EXPERIMENTAL ESTABLISHMENT OF THE PHYSICAL MECHANISM OF THE DRYING PROCESS

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Annotation: In solar dryers (combined systems), a method of convective-conductive drying is provided. With this method of drying, thermal energy is transferred to the grain from heating the web of belt conveyors and with the passage of sunlight through the transparent walls of the additional drying chamber, as a result of which the air in the chamber is heated and the grains are heated by convection.

Keywords: solar dryers, convective, technological, thermal, solar, dryers, energy.

In many countries of the world, including the Republic of Uzbekistan, there are whole state programs of alternative sources of energy production.

Renewable energy sources, especially solar energy, make it possible to replace energy fuel in thermal technological processes.

Humanity has learned to receive energy from the sun in the form of water heaters, devices for heating homes, solar stoves, heating greenhouses, desalination of marine and mineralized waters, electric current, etc. Foreign experiments on the use of solar installations for thermal technological processes can be considered quite wide and can be used to create combined energy supply systems for agricultural production with increased energy efficiency by 1.2-1.3 times. Currently, solar-air methods of drying fruits are widely used, especially fruits that are developed in the south of the United States, the Middle East, Iraq, Turkey, Greece, Morocco, Tunisia, Italy and Russia. They are simple, cheap, but due to the use of lower temperatures compared to artificial drying, it is very long (2-5 weeks), time-consuming and requires large land areas for the fruit drying process.

To speed up the drying process and high-quality production of dried products, there are a number of technological techniques: blanching, peeling of fruits, sulfitation, cutting fruits into slices, etc., the drying method on solar dryers also plays an important role. Especially the use of the radiant energy of the sun is promising for areas where fruit ripening coincides with the period of the greatest solar energy intake. For example, in the Republic of Uzbekistan, fruits ripen in May-September months of the year. During these periods of the year, sunny days reach 110-125 days (for 2019).

The drying chamber consists of shelves in which pallets with serviced products are placed, a backup electric heater, an exhaust pipe and a shut-off valve. The drying chamber and the wooden box are connected by a common duct. The air is heated in the heater section to 60-80 °C and pumped into the drying chamber where the dried products are placed, absorbs moisture from it and, cooling, is removed outside. The authors' conclusion is that in comparison with air-solar drying, the duration of drying fruits and grapes in solar dryers is reduced by two to three times with high product quality.

Although joint studies have shown high efficiency of drying grapes in these plants, only a few summer months function when there is an excess of raw materials. In the rest of the year (8-9 months) such installations are not used, which significantly reduces their economic performance.

To eliminate such insufficient indicators, the authors proposed and tested the design of a solar combined installation, which can be used both as greenhouses and as a dryer in the summer and operated almost all year round.

Analogical developments of an indirect type solar dryer were proposed by the authors, whose heating part was performed by solar collectors with an average thermal efficiency of $\eta_{н}$=31,5%, and a drying chamber $\eta_{с.к.}$=22,4%.

An installation based on a mixed mode of operation with a direct and indirect type of heating mechanism for drying tobacco was proposed by M.S.Dyulavot et al.. It was found that the coupling of a collector heater to the proposed installation increases the drying speed of fruits by 1.5 times than in installations without a solar collector heater for them.

Over the past 40 years, many types of solar dryers have been developed in various countries, and many studies of natural convection drying in the sun of agricultural products have also been reported.

However, the success achieved by solar dryers with forced convection of the drying agent inside the installations was limited (due to their low buoyancy).

Based on the analysis of scientific literature revealed:

-drying plants for drying vegetables and fruits at the expense of solar energy can be divided into direct-type dryers, indirect-type dryers and dryers powered by traditional energy sources with solar-air heating chambers additionally connected to them;

-indirect type solar dryers and dryers powered by traditional energy sources have two chambers: heating and drying; and direct type solar dryers have one chamber: heating - drying;

-если термический КПД нагревательной камеры имеет значение $\eta_{н}$, а термический КПД сушильной камеры имеет значение $\eta_{с.к.}$, тогда у представленных сушильных установок термический КПД будет иметь значение $\eta = \eta_{н} \cdot \eta_{с.к.}$, на 3-5 раз меньше чем термический КПД в каждом камере [18]. Например, при значениях $\eta_{н} = 0{,}315$ и $\eta_{с.к.} = 0{,}224$ термический КПД сушильной установки будет иметь значение $\eta = 0{,}07$;

-if the thermal efficiency of the heating chamber has a value of $\eta_{н}$, and the thermal efficiency of the drying chamber has a value of $\eta_{с.к.}$, then the thermal efficiency of the presented drying plants will have a value of $\eta = \eta_{н} \cdot \eta_{с.к.}$, 3-5 times less than the thermal efficiency in each chamber. For example, at values $\eta_{н} = 0{,}315$ and $\eta_{с.к.} = 0{,}224$, the thermal efficiency of the drying plant will have a value of $\eta = 0{,}07$;

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-the inclusion of additional solar - air heating chambers to solar drying plants directly increases the area of the fence of the drying plant, which leads to an increase in heat losses and naturally reduces the thermal energy efficiency of the installation.

The presence of objective prerequisites: climatic and technical makes it possible to use solar energy in the field of drying fruits and vegetables. It is advisable to develop research work in the direction of developing many functional design models of direct-type solar dryers, for which there are currently insufficient publications in the press.

The development of structural equipment for direct-type solar dryers for fruits and vegetables will avoid the cost of energy fuel, which makes the installation cost-effective compared to a number of installations running on traditional fuel, where fuel costs account for about 20% of total costs. The operation of such solar installations makes it environmentally safe for the environment. They are quite reliable and practically do not require maintenance compared to existing drying units, in which maintenance costs reach 11% of the total.

The purpose of this work is an experimental study of the physical mechanism of the drying process in a direct type solar dryer.

To achieve this goal, an experimental direct-type solar drying plant was developed, the drained raw materials-grapes were selected, conditions for rational operation of the plant were created, thermodynamic parameters were measured: relative humidity, temperature, relative pressure and density of the drying agent at the appropriate points, humidity measurements of the drained raw materials were carried out.

A direct-type solar drying plant has been developed and installed at the field research laboratory of Bukhara State University in the Republic of Uzbekistan. The installation consists of a structure: a roof in the form of a parallelepiped with an isosceles triangle base and fenced with a polyethylene film (drying chamber), the lid is hermetically coupled with a parallelepiped with a quadrangle base and also fenced with a polyethylene film (heating chamber). Figure 1 shows a natural image.

Mesh pallets are placed at the bottom of the drying chamber, grape raw materials are placed on the pallet. An air damper (point D) with a siphon pipe into the environment is installed in the acute corner of the side wall.

The bottom of the heating chamber is insulated (with foam) from heat loss, thermal accumulators (crushed stones, jackdaws) are placed above the insulation. Air dampers (points) are installed in the side walls of the chamber.

Fig.1. Natural image of a solar dryer:

A, B, C, D and M are the measurement points of temperature, relative humidity, pressure and density of the drying agent.

The seedless variety "Black ellipsoid Kishmish" was selected for solar drying. To speed up the drying process and obtain high-quality products, the following technological techniques were carried out: clusters were inspected, fruit was cut into slices, damaged berries were removed; blanched in boiling 0.3-0.4% alkali solution (caustic soda) for 4-6 seconds; bunches were soaked in cold water; laid out on mesh trays with material on top nets in one layer and then installed in the drying chamber. In this study, 17,589 kg of black Kishmish grapes were dried in a direct-type solar dryer to demonstrate its drying capabilities. 18,792 kg of grapes "Kishmish black" were dried by the usual solar-air method (Fig.1).

Solar drying of grape raw materials was carried out in the research laboratory of Bukhara State University, Bukhara, Republic of Uzbekistan. The experiments were carried out for 45 days, between October 17 and November 31, 2022. In Bukhara, the number of average cloudy sunny days in 2022, the months of October-November took only 42 days and.

Every day, measurements of parameters were carried out from 8:00 am to 18:00 pm. The drying process of grape raw materials in the studied solar installation lasted 45 days. At the end of the experiment, the moisture content relative to the initial mass of the raw material reached 25.6%.

Solar radiation was measured using a pyranometer (model M 80m with a pointer actinometric galvanometer GSA-1, the sensitivity of the head of the pyranometer is 10-16 mV per 1 kW/m^2), located at the bottom of the drying chamber of the installation. To measure the temperature of the air (air agent) in the dryer, thermocouples were used (type TM, sensitivity:=±1^{o}C). The relative humidity of the ambient air and the drying agent inside the installation was periodically measured with hygrometers (Digital hydro-thermometer, sensitivity: ±5%). The positions of the thermocouple and moisture meters for measuring the temperature and humidity of air and grape raw materials (points A, B, C, D and M) are shown in Figure 1. Voltage signals from the pyranometer, electronic hygrometer and thermocouples were recorded every 1 hour manually.

Figure 2 shows the changes in solar radiation during typical experimental runs of drying dried grapes in the sun in the test installation. During the drying period of grape raw materials, due to cloudy and cloudy weather, there was a fluctuation in the daily total solar radiation. However, the general cyclic patterns of solar radiation show that from the beginning to the end of the day of the experiment, solar radiation, i.e. the amount of solar radiation on a horizontal surface under cloudy conditions decreases by 4 MJ/m^2.

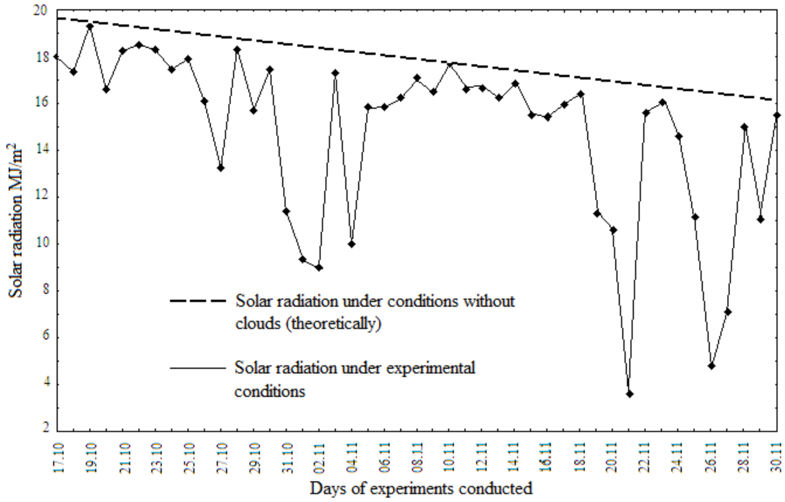

Fig. 2. Changes in solar radiation during the day for the experimental run during the drying of grapes.

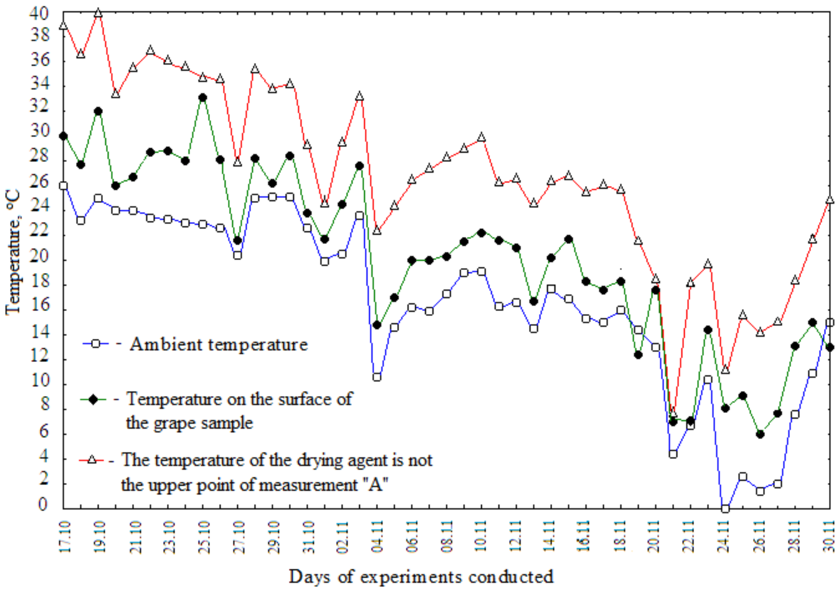

Fig.3. Changes in the ambient temperature, the temperature on the surface of the studied grapes and the temperature of the drying agent (at point "A") during the day.

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Figure 3 shows the changes in three average daily temperatures during the entire drying period: the average ambient temperature; the average temperature on the surface of the sample under study (grape raw materials); the average temperature of the drying agent (steam-air medium having the properties of a coolant). According to the general nature of the temperature change curves in different positions, it can be seen that the cyclic temperature patterns were similar, and the nature of the temperature change curves was similar to the nature of the change in solar radiation coming to the solar drying plant (Fig.2).

Under the given environmental conditions, the average temperature at the sample surface and the temperature of the drying agent inside the drying unit differed significantly from each other and more than the ambient temperature. The temperature of the drying agent inside the drying chamber is greater than the temperature at the surface of the test sample; the temperature at the surface of the test sample is greater than the ambient temperature. In this scenario of temperatures, a temperature pressure is created inside the solar drying plant, on the basis of which the process of natural convection of the drying agent takes place.

The results of experimental measurements of the relative humidity of the drying agent at point "A" and at point "D", as well as the relative humidity of the air at point "M" of the installation are graphically presented in Figure 4. By the nature of the curves, it follows that in the initial days of the experiment, i.e. the period of the first stage of the drying rate at all at points "A", "D" and "M", the relative humidity is the same. At the first stage, the drying speed or the rate of flow of the drying agent from inside the installation to the outside is equal to the speed of the incoming air into the drying installation, i.e. the energy capacity of the drying agent is sufficient to remove it from the inside of the installation to the outside.

During the period of the second and further speed, the energy capacity of the drying agent is not enough to remove it from inside the installation.

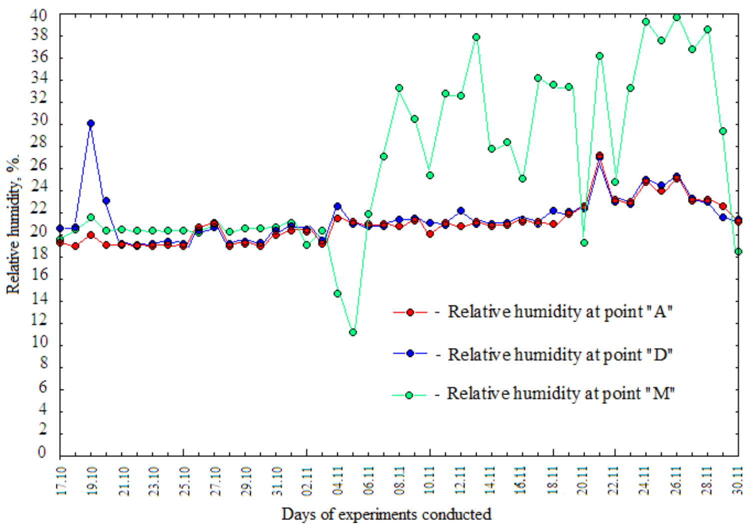

Fig.4. Changes in relative humidity at measurement points "A", "D" and "M" during the day.

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Having received additional energy from solar radiation, the temperature of the drying agent increases. Consequently, the pressure of saturated water vapor in its composition increases. A temperature pressure is created between the media by the drying agent and the environment. There is a movement of the drying agent from inside the installation to the outside. Figure 4 shows the curves of the dependence of the pressure of saturated water vapor of the drying agent and the outside air. The difference in pressure curves differed from each other within 20%. Due to this pressure drop, the consumable drying agent performs work, i.e. the drying agent receives thermal power.

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