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DEVELOPMENT AND PRACTICAL TESTS OF A SOLAR DRYER WITH VARIOUS COATINGS FOR DRYING AGRICULTURAL PRODUCTS

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ABSTRACT

A solar dryer for drying fruits, vegetables, medicinal plants, and other agricultural products is proposed. This solar dryer (s/d) is simple to construct, and its drying chamber can be covered with polyethylene, polycarbonate, glass, metal sheet, or other material, depending on the dried raw material. As the results of the experiments in the solar dryer showed, the drying speed is high; products obtained in a solar dryer are of high quality - without preservatives and dyes, with a high content of vitamins, with good taste properties. For example, when drying cornel in a solar dryer, vitamin C losses are almost 2 times less than with natural drying.
The shelf life of dried products is also increased when the storage conditions are properly observed. The high drying speed is explained by the enhanced convective movement of air in the dryer. The proposed solar dryer can be used on farms, as well as by urban residents, depending on the size of the dryer.

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1. Introduction.

To date, one of the promising directions in ensuring the safety of agricultural products is the development of the processing industry, including the improvement and development of new technological installations for drying and storing products. The use of solar energy is an important reserve for improving the energy supply of agricultural processing equipment. One of the developing areas in this industry is solar energy, which is based on solar radiation. Solar energy is a renewable and environmentally friendly source of energy and does not produce harmful waste [1].

Analysis of the current state of the problem of using solar energy for drying agricultural products shows the need to solve a number of scientific and technical problems aimed at the development of new efficient solar drying installations, the creation, production testing and generalization of the experience of operating solar drying installations and complexes. Inventions of various complexity of solar energy collectors are known.

The choice of type and design of a solar dryer depends on the following factors:

- Volume of product to be dried.
- Type of product to be dried.
- Availability of sunlight.
- Budget.

Solar dryers are an environmentally friendly and economical way to preserve food. They can be used to dry a variety of products, including fruits, vegetables, mushrooms, meat, fish, and herbs.

The development of a new solar dryer requires careful research and design. Various factors need to be considered, such as the type of product to be dried, the climatic conditions in which the dryer will be used, and the budget [2, 3, 10].

2. Purpose of the work.

1. Creating a solar drying device of a simple design, which is an important task, because it will make solar drying more accessible to middle-level farmers. Such devices should be easy to assemble and operate, so that farmers can make or purchase them themselves at no great cost. Solar dryers can be useful not only for farmers, but also for urban residents. In case of acceptable size and location of the solar dryer on the balcony, it can be used for drying fruits, vegetables and other products.
2. Production of high-quality products without preservatives, dyes, with a high content of vitamins and good taste.
3. Drying agricultural products in a developed solar dryer would allow to increase the shelf life of products, preserving their nutritional properties.
4. Obtaining clean dried products that are not contaminated with dust or insects.
5. Reducing agricultural product losses due to rotting and spoilage with solar dryer. Drying products helps prevent food waste, as it allows for the preservation of a large portion of the harvest, which may expire if not properly stored.
6. Improvement of the drying process efficiency by developing a new dryer that provides energy savings while maintaining the required quality of the finished product.

3. The main part.

3.1 A solar drying unit is proposed (fig.1). It consists of a housing (3), into which perforated trays (2) are inserted; an inlet (1) or the bottom of the solar dryer; an exhaust pipe (4). The drying chamber can be covered with polyethylene, polycarbonate, glass, metal sheet, or other material, depending on the drying material (for drying some types of agricultural products and medicinal plants, a relatively low drying temperature is required for a short period of time).

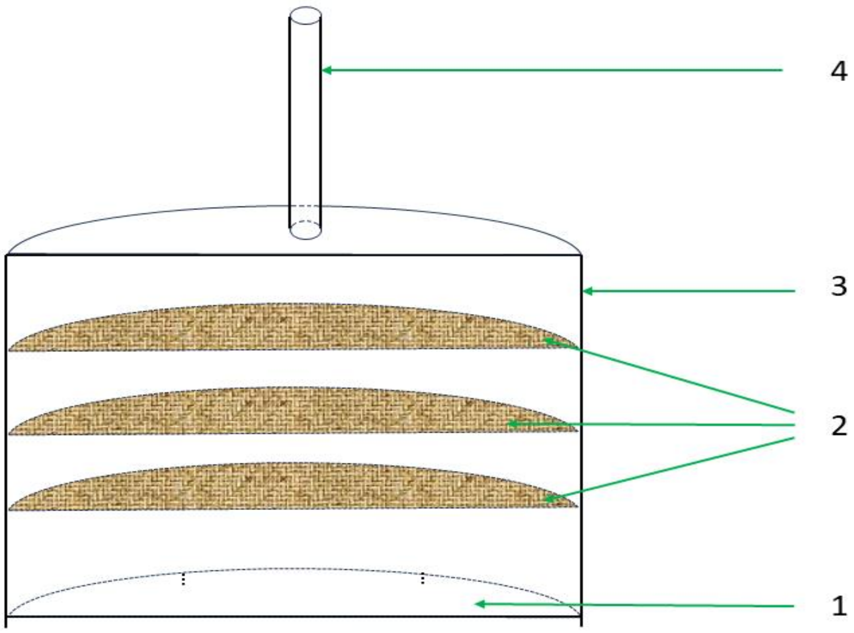

Fig.1. Solar drying.

Atmospheric air enters the drying chamber through the bottom of the solar dryer (1). It is heated by the sun and the metal housing (3), which is also heated by the sun's rays. Due to the difference in pressure and temperature at the inlet (1) and outlet (4) of the solar dryer, the heated air moves upwards. The entire body of the sheet solar dryer is painted black to enhance the thermal effect. Warm air from the collector flows over the perforated trays with the product (2) from the bottom and top and dries the product, which is also heated by solar radiation in the drying chamber. The solar dryer is placed in the sun. The heated and circulating air in the solar dryer provides high drying speed and quality. Solar energy is absorbed directly by the product itself and the black-painted internal walls of the chamber in which the dried raw materials are located.

Moist air is removed from the dryer through the exhaust pipe (4). The difference in height between the bottom air inlet (1) and the top end of the pipe (4) is approximately 1.5 m. After the drying process is complete, the dried product is unloaded from the chamber along with the tray. As studies have shown, the maximum temperature increase in a solar dryer, depending on the coating and weather conditions, is on average 24-35 degrees Celsius higher than the temperature on the sun [4].

To test the proposed solar dryer, simultaneous drying of agricultural products in a solar dryer and natural solar-air drying was carried out in order to compare the results. More than 15 types of agricultural products were dried in the solar dryer. We offer the results of drying medicinal plants of St. John's wort and mint in a solar dryer and traditional drying – indoors in the shade, as well as drying dogwood.

3.2 Drying of medicinal plants.

Drying is the main method of preserving plant material. Dried plant material can be stored for a long time without losing its medicinal properties or being damaged. By quickly drying the material under appropriate conditions, it is possible to preserve the content of biologically active substances at the same level as in the fresh plant. Improper drying can completely deprive plant material of active substances. Drying is carried out mainly in spring or summer, most often in dryers using normal temperature and natural air movement. Fresh plant material contains 60-80% moisture. Reducing the moisture content to 10-16 % stops the biochemical processes that lead to the destruction of biologically active substances in the plant.

The mass of medicinal plants decreases by an average of 80-90% during drying. This is due to the fact that fresh plant material contains a large amount of moisture, which is removed during the drying process.

The specific value of mass loss depends on the type of plant, its moisture content, drying conditions, and other factors.

For example, leaves and flowers dry faster than stems and roots, and herbs collected during flowering dry faster than herbs collected during vegetative growth.

The main task of drying is to quickly remove moisture from the material, as a result of which the vital activity of cells and enzymes stops. The faster the material is dried, the higher its quality [5].

For comparison, St. John's wort and mint were dried using the traditional method in a shaded room and in a solar dryer covered with corrugated sheet metal, since medicinal plants are not dried in direct sunlight [6, 8].

Table 1. Analysis of experimental data.

PRODUCT NAME		
MEDICINAL PLANTS		
	solar dryer	natural drying
initial mass, (gr)	850	840
final mass, (gr)	145	168
weight reduction, (%)	83	80
drying time, (hours)	4.5	96

As can be seen from the results of the experiments, the drying of medicinal herbs, St. John's wort and mint, in a solar dryer took 4.5 hours, while natural drying in the shade lasted 4 days. The process of drying medicinal plants in a solar dryer took 21.3 times less time than natural drying in the shade.

3.3 Drying of dogwood.

For long-term storage, dogwood is dried, frozen, or sprinkled with sugar and stored in a cool place. Dogwood berries are dried not only for culinary purposes, but also for the prevention and treatment of many diseases. Dried dogwood retains all the beneficial properties of fresh berries. It is a rich source of vitamins and minerals, including:

- Vitamin C, which is a powerful antioxidant and helps to strengthen the immune system.
- Vitamin A, which is essential for eye and skin health.
- Iron, which helps to prevent the development of anemia.
- Calcium, which is essential for bone and teeth health.
- Magnesium, which helps to maintain the health of the nervous system.

In addition, dried dogwood contains organic acids, pectins, flavonoids, antioxidants such as resveratrol and quercetin, which help protect cells from damage caused by free radicals, and other beneficial substances.

Ripe (but not overripe) berries are harvested, but they can also be harvested even unripe - during ripening, dogwood gains flavor and does not lose its medicinal properties. Since the seeds also have healing qualities and contain a lot of useful substances, they are not removed from the berries. The mass of dogwood decreases by an average of 70-80% during drying. The initial moisture content of dogwood can vary greatly depending on the variety and ripeness of the fruit. Therefore, the percentage of mass loss will depend on the initial moisture content and drying conditions, such as temperature and humidity of the environment, as well as the duration of the process.

In the drying process, moisture is removed, and the berries become dry and hard.

A more accurate figure for the mass loss of dogwood during drying depends on several factors, including:

- Variety of dogwood. Some varieties of dogwood contain more water than others.

- Drying conditions, such as temperature and humidity of the environment, as well as the duration of the process. The faster the drying is carried out, the more moisture is removed from the berries, and the more the mass decreases [7, 8, 9].

The garden dogwood was dried (without blanching).The product was prepared for drying in advance. The results of the studies are presented in Fig. 2. Due to the long drying process, the change in the mass of cornelian cherry is shown on the graph by days.

Drying of dogwood.

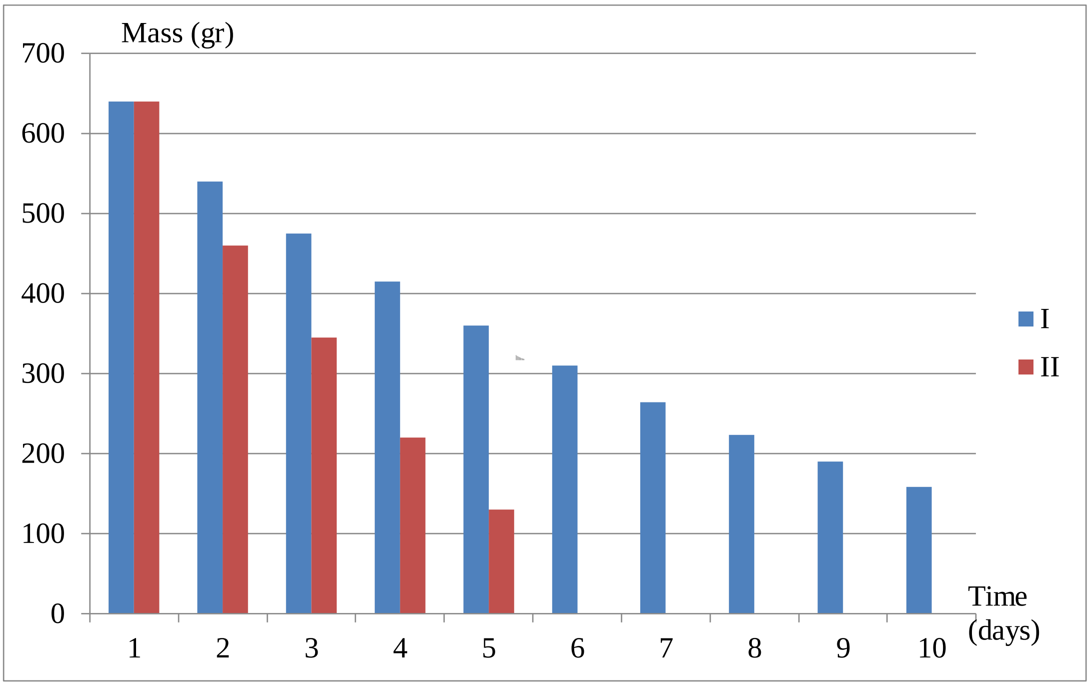

Fig.2. Change in the mass of raw materials (dogwood) by day.
1 - change in the mass of raw materials dried by natural drying in the open air;
2 - change in the mass of raw materials dried in a solar dryer.

Table 2 Shows the results of dogwood drying experiments.

Table 2. Analysis of experimental data.

PRODUCT NAME		
DOGWOOD		
	solar dryer	natural drying
initial mass, (gr)	645	645
final mass, (gr)	128	137
weight reduction, (%)	80.1	78.7
drying time, (hours)	95	225

The duration of drying in a solar dryer took 2.4 times less time than natural drying in the open air.

As the results of tests on the vitamin composition of products before and after drying showed, the loss of vitamin C in dogwood dried in a solar drying device is 22%, and by natural drying - up to 43%. Consequently, when drying dogwood in g / s, the loss of vitamin C compared to natural drying is almost 2 times less. Vitamin C is one of the most sensitive vitamins to the effects of high temperatures.

Conclusions.

1. An original and simple design of a solar dryer with different coatings for drying agricultural raw materials, capable of simultaneously producing a wide range of products, is proposed. The air heated and circulating in the solar dryer ensures high speed and quality of drying.

2. The creation of solar dryers is also of scientific and technical importance, as it contributes to the development of new technologies and methods of drying, as well as improving the efficiency of solar systems.

3. High quality products were obtained - dried products without preservatives and dyes, with good taste properties, with a high content of vitamins. Vitamin C is one of the most sensitive vitamins to the effects of high temperatures. As the results of tests on the vitamin composition of products before and after drying showed, the loss of vitamin C in dogwood dried in a solar drying device is 22%, and by natural drying - up to 43%. I.e., when drying dogwood in a solar dryer, the loss of vitamin C compared to natural drying is almost 2 times less. Increased shelf life of products with proper observance of storage conditions.

4. When drying products with a solar dryer, energy is saved, since the solar dryer runs on solar energy and does not require electricity or gas.

5. There is also no environmental impact. The use of solar dryers instead of traditional drying methods, which require the use of fuel, helps to reduce carbon dioxide emissions and other pollutants.

6. Studies have shown that the proposed solar dryer provides more efficient drying of medicinal plants of St. John's wort and mint, as well as dogwood, than traditional drying of these raw materials. The color of the dried products obtained was brighter and richer, and the smell and taste were more pronounced. This is due to the fact that this solar dryer provides a more uniform distribution of heat and humidity, which contributes to better drying. The research results indicate that the proposed solar dryer is an effective way of drying agricultural products, including medicinal plants.

7. At night (from 22.00 pm to 10.00 am), the drying speed in a solar dryer is higher (2-3 times) than natural drying in the open air.

8. The drying speed increases 3-5 times compared to traditional outdoor drying, and in the case of drying medicinal herbs by 21.3 times.

The use of a solar dryer ensures the sterility of products and allows you not to monitor the drying process.

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