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IMPROVEMENT OF AIR-SOLAR APRICOT DRYING TECHNOLOGY IN HELIOTHEADERS

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Annotasiya: Buxoro Davlat Universiteti ilmiy laboratoriyasida quyosh qurilmalarida oʻrikni quritish uchun havo-quyosh texnologiyasi boʻyicha tajribalar oʻtkazildi. Taklif qilinayotgan quyosh tizimida tabiiy konveksiya xodisasi qoʻshimcha tirqishlar yordamida yaratiladi. Konsepsiyalar tanlandi, uning asosida hisoblash usuli ishlab chiqildi va toʻgʻridan-toʻgʻri quritgich elementlarining geometrik oʻlchamlari aniqlandi. Balandlik oʻlchovlarining uzunlikka va shunga mos ravishda quritgichning kengligiga nisbati formulasi aniqlandi va atrof -muhitdan havo oqimi uchun moʻljallangan tirqishlarning oʻlchamlarini aniqlash usuli ishlab chiqildi. kameraga va bugʻ-havo aralashmasining quritgich kamerasining ichki qismidan atrof-muhitga chiqishi uchun. Quritgich elementlarining oʻlchamlarini tanlashning bunday usullari ularning ishlashining maqbul rejimini yaratadi, shuningdek uning kamerasi ichida tabiiy konveksion havo aylanishini yaratadi. Ishlab chiqarilgan quyosh qurilmasida oʻtkazilgan tajribalar natijalari grafik jihatdan tahlil qilinadi.

Kalit soʻzlar: Havo-quyoshli quritish, quritish texnologiyasi, energiya tejamkorligi, quyosh radiasiyasi, quritish agentti, issiqlik quvvati, quyoshli isitish kamerasi, muvozanatli namlik.

Аннотация: В научной лаборатории Бухарского государственного университета проводились эксперименты по воздушно-солнечной технологии сушки абрикосов на солнечных установках. В предлагаемой солнечной системе явление естественной конвекции создается дополнительными заслонками. Выбраны концепции, на основе которых разработан расчетно-вычислительный метод и определены геометрические размеры элементов сушилки прямого типа. Установлена формула соотношения размеров высоты на длину и соответственно на ширину сушилки, также разработан метод определения размеров заслонок, предназначенные для поступления воздуха из окружающей среды вовнутрь камеры и для выхода паровоздушной смеси изнутри камеры сушилки в окружающую среду. Такие методы выборов размеров элементов сушилки создают оптимальный режим их работы, также создают естественную конвекционную циркуляцию воздуха внутри его камеры. Результаты экспериментов, проведенных на изготовленном солнечном устройстве, проанализированы графическим методом.

Ключевые слова: воздушно-солнечная сушка, технология сушки, энергосбережение, солнечное излучение, сушильный агент, теплоемкость, солнечная нагревательная камера, сбалансированная влажность.

Abstract: In the scientific laboratory of Bukhara State University, experiments were carried out on air-solar technology for drying apricots on solar installations. In the proposed solar system, the phenomenon of natural convection is created by additional shutters. Concepts were selected, on the basis of which a computational and computational method was developed and the geometric dimensions of the elements of a direct-type dryer were determined. The formula for the ratio of the dimensions of the height to the length and, accordingly, to the width of the dryer has been established, and a method for determining the dimensions of the dampers has been developed, designed for the flow of air from the environment into the chamber and for the exit of the vapor-air mixture from the inside of the chamber of the dryer into the environment. Such methods of choosing the sizes of the elements of the dryer create an optimal mode of their operation, and also create a natural convection circulation of air inside its chamber. The results of experiments carried out on the manufactured solar device are analyzed graphically.

Key words: air-solar drying, drying technology, energy saving, solar radiation, drying agent, heat capacity, solar heating chamber, balanced humidity.

Introduction. To use solar installations operating in different modes in the process of direct drying of fruits in Uzbekistan, it is necessary to study the following problems on a scientific basis:

- it is necessary to coordinate the optimal operating modes for the selected fruits, which requires the construction of each type of solar technology;
- Only after careful mastering of the technology of air-solar drying of selected fruits, it will be necessary to conduct an experimental study on which part of the drying process and at what time one of the solar devices can be used.

The research was based on the analysis of the experimental results obtained in the solar dryer created by the authors and their processing.

Literature review. The most efficient type of solar dryers are natural convection direct type dryers, which are easy to manufacture and use. These types of dryers do not use any auxiliary equipment, which protects the dried fruit from external contamination. Scientists from different countries have created different designs of such dryers and conducted research on them. In the studied works, additional devices were installed on the devices, which required electricity [1], [2], [3]. The authors [3] and [4] in their scientific articles focus on direct-type solar dryers with natural convection air circulation inside its chamber. These dryers are simple in design model and the most economical types. They do not use any auxiliary equipment and are cheap compared to other types of solar dryers.

Problem statement. Determining the optimal size of the solar dryer, drying apricots using the improvement of air-solar drying technology in solar devices, creating a natural convection phenomenon.

Research methodology. The dimensions of the solar dryer are selected according to the following formula: $\alpha = \frac{F_{dno}}{F_{ogr.}} = \frac{2,06}{4,94 + 2,06\frac{H}{L}}$

Fig. 1. Experimental direct type solar dryer.

Taking into account the utilization factor of the bottom of a solar dryer $\alpha = \frac{F_{dno}}{F_{ogr.}} = 0,36$ with the angles of an inclined surface in relation to the horizon (through which direct and scattered solar radiation comes) $\beta_1 = 38^o$, $\beta_2 = 52^o$, (taking into account the geographical latitude of the region), a solar dryer was developed and used for drying apricots. Figure 1 shows an actual view of an experimental direct type solar dryer.

To determine the kinetic dependence of the drying process, a combined view of the drying curves, drying speed $u(\tau)$, temperature of dried apricots $T_a(\tau)$ and drying materials $T_{a.c.}(\tau)$, as well as moisture content of drying materials $d_{a.c.}(\tau)$ and moisture content $U(\tau)$ of dried apricots is shown in Figure 2. The average daily moisture content of the drying agent is determined from the humid air i,d – diagram according to the recorded average values of daily relative humidity. The average daily temperature $T_{a.c.}(\tau)$ and humidity $d_{a.c.}(\tau)$ of the drying agent are shown in Figure 2 in the form of curves 1 and 2, and their dependence on the drying process time is shown. Figure 2 shows the average daily temperature $T_a(\tau)$ and humidity $U(\tau)$ ^oC of dried apricots in the form of curves 3 and 4, depending on the time of their drying process. Based on the above data, the average values of the daily drying rate of apricots per hour according to Dalton's law were determined [5]:

$$u = \frac{W}{F \times \tau}$$

u -Daily drying rate of apricots, *F*- surface, τ - time, *W*- Apricot mass.

Figure 2 shows a graph of the time $10^{-3} \times kg / м^2 \cdot s$ dependence of its drying process in the unit of measurement in the form of a 5 curved line.

Analysis and results. During the drying process, the average hourly average temperature (($T_{вх.}(\tau)$ and $T_{вых.}(\tau)$), and the relative humidity (($\varphi_{vx}(\tau)$ and $\varphi_{вых.}(\tau)$) of the drying agent were recorded at the inlet and outlet barriers in order to prove that the natural convection cycle of the dryer took place directly inside the solar dryer chamber. Table 1 shows the recorded results. Based on these data and using the humid air (i-d) diagram, the following were determined: hourly average density $\rho_{вых}(\tau)$, moisture content $d_{вых}(\tau)$, $d_{вх.}(\tau)$ and partial pressure of the drying agent at the incoming and outgoing barriers during the day $P_{вх..}(\tau)$ and $P_{вых.}(\tau)$ (Table 1).

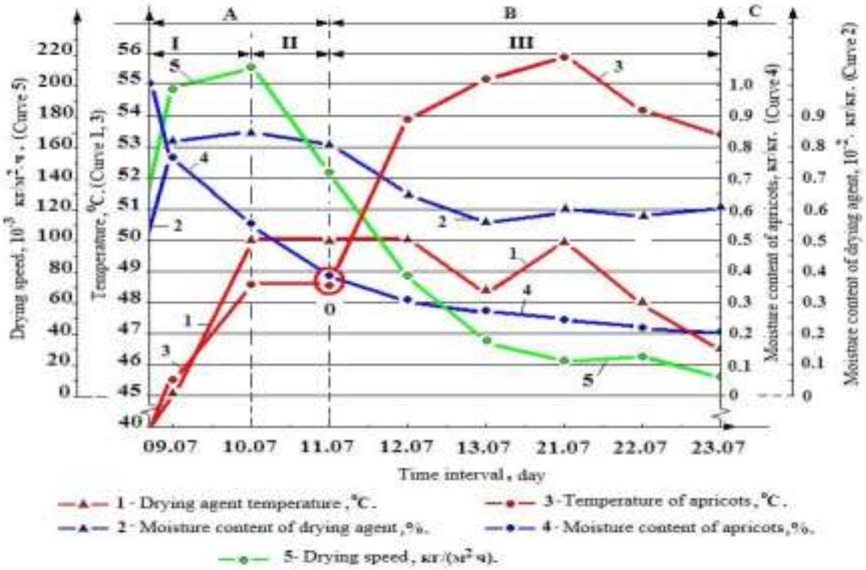

Figure 2 Stages of the apricot drying process and periods: A, B and C - wet, hygroscopic and balanced state of apricots, respectively;

1- Table

Recorded results of temperature and relative humidity at the inlet and outlet barriers of the dryer

№	Date of measurement	Relative humidity in the input barrier, %.	Relative humidity in the outlet barrier, %.	Inlet barrier temperature , oC	Outlet barrier temperature, oC	Partial air pressure in the inlet barrier, кPa.	Partial pressure of air in the outlet barrier, kPa.
	τ, кун	$\varphi_{вх.}$	$\varphi_{вых.}$	$T_{вх.}$	$T_{вых.}$	$P_{вх.}$	$P_{вых.}$
1	09.07.	21,6	32,6	40,1	46,9	3,2	3,4 (0,2)
2	10.07.	23,4	35,5	40,5	47,2	3,22	3,5(0,28)
3	11.07.	25,0	33,9	40,3	45,0	3,21	3,35(0,14)
4	12.07.	18,6	24,0	42,5	47,5	3,25	3,45(0,2)
5	13.07.	16,3	19,0	44,5	49,5	3,4	3,6(0,2)
6	21.07.	18.0	24.6	42,4	47,4	3,25	3,45(0,2)
7	22.07.	17.3	23.7	40,9	46,8	3,15	3,4(0,25)
8	23.07.	16.4	21.6	41,2	46,8	3,20	3,36(0,16)

Using the data obtained, the density and humidity of the drying agent at the inlet and outlet barriers, the average hourly air consumption for evaporation of moisture from the apricot during the day by the solar dryer are determined using the following formula [6]:

$$\Delta L = \frac{W}{\rho_{в} 0,001(d_{\text{introduction.}} - d_{\text{exit.}})}$$

The results of the calculation of air consumption during the day by the solar dryer for evaporation of moisture from apricots are given in Table 2.

Excluding the losses, the heat capacity of the drying agent was calculated by the following formula:

$$Q = \Delta L \cdot (P_{\text{introduction.}} - P_{\text{exit.}}).$$

The results of the calculation of the heat capacity of the drying agent and the production of thermal energy are given in Table 2.

By the nature of the interaction between the humidity of the dried apricot and the drying agent (Fig. 2), we determine the law of variation of the average moisture content and the average temperature of the dried apricot from the time of drying. According to the method proposed by the author [7], the drying process of apricots is divided into three stages: wet (A), hygroscopic (B) and equilibrium state (C) (Fig. 1).

Table 2

Determining the average air flow rate per hour to evaporate apricot moisture from a solar dryer

Measurement days	9.07.	10.07.	11.07.	12.07.	13.07.	21.07.	22.07.	23.07.
Dryer air consumption, m^3/h	699,1	212,6	97,4	76,1	35,2	15,2	15,9	8,4
Heat capacity, kJ/h	139,8	59,5	13,64	15,22	7,04	3,04	3,98	1,34
Heat energy generation, kJ (kV*s)	419,4 (0,12)	595 (0,17)	163,7 (0,045)	182,6 (0,05)	84,.5 (0,024)	36,6 (0,01)	47,81 (0,013)	16,1 (0,005)

Conclusions and suggestions. In the wet state (A) stage, the process of drying apricots continues mainly under the influence of sunlight from 09.07.2020 to 11.07.2020 with evaporation of moisture from the surface of apricots (top layers of apricot flesh) for 25 hours. It should be noted that at this stage the temperature of the drying agent is higher than the surface temperature $\approx 1,5^{o}C$ of the dried apricots and the ambient temperature $\approx 10^{o}C$. At this stage, the top layers of apricot flesh are dried. The moisture content of apricots reaches 40%.

In the hygroscopic stage (B), moisture evaporates from the inner layers of the apricot flesh. This phase lasts for 60 hours under the influence of sunlight from 12.07.2020 to 13.07.2020 and from 21.07.2020 to 23.07.2020. In this case, the reverse process, i.e. condensation and moisture absorption by the masses of the upper layers of dried apricots from the drying agent, can also be observed. It is noteworthy that the surface temperature of dried apricots at this stage is higher than the temperature $6^{o}C$ of the drying agent. In this case, the temperature of the apricot peel changes the quality of sensitivity.

In the second period of drying (II), when the drying rate decreases ($210\cdot10^{-3}kg/м^2\cdot s$ from $140\cdot10^{-3}kg/м^2\cdot s$), a heat balance (curve 1) is established between the amount of heat delivered to the apricot surface and the amount of heat used to evaporate the water. At the same time, the surface of the dried apricot remains moist, but the moisture comes from the inner layers of the apricot flesh through the capillaries.

The second stage of the drying process (B) corresponds to a period of decline $140\cdot10^{-3}kg/м^2\cdot s$ from $10\cdot10^{-3}кг/м^2\cdot c$ the full drying rate to. The reason why the temperature of the drying agent (curve 1) rises relative to the temperature on the surface of the dried apricot (curve 3) and the ambient temperature is explained as follows:

- Water vapor molecules in the drying agent receive additional energy due to the absorption of solar radiation by wavelengths $\lambda=(2,2-3,0)mkm;$ $\lambda=(4,8-8,5)mkm;$ $\Delta\lambda_3=(12-30)mkm;$;

- due to this energy the temperature of the drying agent increases with respect to the surface of the apricot and the ambient temperature [7].

REFERENCES

[1] Artikov A.A., Juraev H.F. Methodology of Computer Modeling of the Fruit and Vegatables Drying Processes " Asiya Pacifie Drying Conference, 1-3 September 2003, Asian Institute of Texnology, Bangkok, Thailand" 2003

[2] A. Madhlopa and G. Ngvalo, "Solar dryer with heat accumulator and backup biomass heater", Sol. Energy, pp. 449-462, 2007.

[3] Shafiq X, Ekwan M. R. Experimental study of direct and indirect solar biomass desiccant, Department of Mechanical Engineering, Themed Section: Engineering and Technology. National University IJSRSET Volume 3, Issue 5, Print ISSN: 2395-1990 Online ISSN: 2394-4099 . Malaysia. 2017.

[4] Chebotarev V.P. Theoretical study of the drying process of a fixed grain layer, Agricultural engineering. Metalworking. Russia 2017, 4s.

[5] Mikheev M.A., Mikheeva I.M. Fundamentals of heat transfer. Moscow 1977 "Energy". Second edition. Publishing House, From 182-193.

[6] Chouicha, S., Boubekri, A., Mennouche, D., Bouguetaia, H., Berrbeuh, MH, Bouhafs, S., and Rezzoug, W., "Study of valorization of processed Deglet-Nour dates, Solar drying using three different solar desiccants", India "Energy". 2014, pp. 907-916.

[7] Veselova N.M., Nekhoroshev D.D., Melikov A.V. Power plant for drying grain by means of solar energy, International Scientific Research Journal. Russia, 2017. No.8 (62) P.39-42.

[8] BMA Amer, M.A. Hossein and K. Gottschalk, Design and performance evaluation of a new hybrid solar dryer for bananas. India 2010, "Energy Convers. Manag., Volume 51, No. 4, pp. 813-820,.

[9] Akinola, A.O., Fapetu, O.P. Exergetic analysis of a mixed-mode solar dryer. Nigeria (2006). Journal of Technical and Applied Sciences, pp. 1, 205-210.

[10] Shafiq X, Ekwan M. R. Experimental study of direct and indirect solar biomass desiccant Department of Mechanical Engineering, Tenaga National University, Kajang, Selangor, Malaysia. Engineering and Technology. 2017 IJSRSET, Volume 3, Issue 5, Print ISSN: 2395-1990 , Online ISSN : 2394-4099

[11] Augustus Leon M., S. Kumar, S.S. Bhattacharya, A comprehensive procedure for evaluating the performance of solar food dryers, India (2002), Renewable and Sustainable Energy Reviews From 6(4), 367-39