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DETERMINING COMPARATIVE EFFICIENCY IN COMPOSITE FILM SOLAR DRYERS

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Abstract:

Objective. For the development of mobile structures of solar drying devices, it is proposed to use a composite film developed on the basis of functional ceramics as a transparent wall. Determination of comparative efficiency in terms of drying speed of products in each device on the basis of experimental studies on drying of fruits and vegetables in drying devices. To provide suggestions, explanations and conclusions based on the conducted research.

Methods. In the drying chamber, the conversion of solar radiation, i.e. exposure to the pulse to dehydrate the product to be dried by generating infrared rays.

An empirical formula for determining the dynamics of drying in radiation drying devices has been developed.

Results. Using the results of research conducted on drying devices, the comparative drying efficiency of devices for each product was determined.

Conclusion. Based on the research conducted on the drying of apples, grapes, cherries, onions and carrots in drying devices, the comparative efficiency and drying speed of the Composite-1 film solar drying device were found to be 25% to 67% more efficient than the traditional film solar drying device. Also, in the final stage of drying of products, the differences in safe moisture content determined by each device are presented, and an empirical formula for determining the dynamics of drying in radiation drying devices and a methodology for its use are developed.

Keywords: Composite-1 film, composite-2 film, conventional film, direct, comparative efficiency, speed, product.

Introduction. Since drying is now an important part of daily activities, this activity has become an integral part of many processes around us. Solar dryers have been developed in different sizes and designs depending on the requirements of different types of products to be dried. Among them, the simplest and cheapest type are direct, radiation solar dryers.

Working principle of direct solar dryers – In this type of solar dryers, sunlight falls directly on products placed in a chamber with a transparent wall. The relative humidity of the air decreases in the drying chamber. As a result, the moistened air is expelled from the chamber naturally or with an artificially created pressure difference. Dryers of this type are installed in places where there is no possibility of receiving direct sunlight during the main part of the day [1, p. 463].

Directly in the dryers, as a transparent body, for example, glass, various transparent plastics and polyethylene films are covered, which provides short-wave radiation, the light passing through the transparent body turns into long-wave radiation and increases the temperature of the air in the dryer. The materials used for the transparent coating usually do not allow long-wave solar radiation to escape. However, it is recognized that polyethylene films are less durable than glass, which means that polyethylene films are constantly adversely affected by wind and sun [2, p. 623].

Indian scientists conducted thermal modeling and experimental investigation of solar tunnel dryer. The tunnel dryer is covered with a 200 μm UV-stabilized plastic sheet and operates in free convection mode. The experimental energy and exergy efficiency of the drying chamber was found to be from 2.72% to 28.01% and from 69.43% to 90.76%, respectively [3, p. 211].

Indian scientists tried to evaluate the performance of a dryer developed for drying grapes. The study found that untreated grapes took seven days to dry at 16% (wb) moisture. The temperature gradient inside the tunnel dryer was about 10-28 °C during the open day. It was found that drying in open sun took more than 11 days [4, p. 269].

Indian scientists have developed multi-storey house-type solar dryer for drying vegetables. The relative humidity inside the dryer varied from 21% to 74% compared to the outdoor environment of 40% to 75%. The temperature inside the dryer was 62% to 76% above ambient conditions. dryer drying time reduction from 33% to 53% was achieved [5, p. 290].

Below is the comparative performance of proposed solar dryers using natural convection functional ceramic based composite films.

Methods. The mechanism of converting solar radiation energy into a pulsed infrared spectrum and effectively affecting the product is presented in detail in [6,7,8,9,10,11].

Empirical formula for determining drying dynamics in radiation drying devices was developed. This formula makes it possible to evaluate the drying efficiency of the device on the firs.

$$M_2 = \frac{1}{k}\frac{M_1 \lambda M_3}{tSI} \qquad (1)$$

M_2– residual weight (kg), M_1– initial product weight (kg), λ– average specific heat of vaporization of water (J/kg), M_3– total sugar content (kg), t– drying time (Seconds), S – the surface of the solar radiation receiving device (m^2), I– average daily value of cumulative solar radiation flux (J/m^{2}sec), k– drying coefficient.

Based on the empirical formula (1) above, the dynamics of construction of various products were determined, and the reliability of the formula was evaluated based on experimental studies.

For a detailed analysis of the comparative effectiveness of solar dryers with composite film, the results of experimental studies on drying products such as apples, grapes, cherries, vegetables, onions, tomatoes, and carrots are presented.

$$\eta = \left(\frac{\tau_1}{\tau_2} - 1\right) \cdot 100\% \qquad (2)$$

Based on the following expression, the relative efficiency of the devices in terms of drying speed is determined.

Here:

τ_1 – drying time until final drying, (hours, days)

τ_2 – time spent until final drying in an efficient drying device, (hours, days)

Results and discussions. The final drying results of apple drying are presented in Table 1 below[11,12].

Device type	Drying time, day						
	0	3	4	5	6	7	8
	Residual mass, %						
Composite-1	100	16	16	15	15	15	15
Traditional	100	19	18	18	18	17	17

Based on the data presented in Table 1 above, the relative efficiency in terms of drying speed was determined using expression (2).

In devices for drying apples, the final residual mass was 15% of the initial poured product. This value was reached in 5 days by the drying device using Composite-1 film according to Table 1. A drying device using conventional film reached 17% value in 8 days. The observed difference in drying rate between these two devices was 40% based on expression (6). As a result, when drying an apple with an average diameter of 3-4 cm in 4 parts to reach the final safe moisture, the drying device using Kompozit-1 was able to dry 40% faster than the drying device using traditional film.

Table 2 below shows the results of grape drying in drying devices[12,13,14].

Table 2

Device type	Drying time, day								
	0	16	17	18	19	20	21	22	23
	Residual mass, %								
Composite-1	100	24	23	23	23	22	22	22	21
Traditional	100	28	27	26	26	26	25	24	24

Based on the data presented in Table 2 above, comparative efficiency in terms of drying speed was determined.

When the residual mass is 24% of the initial poured product for drying grapes in the devices. This value was reached in 16 days by the drying device using Composite-1 film according to Table 2. A drying device using conventional film achieved this in 23 days. As a result, when drying grapes, the drying device using composite-1 film achieved 44% faster drying compared to the drying device using conventional film.

Table 3 below shows the results of a study on cherry drying [15].

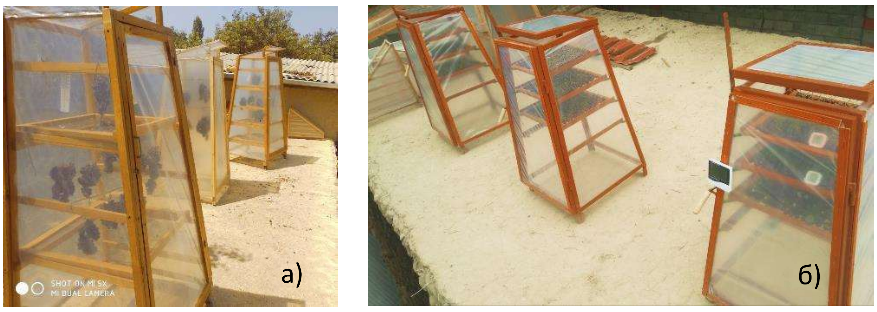
Table 3

Device type	Drying time, day								
	0	10	11	12	13	14	15	16	17
	Residual mass, %								
Composite-1	100	45	40	37	33	30	27	25	25
Composite-2	100	46	41	35	34	28	26	24	23
Traditional	100	44	40	35	31	28	25	24	23

Based on the results presented in Table 3 above, the comparative efficiency in terms of drying speed was determined.

In the devices for drying cherries, the residual mass was 25% of the original poured product. This value was reached in 15 days by the drying device using Composite-2 and Conventional film according to Table 3. This result was achieved in 17 days in a dryer using composite-1 film. There was no significant difference between the two devices with Composite-2 and Conventional film in terms of drying speed.

When comparing the drying speed of the drying device using the traditional film with the



drying device using the Composite-1 film, the efficiency of the devices was 13%.

a) drying of grapes is described, b) drying of cherries is described.

Figure 1. Experimental process

Below, the comparative effectiveness of drying vegetables in composite and traditional films is considered.

The final results of onion drying are presented in Table 4 below [16,17].

Table 4

Device type	Drying time, day							
	0	1	2	3	4	5	6	7
	Residual mass, %							
Composite-1	100	47	21	11	10	10	9	9
Composite-2	100	56	29	15	11	10	9	9
Traditional	100	54	27	14	12	11	11	11

Қурилма тури	Қуритиш вақти, сутка						
	0	1	2	3	4	5	6
	Қолдиқ масса %						
Композит-1	100	71	37	20	10	8	8
Композит-2	100	73	40	21	12	9	9
Ананавий	100	73	40	20	11	9	9

Очиқ қуёшда	100	72	47	31	17	10	10	
1		2	3	4	5	6	7	
	Residual mass, %							
Composite-1	100	47	21	11	10	10	9	9
Composite-2	100	56	29	15	11	10	9	9
Traditional	100	54	27	14	12	11	11	11

Based on the data presented in Table 4 above, the comparative efficiency in terms of drying speed was determined.

When the residual mass for drying onions in the devices reaches 11% of the initial poured product. This value was reached in 3 days by the drying device using Composite-1 film according to Table 4. And the drying device using traditional film reached in 5 days. The observed difference in drying rate between these two devices was 67% based on expression (6). As a result, the dryer using Composite-1 achieved 67% faster drying compared to the dryer using conventional film.

According to Table 4, the drying device using composite-2 film achieved a residual mass of 11% in 4 days. As a result, the drying device using Composite-2 achieved 25% faster drying compared to the drying device using traditional film..

According to Table 4, the drying device using Composite-1 film achieved 33% faster drying compared to the drying device using Composite-2 film.

The final drying results of tomato drying are presented in Table 5 below[18].

Table 5

Device type	Drying time, day						
	0	1	2	3	4	5	6
	Residual mass, %						
Composite-1	100	71	37	20	10	8	8
Composite-2	100	73	40	21	12	9	9
Traditional	100	73	40	20	11	9	9
In the open sun	100	72	47	31	17	10	10

Based on the data presented in Table 5 above, the comparative efficiency in terms of drying speed has been determined.

When the residual mass during drying of tomatoes in the devices reaches 10% of the initial poured product. This value was reached in 4 days by the dryer using Composite-1 film according to Table 4. When dried in the open sun, it reached this value in 5 days. As a result, 25% faster drying was achieved in the drying device using Kompozit-1 compared to drying in the open sun.

The final drying results of carrot drying are presented in Table 5 below[19].

Table 5

Device type	Drying time, day				
	0	1	2	3	4
	Residual mass, %				
Composite-1	100	36	13	11	11
Composite-2	100	46	15	11	11
Traditional	100	37	12	11	11

Based on the data presented in Table 5 above, the comparative efficiency in terms of drying speed has been determined.

When drying carrots in devices, the residual mass reaches 11% of the initial poured product. According to Table 4, this value was reached in 3 days in all three dryers. As a result, there is no significant difference between devices.

a) onion drying is described, b) tomato drying is described, c) carrot drying is described.

Figure 2. Experimental process

The above considerations are relative efficiency determined by drying speed.

Based on this research, the following recommendations are given.

Mobile solar dryers using composite film can be used in agriculture and large-scale production. Of course, devices of this type are highly efficient, cheap to develop, easy to repair, and easy to use..

The following are the specifications of the proposed composite film for use in solar dryers.

In dryers, the product under the composite film prevents overheating of the product to be dried compared to the product under the traditional film. That is, with the help of solar radiation energy generation, only the water content of the product is brought to a suitable spectrum.

Products dried in composite film dryers have significantly higher organoleptic (appearance, smell, taste, and self-recovery) characteristics compared to products dried in traditional film dryers [20], such devices can be used to obtain high-quality dried products. It should also be noted that there is a significant positive difference in the shelf life of dried products.

Positive results were also achieved in terms of duration of work. That is, the operating period of the Composite-1 film in the solar drying device is 3-4 times longer than that of the conventional film, and Composite-2 is 6-7 times longer, it was determined based on experiments.

Composite-1 film solar dryers can be used as high drying rate devices.

During drying under composite film solar dryers, there was no formation of mold inside the drying chamber or under the film.

Conclusion. A solar drying device was developed using a composite film;

Empirical formula for determining drying dynamics in radiation drying devices and methodology of use was developed. It has been determined based on experiments that the duration of operation of Composite-1 film in a solar drying device is 3-4 times longer than that of conventional film, and that of Composite-2 film is 6-7 times longer. It was found that the drying device using Composite-1 film in drying apples achieved 40% faster drying compared to the drying device using traditional film. When drying apples, it was determined that the composite film is more effective in removing moisture from the deep layers of the product compared to the traditional film, that is, the final moisture content is 15% in the Composite-1 film dryer and 17% in the traditional film dryer. When drying grapes using Composite-1 film drying device, it was found that 44% faster drying was achieved compared to drying device using traditional film. When drying grapes, it was found that the composite film is more effective in removing moisture from the deep layers of the product compared to the traditional film, that is, the final moisture content is 21% in the Composite-1 film dryer and 24% in the traditional film dryer. When drying onions, it was found that the drying device using Composite-1 achieved 67% faster drying compared to the drying device using traditional film. When drying onions, it was determined that the drying device using Composite-2 film achieved 25% faster drying compared to the drying device using conventional film. When drying onions, it was found that the drying device using Composite-1 film achieved 33% faster drying compared to the drying device using Composite-2 film. When drying tomatoes, it was found that the drying device using Kompozit-1 achieved 25% faster drying compared to drying in the open sun.

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