the mine dryer.***

A distinctive feature of this type dryers is the design simplicity, high productivity, ease of use [26-27.]. Installations are of both stationary and mobile types [28].

There are a fairly large number of types of these dryers, subdivided into direct-flow and recirculation [22 *p. 50*].

The disadvantage of this type of dryers, which is the uneven heating of the material being dried, a significant effect on seed performance and high metal consumption, the possibility of gas losing its properties as a drying agent as it moves through the material layer due to its saturation with moisture [29], the impossibility of uniform washing of each grain due to the uneven movement of gas and grain, leading to uneven drying [30]. In addition, it can be noted the need for thorough cleaning of the grain before drying, the cleaning complexity the unit from blockages, the need to re-dry seeds with high humidity [27,31].

There are a number of inventions and patents [32-35], which deal with increasing the efficiency of installations of this type. Thus, in operation [36] it is proposed to use the lower working chamber of the dryer as an additional drying zone during grain cooling in cooling columns. At that, increase of grain dryer efficiency is provided by possibility of switching flows of drying agent providing operation of its lower chamber in two modes of grain cooling: in the first mode there is suction from the chamber collector of spent refrigerant with recovery of heat contained in it or in the second mode - with delivery of external air to its collector. In [37], the drying quality of loose materials is proposed to be improved by reducing the non-uniformity of drying achieved by dividing the material flow before inversion into two parts, mechanically mixing it and adjusting the speed of gravitational movement. In [38], the disadvantage of the apparatus described in [39] is proposed, which consists in the fact that the apparatus has impressive overall dimensions, the shaft-modular design does not ensure heating uniformity and grain cooling, there are significant specific energy costs, environmental pollution due to the release of the drying agent into the environment should be eliminated by perforating the outer walls of grain channels, installing an external housing for recirculation of spent coolant, and installing cyclones for cleaning heat carriers, after which, the fluxes of spent heat carriers will be returned to the drying and cooling zones, respectively, to form recirculation circuits, thereby reducing energy costs. In [40], a method of increasing productivity is proposed by connecting alternating rows of supply boxes with an open end surface with a supply chamber, and outlet boxes with a discharge box located on the opposite side of the drying chamber, reducing the dimensions of the grain dryer by reducing the height of the bucket elevators, increasing the stability of the mine grain dryer, as well as reducing installation costs. In [41], energy saving and more complete exhaustion of the coolant is achieved by equipping the unit with an internal separating cylinder, a movable regulating cylinder and a movable ring.

The analysis of the mine type dryers shows that this type dryer is continuously being improved. However, the main disadvantages inherent in this type of installation still remain:

- the need to re-dry seeds with high humidity;
- uneven heating of the grain layer;
- the possibility of gas losing its properties as a drying agent as it moves through the layer of material due to its saturation with moisture;
- uneven drying due to uneven movement of gas and grain;
- the need for thorough cleaning of grain before drying;
- a decrease in the seed quality of grain;
- large dimensions;
- high metal content, etc.

2. Conveyor dryer. Conveyor dryers are the conveyor chambers, with conveyors located inside (Figure 3.). The dryers are equipped with ventilation equipment. The product is dried in them continuously at atmospheric pressure. The drying agent is clean air heated in steam or fire heaters. In this

case, the air movement can be organized in the form of a counterflow or crossflow to the direction of the material to be dried. The air temperature depends on the product type to be dried and its initial moisture content. A layer of wet material fed to one end of the belt moves along the belt, the dried layer is removed from the opposite end of the belt. There are also multi-level conveyor dryers, in which grain is poured from one belt to another for more uniform drying.

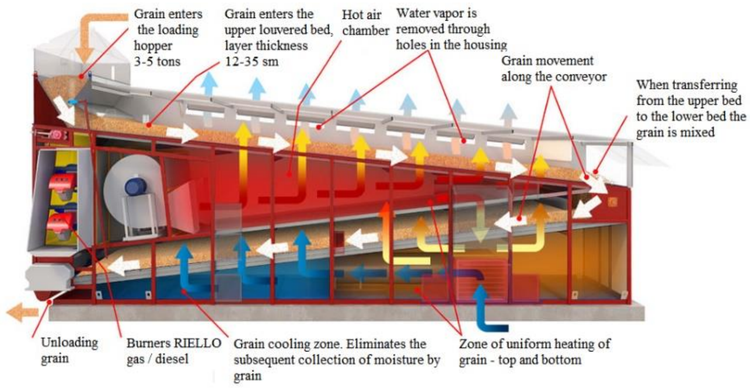

Fig. 3. ***Conveyor grain dryer diagram.***

Conveyor dryers in comparison with mine dryers have a number of advantages: the ability to dry various materials with different sizes, the ability to mix layers of grain during the drying process, the design of the dryer allows visual observation of the drying process and its stabilization. However, they are bulky, have low productivity and high specific heat consumption, distortions and stretching of the belts make maintenance difficult.

In the literature, there are the results of studies aimed at improving the performance of dryers of this type. In [42], in order to reduce the specific heat consumption in the apparatus, a hopper dispenser is installed, in the drying zone - infrared radiator with an automatic radiation power control system, an automatic control system of the drying process is provided. In the drying zone, there is a duct with a fan that supplies heated air from the drying zone. In operation [43], the drying chamber is divided into drying, cooling and drying zones, the dryer is equipped with two IR radiators, a system for automatic control of radiation power depending on the moisture content of the material, humidity and temperature sensors, a hopper-dispenser and a mechanism for adjusting the thickness of the layer of loose material. In [44], in order to increase drying efficiency, the drying unit is supplemented by a conveyor with heat fans installed along it with permanent magnets installed on different sides of the fan blades symmetrically to each other.

On the basis of research aimed at improving the drying process in this type apparatus, mathematical models have been created that allow predicting the required temperature regime of drying depending on the initial humidity and thickness of the dried grain layer and the intelligent control system of the drying plant [45-47]. Despite certain changes aimed at improving the efficiency of this type dryer, these disadvantages still persist.

3. Fluidized bed dryer is a progressive type of dryers with intensive mixing of material, accelerated heat and mass transfer, allowing a significant increase in the heat and mass transfer surface between the material particles and the drying agent.

Drying in a fluidized bed significantly reduces the drying time due to the moisture evaporation intensification from the material. Modernization of devices of this type can reduce energy consumption for drying while increasing the amount of moisture removed per unit volume of the drying chamber of the device. Dryers of this type differ in the number of chambers, process mode, drying chamber configuration, hydrodynamic mode [21 p. 620-622]. The most common is a single-chamber type of fluidized bed dryer (Figure 4), consisting of a receiving hopper (1) with a feeder (2), a drying chamber (3), inside which there is a grate for gas distribution, a mixing chamber (6) and a cyclone (10). The dried material is discharged through the nozzle (8).

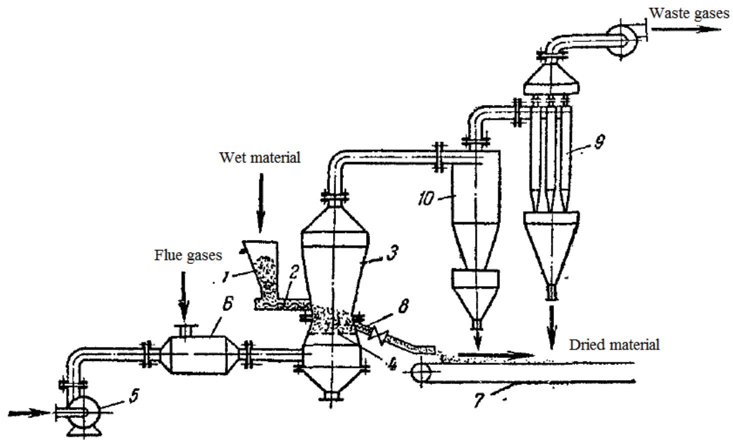

Fig. 4. ***Single chamber fluid bed dryer.***
1-hopper; 2- bulk material feeder; 3- drying chamber; 4-gas distribution grid; 5- air fan; 6-mixing chamber; 7- conveyor; 8-nozzle for unloading dried material; 9-battery dust collector; 10-cyclone.

Dryers of this type come with failed and wireless grids. In industry, a second type of grating is more commonly used, allowing too large or sticky pieces that are not fluidizable at the selected gas flow rate to be automatically removed from the granular material.

The high speed of the drying process provides moisture removal from 1m^2 of the gas distribution grid from 500 to 3000 kg/(m^2·h). The moisture removal volume is determined by the material particles size and the temperature regime of drying.

The advantage of this type dryers is the possibility of material regulation time, calculated by the formula: $\tau_{av} = G_{lw} / G_{dp.}$, here $G_{сл}$ - layer weight, $G_{в.м.}$ - dryer performance. The average residence time of a material in a layer depends on the layer height, which determines it’s mass.

In fluidized bed dryers, the operating parameters of the material particles to be dried can influence the heat transfer coefficient. For example, if changing the diameter and height of the fluidized bed has no effect on the thermal conductivity coefficient, then increasing the fluidized bed temperature leads to an increase in the thermal conductivity coefficient of small particles, and for large particles, this coefficient decreases [48].

Combination dryers are also available to improve the efficiency of fluidized bed dryers. For example, in works [49-50] the issue of accelerating the moisture diffusion process from a material with an increase in the power of a microwave oven used as a preliminary dryer is studied using a mathematical model.

In the article [51], using neural networks, a mathematical model was developed that allows predicting the result of drying various oil-containing materials. Perhaps this model can also be used to study the drying process of sunflower seeds.

There are a number of patent studies [52-55] with proposals for improving apparatus designs and drying technology, aimed ultimately at reducing drying energy costs.

Due to this type specifics of drying (heated air washing the material particles and moving vertically from bottom to top, balances the gravitational forces acting on the material particles), the entire surface of the particles is the evaporation area. This is an argument for reducing the energy consumption of the process in comparison with the drying types described above. However, the heat process and mass transfer between the outer surface of the particles and the area around the core corresponds to typical convective drying.

At the beginning of drying, the interaction between the material particles and the hot air is quite efficient, the process proceeds at a fairly high speed, with low energy consumption. However, as the particles of the material dry out, its thermal and mass conductivity decreases, the amount of energy penetrating deep into the interior decreases, most of it is re-emitted into space, which leads to a sharp drop in the drying speed, a multiple increase in energy consumption, an increase in the drying time, local overheating of the surface layers of the product is possible, leading to a decrease in product quality. The evaporation rate of the material can be determined by the partial pressure ratio in the environment h, the partial pressure of the saturated steam in the boundary layer H and the total pressure by the formula:

$$\frac{1}{S} \cdot \frac{d\chi}{dt} \approx \frac{H-h}{B}, \tag{1}$$

here S – evaporation surface, dx/dt – evaporation rate, B – total barometric pressure.

The evaporation rate depends on the viscosity and other parameters of the air [56].

4. Pneumatic dryer. Pneumatic dryers are used to dry granular, fine, crystallineand fibrous materials. In these installations, the drying process takes place at a highintensity. The pneumatic dryer (Figure 5) consists of a vertically arranged pipe (up to 25 meters), a hopper 1 with a feeder 2 for the material to be dried. The dried material moves due to the air flow created by the fan 3. The drying material is heated in the heater 5. The dried material is unloaded through the unloading device 7.

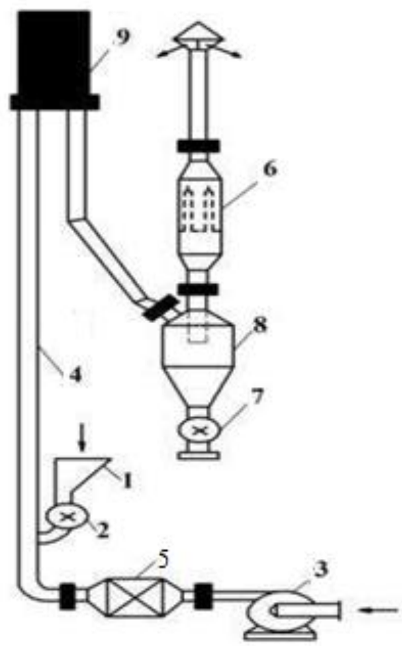

Fig. 5. Pneumatic dryer.

1- hopper; 2- bulk material feeder; 3-air fan; 4- drying pipe; 5-electric heater; 6-exhaust air filter; 7-unloading device; 8-cyclone; 9-collection.

Particles of the material to be dried move in a stream of heated air at a speed (from 10 to 30 m/s) exceeding the hovering speed. Therefore, in dryers of this type, the residence time of the material is seconds. More than 50% of all moisture is removed on the 1/5th of the pipe, mostly surface moisture is removed, and the driving force of the process also changes dramatically, the temperature of the coolant drops rapidly. In addition, the drying process is influenced by a change in the diameter ratio of the dryer pipe to the diameter of the material particles D/d: with an increase in the pipe diameter, the velocity of the gas and material particles decreases, and with an increase in the particles diameter, their moisture content increases [21 p. 624, 57].

Combined dryers, such as pneumatic conveyors, are used to remove moisture from materials with large particles and bound moisture, which increase production productivity [58]. Detailed information about this type dryers, how the drying process proceeds in them, and information about the physical parameters characterizing the process is given in detail in the article [59].

Pneumatic dryers are compact, simple design and operating principle, but the rapid deterioration of the dryer material, the need for periodic cleaning of the dryer bottom, high energy consumption and other shortcomings inherent in the convection drying, limits the scope of pneumatic dryers.

5. Heliodryer.

Drying agricultural products outdoors requires constant mixing of the material from the human side. The impossibility of organizing drying at a constant temperature leads to uneven and incomplete drying of the product, its spoilage and large losses. All this is an argument for the creation of special types of dryers based on the use of solar energy.

The climatic features of the area, the type of material to be dried and the cost of additional energy determine the choice of the drying method. The heat from the drying agent to the material can be supplied by a convective method (convective dryers), where the material to be dried is exposed to solar-heated air, or by radiation (radiation dryers), where the material is exposed to sunlight. The temperature in heliodryers can reach 60...75°C. Combined heliodryers can be used using both types of heat transfer, but, as a rule, with a predominance of convective heat transfer. Solar dryers are subdivided into dryers with direct and indirect action of the absorbed solar energy on the material to be dried. In the first case (Figure 6), solar energy is absorbed directly by the product placed in chamber 4, and by the walls of this chamber [60].

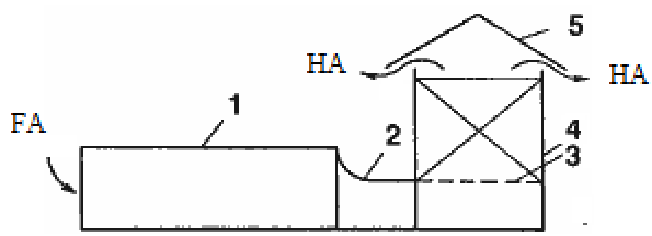

Fig. 6. Solar dryer with foil heater:
1 – foil air heater; 2 - air duct; 3 - grid; 4 - drying chamber; 5 - visor; FA and HA - fresh and humid air.

Upper and southern side parts of chamber are covered with translucent insulating material, holes are made for air entry into chamber heat insulation, and platform for material placement is perforated. The humid air from the solar dryer is removed through the holes made in the upper part of the cold wall. In the second case, solar dryers can contain a chamber or tunnel structure. In the chamber heliodryer material is placed on mesh pallets, air blows material, moving from below-up, and in tunnel dryers the dried-up material moves on the conveyer belt to a countercurrent to air. There are a number of studies [61-63] devoted to the modernization of solar dryers. Drying efficiency as a result of using installations of this type is increased [64], drying time is reduced, quality of dried material is increased, however, their utilization rate is very low (depending on the climatic conditions of the area, such dryers can be used for only a few weeks a year).

6. Thermoradiation dryers. Due to the supply of significant heat fluxes of infrared radiation to the material in installations of this type, an increase in the intensity of moisture evaporation from the material to be dried is achieved. Drying takes place in a thick layer of material. In this case, the main factor is the rate of internal diffusion of moisture and high requirements for the quality of the dried material. [21 p. 628].

At the initial time of drying under the influence of a high temperature gradient, it coincides with the moisture movement direction, that is, moisture moves from the periphery deep into the material. After a while, the moisture gradient begins to prevail and the direction of moisture movement changes to the opposite. With the onset of this moment, moisture evaporates from the material. As a consequence of the above, thermo-radiation drying is preferably used for drying thin-layer materials.

Dryers with infrared emitters are equipped with energy sources obtained by electric current (resistance elements, electric spirals, etc.) or by burning natural gas. For more information about this, see [48 p. 450-463]. Such devices provide greater uniformity of drying, but the complexity of the constituent elements, the high frequency of failure, are the reason for the high cost and limited use of these dryers.

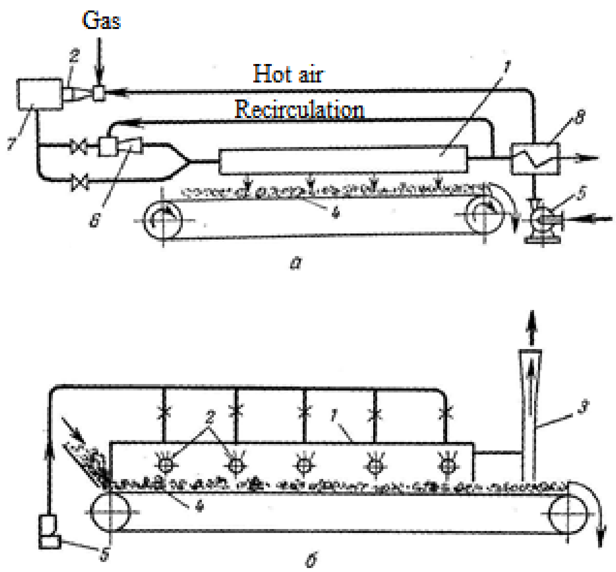

Fig. 7. ***Gas-fired thermo-radiation dryers:***
a - products of gas combustion; b - open flame; 1 - radiating panel; 2 - gas burner; 3 - exhaust pipe; 4 - conveyor on which the material to be dried is located; 5 - fan; 6 - ejector; 7– combustion chamber; 8 - air heater.

Today, in order to increase efficiency, reduce drying time and reduce energy consumption, special attention is paid to installations using infrared dryers as an additional source of energy. The positive effect of infrared radiation on the dried material is also confirmed by model studies. Research results show high efficiency and widespread use of IR dryers in conjunction with convective dryers [65-67]. However, the condition of the need to select the IR radiation wavelength depending on the type and initial moisture content of the material requires an even greater number of studies.

7. Drum dryer.

The most widely used for grain drying are drum dryers, constructed of three parts that make up their basis - a drum, a firebox and a cooling chamber (Fig. 8).

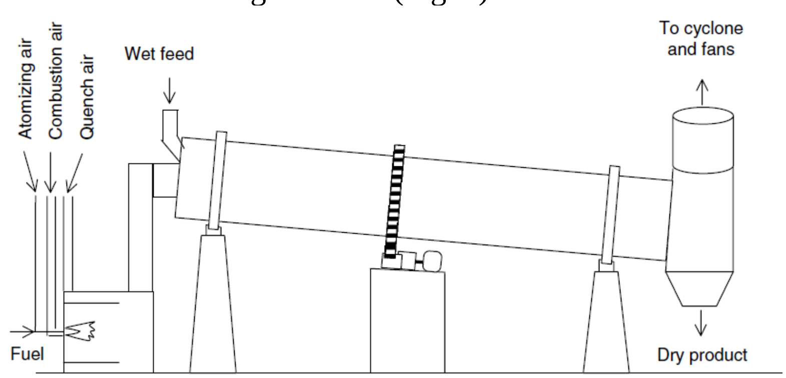

Fig. 8. ***Drum dryer.***

Dryers of this type can be made in one pipe form or a plurality of pipes inserted into one another. The drum axis, equipped with metal plates, moves the grain upward in a spiral. The spiral is at an angle of up to 6 ° relative to the horizontal. With the direct flow of the material to be dried, the drying agent moves along the drum at a speed of 2-3 m / s. The grain, dried to a certain moisture content, is automatically rolled into the cooling chamber. The rotation speed of the drum (on average from 1 to 8 per minute) is determined by its inclination angle and the residence time (15-20 minutes) of the food grain in the machine, at the same time, the drying gas temperature is recommended to be maintained within 180-250°C [68-69].

The advantage of drum dryers is:

- compactness, simplicity and the possibility of using it as a mobile unit;
- high speed, productivity and uniformity of drying;
- cost-effectiveness and financial benefits.

In the literature there is a lot of information about the improvement of the design and drying technologies of drum dryers in order to increase their efficiency [70-80], however, the disadvantage of dryers of this type is the impossibility of obtaining seeds with high rates of germination of seed grain, regulation of the drying time of grain and the speed of its movement.

2.2. Comparative analysis of grain and oilseed drying devices

There are many dryers for drying grain and oilseeds harvested in agriculture, which also differ from each other in their technical characteristics. Comparative technical characteristics of the above grain dryers are given in Table 1.

Table 1.

Comparative technical characteristics of grain dryers

Name and technical characteristics of devices	Mine dryer ДСП-32	Conveyor dryer ASM-AGRO-34	Dryer with fluidized bed СКС-1,5-1000Б	Pneumatic dryer JG1000	Heliodryer	IR ray dryer Sahara-12	Drum dryer СЗСБ-8
Performance, (kg/h)	32000	34000	4500	1500	80	500	8000
Installed capacity, kW	125	91	40	78	0,2	36	28,2
Evaporation capacity (kg/h)	2300	2500	3000	1000	30	30	560
Drying agent temperature, ^{0}C	50÷160	125	190	150÷600	50 ÷ 60	30÷50	140 ÷ 160
Grain heating temperature, ^{0}C	45	50	65	55	35	45	45
Weight, t	32,6	15	10,8	5	0,5	2,4	8,3
Service life, years	10	20	10	10	10	15	15
Fire safety and fire protection	depends on the grain type	+	+	–	+	+	depends on the grain type

Symbol designations in the table: - fire-dangerous, + fire-proof.

Scientific developments regarding dryers over the past decade are analyzed by comparing patents for inventions formed in patent databases of Russia, the United States and Ukraine. The analysis results are shown in Figure 9.

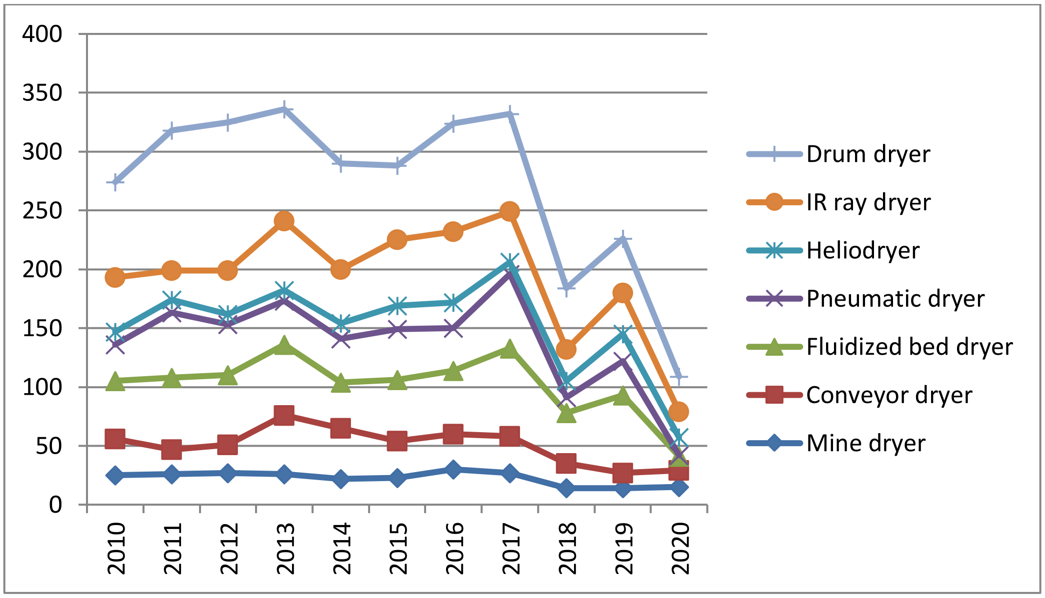

Fig. 9. ***Chart of patents comparison of drying devices based on patent bases of the countries of Russia, USA and Ukraine.***

The comparison results of scientific and patent studies conducted by researchers in Uzbekistan are presented in the following figure.

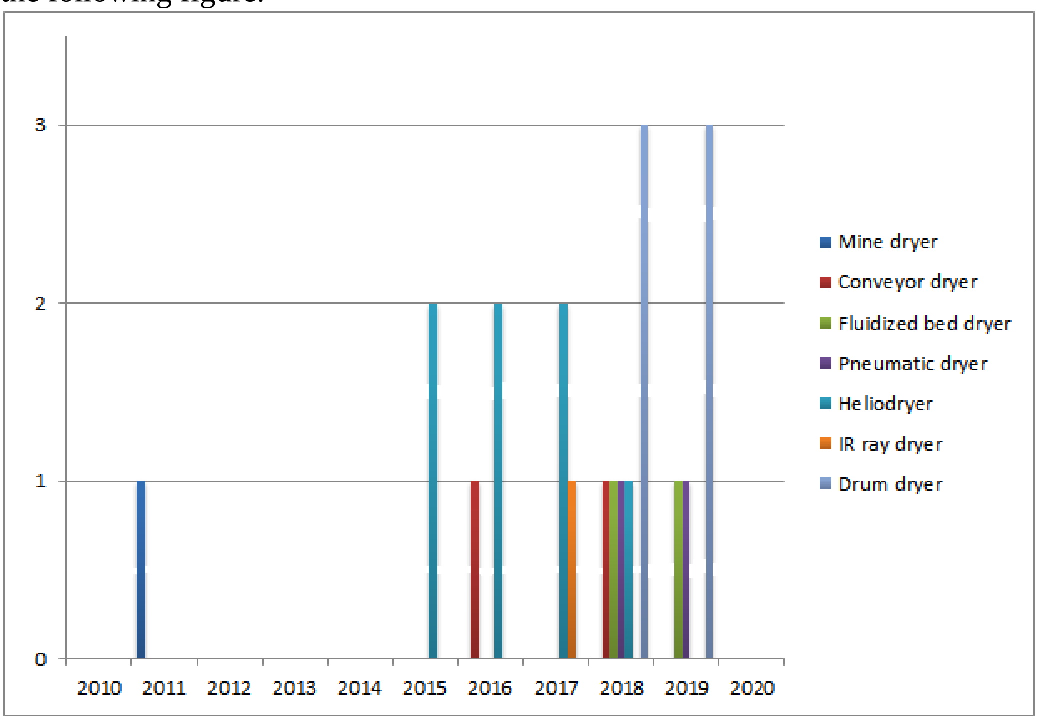

Fig. 10. ***Chart comparing patents of drying devices based on the patent database of Uzbekistan.***

The analysis of the devices indicators for drying grain and oilseeds showed that all of them have both advantages and disadvantages. In order to select the main type of dryer and to create an installation based on it that meets all the requirements for drying grain and oilseeds, the obtained information is summarized in Table 2.

Table 2.

Comparative propertiess of grain dryers

Name and properties of the device	Mobility capability	Versatility	Possibility to combine dryer	The ability to fully automate the drying process	Ability to dry grain and oilseed types of bulk materials	Possibility to use as main dryer	Methods of heating the dried material		
							Convective	Contact	Radiant
Mine dryer	+	–	+	+	–	+	+	–	–
Conveyor dryer	+	–	+	+	+	+	+	–	+
Dryer with fluidized bed	+	–	–	–	–	+	+	–	+
Pneumatic dryer	+	–	+	–	–	–	+	–	–
Solar dryer	+	–	+	–	–	–	+	+	+
Infrared ray dryer	+	–	+	+	+	–	+	+	+
Drum dryer	+	+	+	+	+	+	+	+	+

Symbols in the table: – unsupported, + supported.

From the above analysis, it can be seen that the most fully meeting the requirements of the dryer type is a drum dryer. However, the existing dryers of this type also do not fully meet the modernity requirements.

3. Conclusion

The results of the dryer analysis show that to prevent the existing disadvantages and create a new modern dryer, it is advisable to use the individual advantages of other dryers. To improve the quality, intensity, productivity and reduce the cost of the drying process, the drying installation, in our opinion, it should be a mobile aerodynamic solar dryer using a drum with a rotating channel nozzle with reflectors that focus the solar radiation on the drum, a solar collector designed for preheating the air, an electric heater that heats the air from the solar collector and a device that directs the heated air to create a boiling layer.

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