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UDC 53

USE OF INNOVATIVE METHODS IN FRUIT DRYING

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Abstract. *The article discusses the main aspects of drying fruits and vegetables as an effective, long-term proven method of reproducing all the nutritional and medicinal properties of fruits and vegetables under appropriate conditions and storing them for a long time. Although the use of renewable energy devices requires considerable investment, they are economically viable. Sulfur, nitrogen, and carbon oxides released into the air due to traditional fuel-based energy are spread over long distances. In addition, they mix with rainwater, turn into acid compounds, and fall to the ground in rain, having a negative effect on plants and soil. All over the world, it is recommended to eat an average of 40-50 grams of dried fruits per day in winter and spring. These products make up 10-15% of the total consumption of fruits and vegetables.*

Keywords: *renewable, energy, biosphere, solar energy, bioenergy, convection, drying, air drying, infrared drying, vacuum sublimation.*

ИСПОЛЬЗОВАНИЕ ИННОВАЦИОННЫХ МЕТОДОВ ПРИ СУШКЕ ФРУКТОВ

Аннотация. *В статье рассмотрены основные аспекты сушки фруктов и овощей как эффективного, давно проверенного способа воспроизведения всех пищевых и лечебных свойств фруктов и овощей в соответствующих условиях и их длительного хранения. Хотя использование устройств возобновляемой энергии требует значительных инвестиций, они экономически жизнеспособны. Оксиды серы, азота и углерода, выбрасываемые в воздух из-за традиционной энергетики, основанной на топливе, распространяются на большие расстояния. Кроме того, они смешиваются с дождевой водой, превращаются в кислотные соединения и с дождём выпадают на землю, оказывая негативное воздействие на растения и почву. Во всём мире зимой и весной рекомендуется съедать в среднем 40-50 граммов сухофруктов в день. Эти продукты составляют 10-15% от общего потребления фруктов и овощей.*

Ключевые слова: *возобновляемые источники энергии, энергетика, биосфера, солнечная энергия, биоэнергетика, конвекция, сушка, воздушная сушка, инфракрасная сушка, вакуумная сублимация.*

МЕВАЛАРНИ ҚУРИТИШДА ИННОВАЦИОН УСУЛЛАРИДАН ФОЙДАЛАНИШ

Аннотация. *Мақолада мева ва сабзавотларни қуритишнинг асосий жиҳатлари мева ва сабзавотларнинг барча озуқавий ва доривор хусусиятларини тегишли шароитларда қайта ишлаб ва узоқ муддатли сақлашнинг самарали, узоқ йиллар давомида тасдиқланган усуллари сифатида муҳокама қилинади. Қайта тикланувчи энергия манбалари қурилмаларидан фойдаланишга бир қадар салмоқли маблағ сарфланса-да, улар иқтисодий жиҳатдан ўзини оқлайди. Анъанвий ёқилғи билан ишлайдиган энергетика туфайли ҳавога чиқаётган олтингугурт, азот, углерод оксидлари узоқ масофага тарқалади. Бундан ташқари, улар ёмғир сувлари билан қўшилиб, кислота бирикмаларига айланади ҳамда ёмғир таркибида ерга тушиб, ўсимликларга, тупроққа салбий таъсир кўрсатади. Дунёда барча инсонларга қиш ва баҳор мавсумида қуритилган меваларни кунига ўртача 40-50 грамм истеъмол қилишни тавсия қилади. Ушбу маҳсулотларнинг мева ва сабзавотлар умумий истеъмолининг 10-15 фоизини ташкил қилади.*

Калит сўзлар: *қайта тикланадиган энергия, биосфера, қуёш энергияси, биоэнергия, конвекция, қуритиш, ҳаво қуритиши, инфрақизил қуритиш, вакуумли сублимация.*

Introduction. Drying is a thermophysical process aimed at reducing moisture from the product. At the same time, this process is also a technological process, during which it is necessary not only to remove excess moisture, but also to preserve the useful substances, vitamins, aromatic and taste qualities of the product.

Today, there are many high-temperature automated devices for drying fruits. However, their use will be associated with large capital investment and high energy costs. Processing small amounts of fresh fruits in peasant and farm conditions is less efficient. Disadvantages of existing drying devices are: from an ecological point of view, pollution of fruits and the environment with toxic substances from fuel combustion; uneven heating of the fruit mass and high drying speed, which leads to excessive drying, deformation and cracking of the material, as well as high energy costs.

A natural and forced convective method of drying agricultural products is used in fruit processing, which is related to heat transfer methods, material properties, types of moisture binding to the material, and energy consumption.

Renewable energy is continuously renewable in the Earth's atmosphere and globally inexhaustible. They are solar energy, wind, bioenergy, ocean, sea and river water, underground geothermal water. The main advantage of renewable energy is its inexhaustibility and ecological purity. In the world, energy types are divided into two (Figure.1).

In Uzbekistan, the use of renewable alternative energy sources has great prospects, effective work has been carried out in this regard and scientific experiences have been collected [1,3].

The use of natural fruit drying in the open air under natural light conditions requires high labor costs, is not environmentally friendly, and has low productivity.

Therefore, renewable energy that ensures compliance with the requirements of saving energy and resources and maintaining environmental cleanliness the need to develop devices and technical means for drying fruits on the basis of sources determines the relevance of the work topic.

Natural drying is the simplest and most common method of drying fruit raw materials in the open field on farms. During natural drying of the moisture of the raw material takes place in the open air under natural light conditions, without influence on the intensifying processes (temperature of the product and drying agent - air, humidity, etc.).

In the summer season, wet fruits (apples, apricots, grapes, tomatoes, cherries, mulberries, melons and other citrus fruits) are dried in the open air under the influence of light.

In the natural drying areas in the open air, the temporary storage of the product should be clearly marked, in special places, and the parts should be laid out on a clean floor and placed on trays (2-Figure).

The drying time varies slightly depending on the type of product and the drying method. For example, halved apricots are ready in 5-10 days, whole apricots in 10-15 days, halved peaches in 8-12 days, grapes in 20-25 days (untreated), and those treated with alkali in 6-10 days [1,2,].

Disadvantages of natural drying compared to artificial drying:

- the long duration of the process depending on the geographical location, weather conditions, time, time of year and external environment. Materials and fruits are dried to equilibrium moisture with natural convective drying;

- as well as the availability of enough nutrients and vitamins in dried products, if there is little pollution;

- despite its simplicity and cheapness, natural drying is limited to a small amount of raw fruit processing.

If there is an artificial forced chamber method of drying fruit raw materials, it is necessary to choose the right drying method and the optimal option of the drying device (apparatus) according to the technical conditions of the process.

In the artificial drying of fruits, the following drying methods are used depending on the method of supplying heat energy to the product: convective, conductive, thermoradiative, drying by heating with the help of high-frequency current (microwave oven), sublimation, combined.

The artificial method of drying plants or construction materials is carried out in special devices (drying plants or chambers), according to their structure: chamber, belt, conveyor, shaft, tray, roller, shelf, corridor, contact-roller (using high-frequency current) types.

Figure 1. Natural drying of fruits

According to the convective drying method, heat is transferred from the heat source used for drying to the drying surface using a heat carrier. Air, water vapor, and flue gases are used as heat carriers. This method is the most common, and the work of most of the chamber and shaft drying plants is based on the construction (Table 1).

Technical description of the drying line

Table 1.

1	Productivity, kg/h	225;
2	Weight of loading products at one time, kg	200;
3	Duration of drying, hours	5,5-6,0÷8
4	Camera temperature, 0C	
5	In the center	70
6	In the periphery	66
7	Overall dimensions, m,	6x3,3x6

However, this drying method also has a number of disadvantages:

- high energy costs (1.6 to 2.5 kWh of electricity is required to reduce moisture from one kilogram of raw fruit and turn it into steam);

- it will be difficult to manage the drying process in gas and harmful substance-liquefied layer, because it is impossible to take samples and check during the drying process;

- a sudden increase in temperature leads to caramelization (chemical change of the composition) of sugar in raw fruit.

The device consists of a heat generator (1), a drying chamber with two autonomous sections (2) and communication (3) for the release or circulation of steam-gas mixtures. The heat generator is equipped with a gas burner (4) for burning natural gas. The movement system of the working agent is equipped with two ventilators: air transfer (5) and gas-air mixture return (6) or loss through the device (8) through the pipe (7), smoke exhaust devices (11). Cleaning of gas-air mixtures in the heat generator was also taken into account (Figure 2).

The working sections of the drying chamber (2) are equipped with bars (9) for serving the working persons.The sections are hermetically bounded to each other and covered with an insulated shell. Each chamber has rollers and hermetically closing doors.Sections of working chambers are divided into columns (bases) (10). Each section is equipped with shelves in the form of shelves. Under the soles are meshes made of stainless material [2].

A wood-fired special cabinet dryer has a number of advantages in drying various products. Their structure is special channels in the lower part of the abinet, which are used for heating. They are made of brick or iron pipes, and the diameters of the pipes and the chimney of the oven are denser. and it is located under both cabinets.

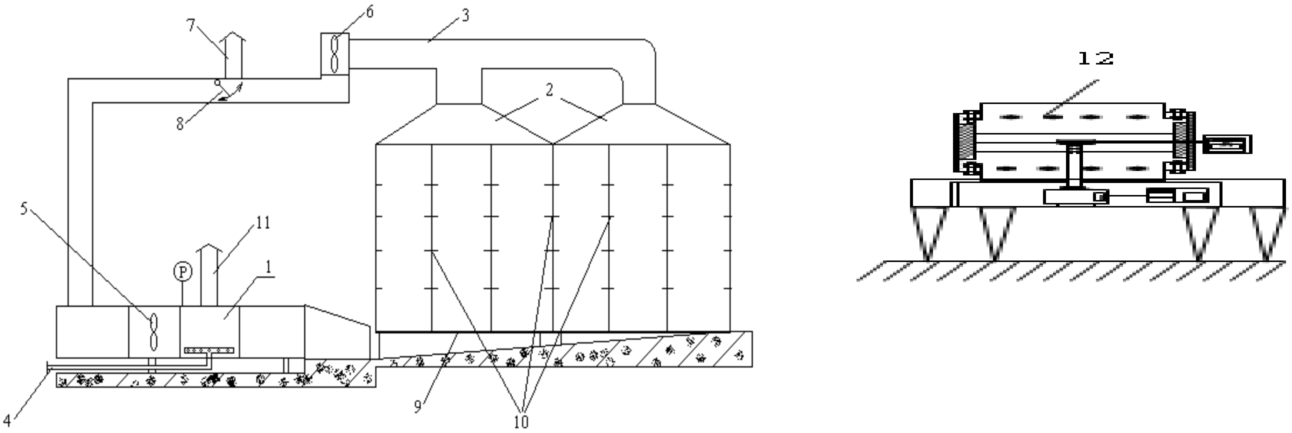

Figure 2. Technological line of IR-convective drying of agricultural products. 1-heat generator; 2-drying chamber; 3-circulatory communication; 4-gas burner; 5 - fan for air transfer; 6-fan for air return; 7-pipe for removing gas-air mixtures; 8-device; 9-fence; 10-columns; 11-fumigation device; 12-drying device for primary treatment of raw materials.

The walls are brick, and they serve as the base for the drying cabinets. The exhaust pipe has slits for temperature control. Controlled doors or slits are left in the wall of the base of the section to allow cold air to enter (Figure 3).

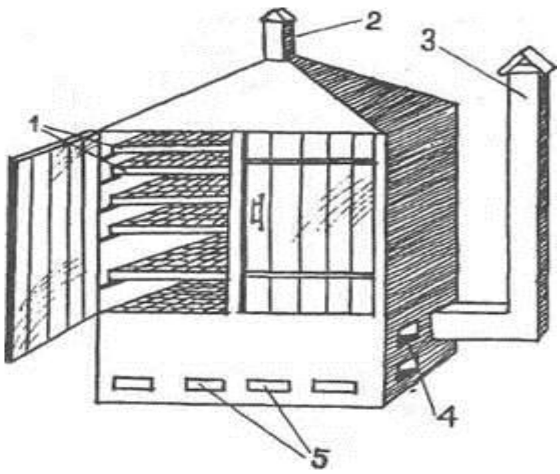

Figure 3. Drawing of a wood-heated special cabinet dryer: 1-pallets; 2-suction pipe; 3-exhaust pipe; 4-fire place; 5-slot for cold air intake.

Drying cabinet (1 or 2 depending on the corners of the dryer) can be made of boards, bricks or other materials. If two cabinets are placed, a barrier is placed between them. The bottom of the cabinet is an iron sheet, and it is placed 20-30 cm below the back wall, the reason for this is that there is an iron cap and a slot on the top of the cabinet to control the ventilation so that hot air can reach the drying cabinet from the compartment. The function of the front wall of the closet is performed by a tightly closed wall. In the special lines of the cabinet, at an angle, the sieve is installed on the back wall in a step-like manner [3,4].

Due to uneven moisture in the product, high quality of the final product cannot be achieved, the product in contact with the heated surface dries out, which leads to deformation and cracking of the product. Roller and tray drying plants based on this product-intensive drying method have high energy costs (1.5 to 1.7 kWh of energy is used for 1.5 kg of reduced, removed moisture).

Despite a number of advantages of this method (low number of conveyors, drying facilities and equipment, flexibility of process control, etc.), drying with infrared rays in its pure form is characterized by uneven heating of the product, low efficiency of infrared radiation generators. The freeze drying method is one of the most effective methods in the fruit drying process. It can be divided into two stages: in the first one, the moisture freezes and rises to the surface with the help of a deep vacuum, and in the second one, due to intensive heat supply, the moisture evaporates (ice bypasses the liquid state and turns into steam). This technology has not been widely used due to the complexity of designing tunnel drying plants, low productivity, high capital cost, production costs and electricity consumption (from 3.9 to 1 kWh per 3 kg of moisture removed) [8,9,10].

Dielectric drying method based on the dielectric properties of water and dry substances (a wet product is more prone to heating than a dry one). During the drying process, wetter material heats up more than drier. Heating is based on the phenomenon of polarization (location in a certain direction) of fruit molecules. During drying, the fruits are placed between the electrodes of the heating condenser, and these electrodes have opposite charges. Controlled heating of the material occurs under the influence of a high-intensity electric field. Evaporation of moisture occurs throughout the volume of the product, and a pressure gradient occurs inside the particle, which accelerates the transfer of moisture. To remove evaporated moisture, it is necessary to continuously blow air through the layer of raw fruit [9,10].

Dried raw materials are cooled in refrigerators. Compared to convective and contact drying, the advantages of high-frequency flow drying are the ability to regulate and maintain a certain temperature, and are characterized by a significant increase in the drying process. All this requires a large amount of electricity (from 5 to 1 kWh for 2.5 kg of moisture removed). Disadvantages of microwave drying plants are the complexity of the equipment, metal consumption, and environmental risk as a result of the harmful effects of microwave radiation on people. These devices require specialized personnel to maintain and constantly monitor the background of microwave radiation, as well as the use of high voltage, which is dangerous for maintenance personnel [10].

Therefore, the introduction of new methods and advanced technologies to the process of drying fruits is the most important task to increase the efficiency of drying plants. Strict requirements are imposed on it:

- the quality of dried fruits (maintenance of product components, nutrients, vitamins, aromatic and taste qualities);
- the possibility of drying fruit raw materials with different moisture ranges; use of drying equipment to dry various fruit raw materials;
- high technical, economic and technical and technological parameters in comparison with analogues;
- minimum weight, overall dimensions and high power of mobile dryers;
- simplicity, high reliability and safety of the drying equipment; the possibility of automated control of the drying process;
- reduce energy consumption. These features are an important requirement for improving or developing a new design of drying equipment.

Therefore, the development of energy- and material-saving dryers for farmers and small farms that use cheap alternative sources of heat energy, such as the sun, while maintaining product quality, remains relevant. With the method of drying fruits using heat from renewable energy sources, the fruits receive heat from the infrared rays of heat. Infrared drying, along with strong heating of the surface of the product, creates a significant temperature gradient that prevents moisture from moving from the inside of the fruit to the surface. Here, the necessary intermittent irradiation is necessary, during which the surface of the material quickly heats up and dehydrates during the irradiation, and the moisture from the inner layers of the product slowly moves to the outer layers during curing.

The analysis of existing means and methods of fruit drying showed that chamber dryers with a convective heat supply method are the most common among private farmers and farms. Based on the analysis, it was found that dryers do not provide adequate energy consumption, they are characterized by low thermal efficiency and increased specific cost consumption. Therefore, it is desirable to dry small fruits in dryers based on solar energy (solar dryers), which provide uniform heating of fruits and an energy-saving drying mode that does not cause deformation and cracking of the material. The use of solar dryers is especially useful for individual farmers and farm conditions, where small quantities of fruit need to be dried.

The choice of solar dryers is determined by the scale of production, the climatic characteristics of the area, the type of product to be dried and the cost of additional energy.

Under the drying unit there is an air channel, through which air is supplied through an inlet mesh window (air pressure or suction mode). In clear sunny weather, the heat-dissipating top of the glass window should transmit sunlight well.

The structure of the combined Solar mini fruit-vegetable dryer-greenhouse device: The device consists of a "hot box" with a length of 1500 mm, a width of 720 mm, a front part of 600 mm, and a height of the rear wall of 900 mm. The unit has glass-framed doors on both sides and mesh windows that provide natural ventilation [4], (Figure 4).

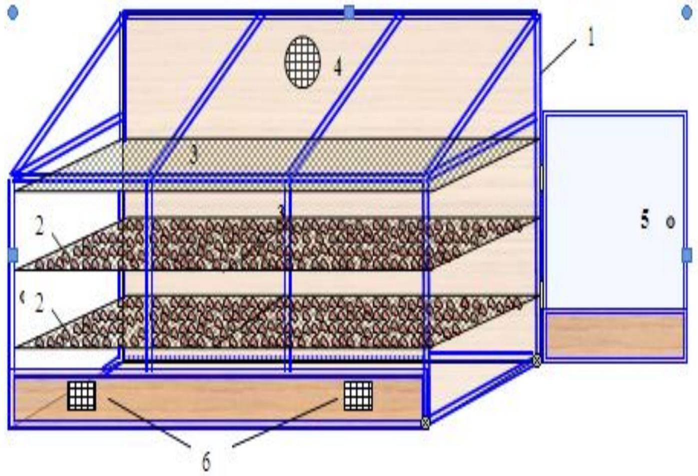

Figure 4. Solar mini fruit and vegetable dryer. 1-glass frame window; 2-set rack; 3-heat-dissolving top glass; 4-exhaust fan; 5-door with glass frame; 6-air intake mesh window

Three rows of sliding mesh racks are installed in the device chamber. The surface of each row of racks is 1 m2 (two 0.5 sq. m.), the product to be dried is placed under the two rows. The upper rack serves as an umbrella that protects the product from direct sunlight, and in some cases it can also be used to dry fruits and vegetables.

Depending on the ripening and season of the product, according to each square meter of the device, in turn - 25-30 kg of apricots, 10-15 kg of cherries, 25-30 kg of tomatoes, 25-30 kg of raisins, 5-10 kg of melons, etc. can be prepared [4,6].

Based on the research conducted on drying with the help of solar devices working with solar energy, it can be said that natural drying lasts a long time, if the weather is unfavorable, the product will perish. For artificial drying, 0.5 kg of fuel is used for each kg of raisins. Solar devices do not require energy. But it requires more space than artificial drying.

Disadvantages of the radiation dryer are the direct impact of sunlight on the dried material, uneven heating of the fruit mass. High drying speed leads to excessive drying, deformation and cracking of the material [11,12,13].

The following table shows the relevant indicators of different dryers (2-Table).

Table 2.

Dryers	It's open in the air	Radiation dryer	Chamber dryer	Combined
Product per m2	15-20	15-20	15-20	20-25
Build time (day)	17-20	7	9	6-8
Productivity kg/m2	0,25	0,65	0,5	0,9

In order to ensure uniform drying in all main installations, the air temperature is regulated by changing the width of the space due to the horizontal movement of the shelves.

Conclusion. Therefore, in the conclusion, the considered options for the constructive solutions of solar dryers from renewable energy sources are to control the temperature change of drying during the day, to create means of controlling the variable flow of solar radiation-energy entering it. Accordingly, the solar dryer should consist of a variable capacity air flow, a rotating device or a flat glass window to improve the morning and evening solar flows, and special drafts to remove excess heating power in the afternoon. Thus, technical solutions on this topic use only certain characteristics of solar energy, not taking into account the numerous spatial and temporal relationships between its parameters. Therefore, it is an urgent issue to create and develop the optimal option of solar fruit dryer for use by private farmers and farms. This problem should be solved taking into account the theoretical rules of solar energy, the latest achievements of specialists and engineering.

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