Reviewing technologies and devices for drying grain and oilseeds

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Sunflowers are one of the most widely grown oilseeds in several countries. Oil-bearing sunflower seeds, after harvesting, are characterised by low flowability, high humidity and low mechanical strength of the husk. Sunflower seed is distinguished by its heterogeneity in size, meaning the difference in mass and moisture.

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

The distinctive feature of freshly harvested oilseeds, particularly 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.

Purpose of drying

The purpose of drying is to process the initial raw material into an industrial material with improved biological, physical, chemical and mechanical properties. However, the structure of specifically sunflower seeds during drying, requires distinctive thermo-humidity conditions and modes. Therefore, grain dryers are used.

The uniformity of dried seeds predetermines the duration of storage without self-heating or other undesirable effects. Additional losses during storage of raw materials can be attributed to weak logistics and infrastructure. Therefore, the creation of new – or modernisation or processing of existing grain dryers to supply high-quality, biologically complete, environmentally friendly, capable of maintaining the organoleptic, nutritional, and sowing qualities of seeds – require urgent attention.

These indicators largely depend on the quality of heat treatment. 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 to reduce the cost of production.

A large variety of materials which are dried are necessary for the proper selection of a drying plant and drying technology. Currently, there are many different drying technologies and apparatuses for each of them, which makes a comparative analysis very difficult.

Drying processes

Modern drying installations can be classified according to a number of characteristics. The state of the grain layer, which affects the main patterns in the drying process, 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, 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. Regardless of the drying method, the directions of moisture movement can either coincide, or thermal moisture conductivity will resist the evaporation of moisture from the material.

Only under the condition that the surface temperature of the material to be dried is less than the temperature in the core, is it possible for the direction of moisture movement to coincide.

Mine dryers

A distinctive feature of this type of dryer is the design simplicity, high productivity and ease of use. Installations are of both stationary and mobile types. There is a fairly large number of types of these dryers, subdivided into direct flow and recirculation. The disadvantage is the uneven heating of the material being dried, which can have a significant effect on seed performance.

There are several inventions and patents which deal with increasing the efficiency of installations of this type. Thus, in operation it is proposed to use the lower working chamber of the dryer as an additional drying zone during grain cooling.

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. The disadvantage of the apparatus is that the shaft-modular design does not ensure heating uniformity and grain cooling.

There are significant specific energy costs. 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.

Energy saving and more complete

exhaustion of the coolant are 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 it is continuously being improved. However, the main disadvantages inherent in this type of installation remain.

Conveyor dryers

Conveyor dryers are the conveyor chambers with conveyors located inside. The dryers are equipped with ventilation equipment where the product is continuously dried at atmospheric pressure. The drying agent is clean-air heated in steam or fire heaters. In this case, the air movement can be organised in the form of a counter- or crossflow to the direction of the material to be dried.

The air temperature depends on the product type and its initial moisture content. A layer of wet material fed to one end of the belt moves along the belt, and the dried layer is removed from the opposite end of the belt.

In operation, the drying chamber is divided into drying, cooling and drying zones. The dryer is equipped with two infrared 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.

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. Mathematical models have been created to predict 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.

Fluidised bed dryers

This is a progressive type of dryer 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.

Dryers of this type differ in the number of chambers, process mode, drying chamber configuration and hydrodynamic mode. The most common is a single-chamber type of fluidised bed dryer, consisting of a receiving hopper with a feeder, and a drying chamber inside which there is a grate for gas distribution, a mixing chamber, and a cyclone. The dried material is discharged through the nozzle.

There are several patent studies with proposals for improving apparatus designs and drying technology, ultimately aimed at reducing drying energy costs. Due to the type of specifics of drying, the entire surface of the particles is the evaporation area.

> 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 to reduce the cost of production.

At the beginning of drying, the interaction between the material particles and the hot air is quite efficient and the process proceeds at a high speed with low energy consumption. However, as the particles of the material dry out, its thermal and mass conductivity decrease, and the amount of energy penetrating deep into the interior decreases.

Pneumatic dryers

Pneumatic dryers are used to dry granular, fine, crystalline and fibrous materials. In these installations, the drying process takes place at a high intensity. The pneumatic dryer consists of a vertically arranged pipe, and a hopper with a feeder for the material to be dried. The dried material moves due to the airflow created by the fan. The drying material is heated in the heater and the dried material is unloaded through the unloading device.

Particles of the material to be dried move in a stream of heated air at a speed exceeding the hovering speed. More than 50% of all moisture is removed on the 1/5th of the pipe, and the driving force of the process also changes dramatically.

Pneumatic dryers are compact, have a 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, limit the scope of these dryers.

Heliodryers

Drying agricultural products outdoors requires constant manual mixing. The impossibility of organising 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, where the material to be dried is exposed to solar-heated air or by radiation where the material is exposed to sunlight. The temperature in heliodryers can reach 60 to 75°C.

Combined heliodryers can be used using both types of heat transfer, but with a predominance of convective heat transfer. Solar dryers are sub-divided into dryers with direct and indirect action of the absorbed solar energy on the material to be dried.

The upper and southern side parts of the chamber are covered with translucent insulating material, holes are made for air entry into chamber heat insulation, and the 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.

Thermo-radiation dryers

Due to the supply of significant heat fluxes of infrared radiation to the material in installations of this type of dryer, 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.

At the initial time of drying under the influence of a high temperature gradient, it coincides with the moisture

Table 1: Comparative technical characteristics of grain dryers.

Name and technical characteristics of devices	Mine dryer ДСП-32	Conveyer dryer ASM-AGRO-34	Dryer with fluidised bed СКС1,5-1000Б	Pneumatic dryer JG1000	Heliodryer	Infrared ray dryer Sahara12	Drum dryer СЗСБ-8
Performance (kg/h)	32 000	34 000	4 500	1 500	80	500	8 000
Installed capacity (kW)	125	91	40	78	0,2	36	28,2
Evaporation capacity (kg/h)	2 300	2 500	3 000	1 000	30	30	560
Drying agent temperature (°C)	50 ÷ 160	125	190	150 ÷ 600	50 ÷ 60	30 ÷ 50	140 ÷ 160
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.

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. Because of the above, thermo-radiation drying is preferably used for drying thin-layer materials.

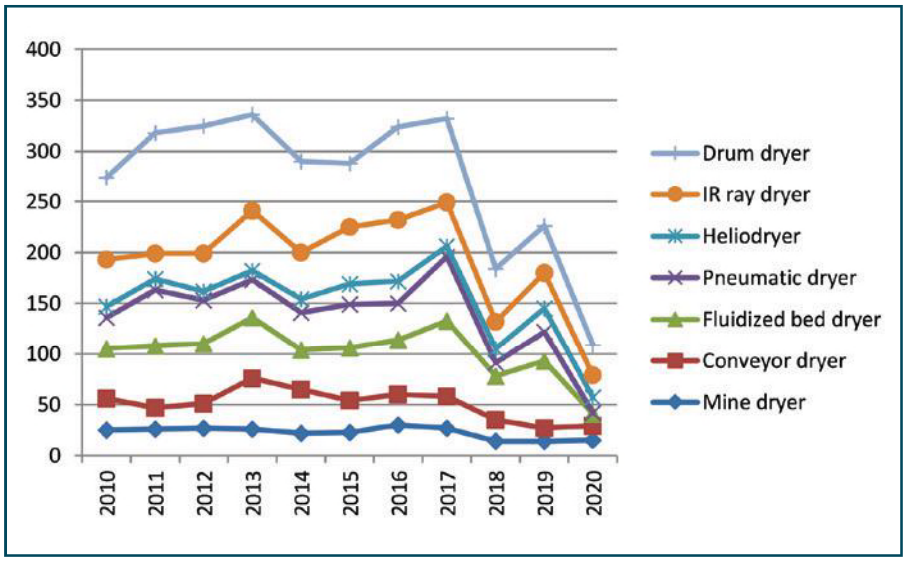
Dryers with infrared emitters are equipped with energy sources obtained by electric current, or by burning natural gas. Such devices provide greater uniformity of drying, but the complexity of the constituent elements and the high frequency of failure are the reasons for the limited use of these dryers. Today, special attention is paid to installations using infrared dryers as an additional source of energy.

Drum dryers

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

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 to 3m/s.

Figure 1: A comparison of drying devices based on patent bases of the countries of Russia, the United States and Ukraine.



The grain, dried to a certain moisture content, is automatically rolled into the cooling chamber. The rotation speed of the drum (on average from one to eight minutes) is determined by its inclination angle and the residence time (15 to 20 minutes) of the food grain in the machine. At the same time, the drying gas temperature is recommended to be maintained within 180 to 250°C.

Comparative analysis of devices

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

Scientific developments regarding dryers over the past decade are analysed by comparing patents for inventions formed in patent databases of Russia, the United States and Ukraine. The analysis results are shown in *Figure 1*.

The analysis of the devices' indicators for drying grain and oilseeds showed that all of them have both advantages and disadvantages. The dryer that meets most of the requirements is a drum dryer. However, the existing dryers of this type also do not fully meet the modernity requirements.

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