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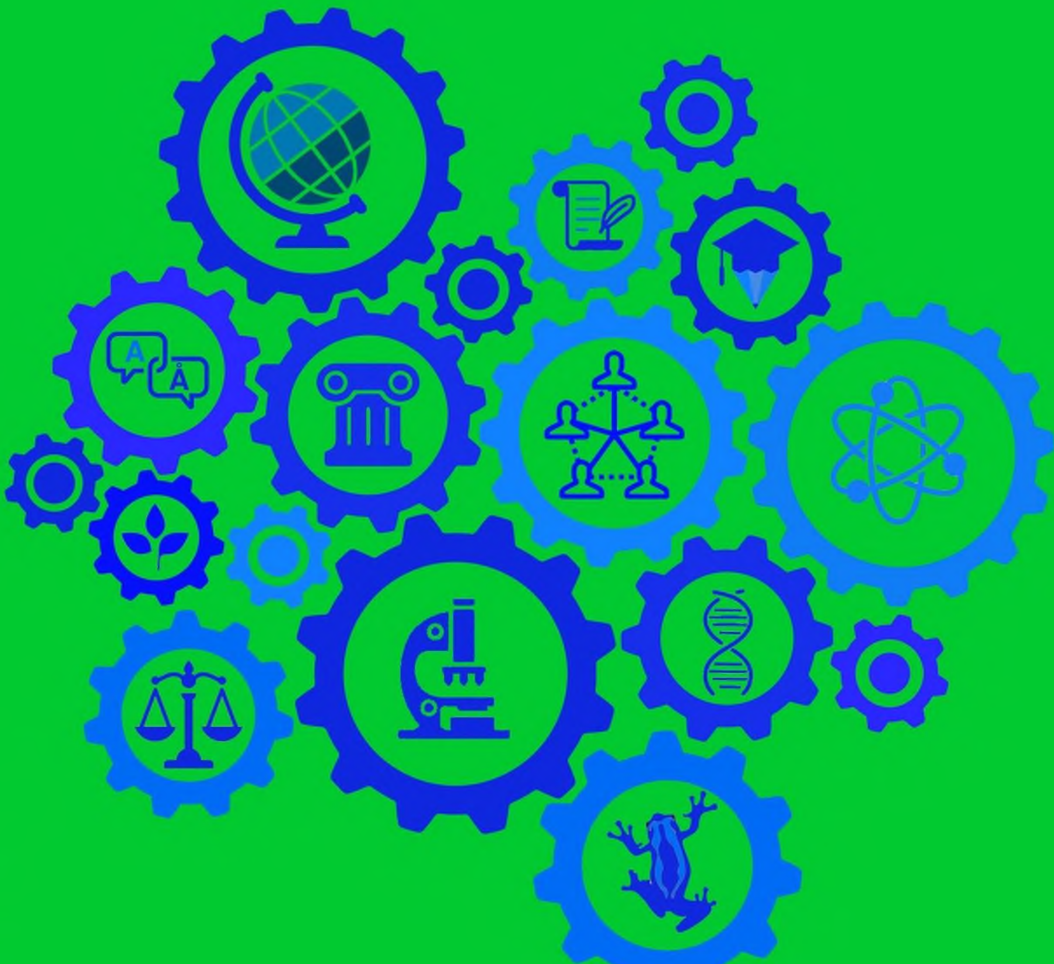

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METHODOLOGY FOR DETERMINING GEOMETRIC PARAMETERS OF ADVANCED SOLAR DRYER ELEMENTS

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Abstract: This article proposes a method for choosing the shape of a direct type solar dryer. As an example, a parallelepiped shape with non-isosceles triangular bases was chosen for a solar dryer. The working surfaces, from which solar radiation comes on the surface of the material to be dried, are inclined with respect to the horizon by 38 and 52 degrees, respectively, to the northern latitude of the region. Concepts were selected, on the basis of which a computational 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. This method of selecting the dimensions of the dryer elements creates an optimal mode of their operation, and also creates a natural convection air circulation inside its chamber.

Keywords: solar energy, solar radiation, working transparent inclined surface, parallelepiped with triangular bases, dried material, scattering solar radiation, solar dryer

On the surface of the Earth, the abundance of solar radiation forces the scientists of the world to renew them for the needs of mankind, which leads to energy saving and replacement of energy fuel in thermal technological processes.

Part of the solar radiation directed to the surface of the Earth, if we take it as 100%, from it: $\approx$5 % reflected from the surface of the Earth; $\approx$21% reflects off the surface of the clouds and air and returns to space (6%); $\approx$25% absorbed by the Earth's atmosphere; $\approx$23% dissipates in the atmosphere, but reaches the surface of the Earth; $\approx$27% directly reaches the Earth [1].

Based on this alignment of solar radiation, humanity needs to make the most of the part of the scattering solar radiation by the atmosphere and from $\approx$27% directly reaching the surface of the Earth [1,2].

The scientists of the world are faced with the task of researching and developing low-inertia installations operating on the basis of solar radiation with its maximum conversion into heat, electricity, etc. energy.

Direct-type solar dehumidifiers with natural convection circulation.

As noted in the work of the authors [3,4,5,6], in solar dryers with natural convection air circulation, the dried products are stored in hot boxes or in a drying cabin. The method of heating products is carried out directly, since solar radiation, penetrating through the transparent surface (lids) due to natural convection, heats the products to be dried [7,8].

To evaluate the different types of solar dryers and their various design improvement models, the authors of [9,10] recommend evaluating performance based on the following parameters:

- physical characteristics of the dryer: type; size and shape; drying capacity (loading density); area and number of trays; convenience of loading (unloading);

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- thermal characteristics of dryers: drying time (drying rate); dry air temperature and relative humidity; air consumption for drying products; dryer efficiency;

- quality of dried products: sensory (color, taste, texture, aroma) quality; nutritional properties; rehydration capacity; drying cost and payback period.

MS Sodha et al. [11,12,13] developed theoretical and experimental methods for researching a solar cabinet dryer. The results showed that on atypical summer days, the pulp of a mango fruit with an original moisture content of 95% dried up to 13% in 12 hours of sunshine. It is concluded that cabinet-type dryers are very useful at home for drying fruits and vegetables in underdeveloped developing countries. Modification of the typical design of the drying cabinet, which was equipped with a wooden chamber, is recommended by SI Ezekwem [14]. This chamber was used to regulate the direction of the incoming air into the dryer. A long plywood chimney was also provided to improve the natural convection of air inside the dryer chamber. This dryer is reported to have a drying speed of about five times faster than drying in the open sun.

Also E.O. Demodeke et al. [15] designed and manufactured a solar dryer with direct natural convection for drying tapioca. Through experiments, it was found that the initial and final moisture content was 79% and 10% raw, respectively. Ambient temperature 32oC and relative humidity 74% with daily solar radiation 13MJ / m2 · day. A dryer with a minimum collector area of 1.08 m2 was developed for the experiment.

SI Singh et al. Developed a solar dryer, which is a portable dryer with multiple shelves and intermediate heating. It consists of four main rack components with multiple movable glazing trays, a shade plate and a tray. The multi-deck rack tilts depending on the geographical latitude of the dryer. The dryer is portable with low cost making it cost effective. It can be used in home-based industries and hard-to-reach places [16].

From the above presented some scientific articles [10], it follows that a comprehensive study has been carried out on how solar dryers with natural air convection inside the chamber work in comparison with other types of dryers. It has been found that direct type natural convection dryers are the most cost effective type of solar dryers and are easy to manufacture and use. Dryers of this type do not use any auxiliary equipment, they protect the dried fruit from external contamination. This is the simplest form of dryers, easy to manufacture, use and more than cost effective. Also recommended: to further increase the efficiency of these dryers, it is necessary to apply to them various methods of improvement and modification of the design, such as drying fruits, heat storage units, etc. [ten].

Also, in the above articles, an increase in the temperature difference up to 9 ° C (the difference in the partial pressures of air and the vapor-air mixture) between the ambient air and the vapor-air mixture inside the dryer chamber was experimentally revealed. Due to the temperature difference, a natural convection circulation of the vapor-air mixture is created inside the dryer chamber, i.e. air from the environment enters the dryer chamber through the incoming dampers and the vapor-air mixture, and from the inner chamber of the dryer through the outgoing dampers is sent to the environment.

The disadvantages are the following:

Note that the reason for the increase in the temperature difference in the above solar dryers between the ambient air and the vapor-air medium inside the dryer chamber has not been established.

In the articles presented above, it was revealed that the geometric dimensions of the elements of solar dryers, including the dimensions of the hot box and the dimensions of the inlet and outlet dampers, were selected empirically.

It was found that in the above articles there is no formula for the physical mechanism of the process of drying fruits in direct solar drying plants.

Based on the above shortcomings, the purpose of this article is established:

- to establish computational and computational methods for determining the geometric dimensions of the structural model elements and determine the size of the barriers assigned to the incoming outside air and the outgoing steam-air mixture in direct-type solar dryers. Based on the calculation results, develop and experimentally investigate a solar apricot dryer. Reveal the formula for the physical mechanism of the sun drying process.

To determine the geometric dimensions of the elements of the structural model of solar dryers, it is necessary to adhere to the following conditions:

- it is desirable for solar radiation to fall perpendicularly onto the working transparent surface of the dryer;
- solar radiation that enters the internal space of the installation should be accumulated as much as possible by additional bodies (solid and liquid bodies) located inside the installation.
- the bottom of the installation should be maximally insulated from the environment (from the soil).

A method for choosing the geometric shape of a direct type solar greenhouse drying plant.

Due to the fact that agricultural products (especially fruits) are harvested on the day they are ripe, and their shelf life is short, therefore, solar dryers with maximum productivity are required. To fulfill this requirement, solar drying installations with a transparent surface are needed, along which solar radiation falls perpendicularly on the surface of the dried fruits or on the surface of the heat accumulator.

To do this, you need to know the following terrain parameters: latitude, where it is planned to install a solar dryer - φ, hour angle ω, solar declination angle δ, the angle of inclination of the working transparent surface to the horizon β and its azimuth of establishment [1].

Note that the perpendicular to the direction of solar radiation and the area of the working transparent surface of the solar dryer, the faster the battery accumulates the required amount of solar radiation. The authors of this article recommend, on December 21 (Total year), that the surface of the installation, which has an angle of inclination with respect to the horizon, should be considered as a working transparent surface. $\beta_2 = 90 - \varphi$, 21 June (Total year) as a working transparent surface, consider that surface of the dryer, which has an angle of inclination with respect to the horizon $\beta_1 = \varphi$ [1].

For example, the city of Bukhara, the Republic of Uzbekistan is located, and $\beta_1 = \varphi = 38^o$ in the northern latitude, then $\beta_2 = 90 - \varphi = 52^o$ (Fig.2). The change in the angle of solar declination for a given region during the year is $\Delta\delta = 52^o - 38^o \approx 14^o$. For this region, we choose a solar greenhouse dryer, which consists of two chambers: chamber I and chamber II (Fig. 2.).

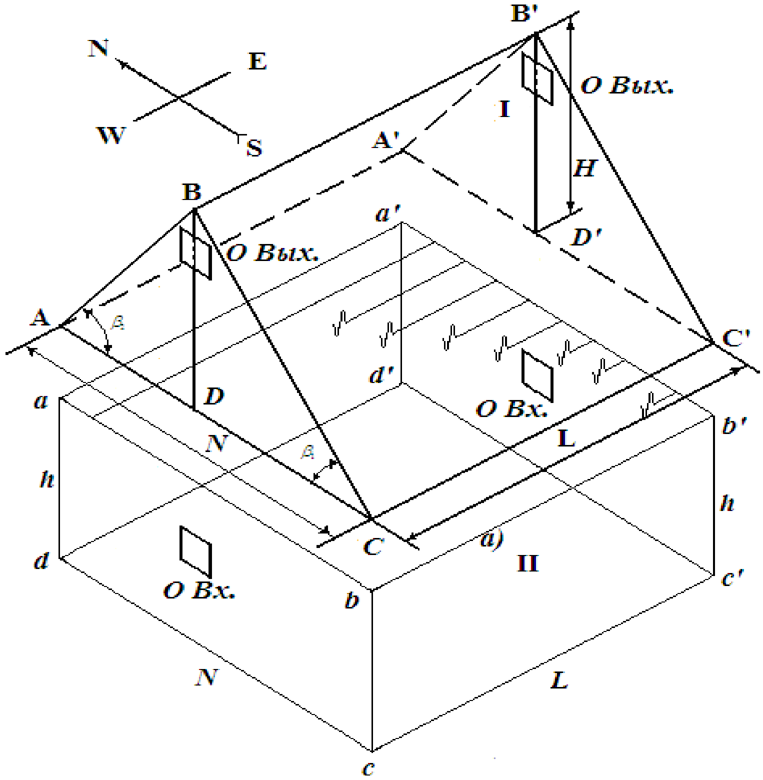

Fig. 1 Diagram of direct type solar drying plant for calculation.

Chamber I is made in the form of a parallelepiped with non-isosceles triangular bases ΔABC and $\Delta A'B'C'$ ($\angle BAC = 52^o, \angle BCA = 38^o$),also quadrangular side surfaces (work surfaces) $\square ABB'A'$, $\square BCCB'$ and the bottom of the chamber I $\square ACC'A'$. The parallelepiped is fenced with transparent material (except for the bottom $\square ACC'A'$). Two windows are inserted on each transparent surface of the triangular base of the parallelepiped: O Out. The windows are covered with a sieve. Working surface with an angle $\beta_2 = 52^o$ solar dryers on December 21 (whole year) are oriented towards the South, and on June 21 (whole year) they are oriented towards the North (Fig. 1).

Chamber II is made in the form of a parallelepiped with quadrangular bases: $\square abcd$; $\square a'b'c'd'$. The parallelepiped is fenced with transparent material on all sides (except for the side $\square aa'bb$). Surface $\square dd'c'c$ heat insulated from the horizontal surface of the Earth (from the soil of the Earth). Two windows are inserted on each transparent surface of the quadrangular base of the parallelepiped: O Bx. The windows are covered with a sieve.

Chamber I and Chamber II with their surfaces $\square ACC'A'$ и $\square a'b'c'd'$ are connected to one single direct type solar drying unit. Partitions are installed between the two chambers, in which the materials to be dried are placed. The frame of both chambers and partitions is made of wooden materials (wooden blocks) (Fig. 1).

Calculation and computational method for determining the geometric dimensions of the elements of the structural model of direct solar drying plants.

To increase the productivity or thermal efficiency of solar drying plants, it is necessary to select the optimal geometric dimensions of the structural model elements. In this regard, the authors of this article propose a computational method, which is based on the concept of a steady heat balance [17] between the surface area of the heat accumulator (dried material) and the area of the enclosed transparent surface of the solar dryer for determining the geometric dimensions.

For the calculation, we select a structural model of a direct-type solar drying plant, which consists of two interconnected chambers: solar-heated chamber I; air supply chamber II (Fig. 2.).

Solar heated chamber I of the dryer.

The chamber of the solar-heated chamber I of the drying installation is selected in the form of a parallelepiped, with the bases of a non-isosceles triangle (Fig. 2).

After that, its frame is created from wooden bars or metal rods. The frame of chamber I is covered (shielded) with a transparent material (polyethylene, etc.). The fruits to be drained are placed at the bottom of chamber I.

One of the corners β_1 an inclined surface in relation to the horizon, we choose equal to the geographic location of the region $\varphi = \beta_1 = 38^o$. The second angle of the inclined surface in relation to the horizon is chosen $\beta_2 = 90 - \varphi = 52^o$.

Let us assume that direct solar radiation comes along an inclined working surface with an area $F_{BB'C'C}$ into the inner part of chamber I of the setup, scattered solar radiation enters along an inclined surface with an area $F_{ABB'A'}$ and along the side walls with areas F_{ABC} and $F_{A'B'C'}$. Along the bottom of chamber I of the installation with an area $F_{ACC'A'} = F_{дно}$, we will assume that no solar radiation is received.

Based on the chosen concept between the surface of the materials to be dried $F_{дно}$ и enclosed transparent surface $F_{дно}$ chambers I of a solar dryer, determine the utilization factor α bottom of chamber I:

$$\alpha = \frac{F_{дно}}{F_{огр.}}. \qquad (1)$$

Calculate the surface area of the solar-heated chamber I of the dryer (Fig. 2):

$$F_{ACC'A'} = F_{дно} = HL \cdot \left(\frac{tg\beta_1 + tg\beta_2}{tg\beta_1 \cdot tg\beta_2} \right) \text{ - bottom surface area;} \qquad (2)$$

$$F_{ABB'A'} = \frac{HL}{\sin\beta_2} \text{ - ramp area } ABB'A'; \qquad (3)$$

$$F_{BB'C'C} = \frac{HL}{\sin\beta_1} \text{ - ramp area } BB'C'C; \qquad (4)$$

$$F_{ABC} = F_{A'B'C'} = \frac{H^2}{2}\left(\frac{tg\beta_1 + tg\beta_2}{tg\beta_1 \cdot tg\beta_2} \right) \text{ - side wall surface area;} \qquad (5)$$

$$F_{огр.} = F_{дно} + F_{ABB'A'} + F_{BB'C'C} + 2F_{A'B'C'} =$$

$$= HL \cdot \left(\frac{tg\beta_1 + tg\beta_2}{tg\beta_1 \cdot tg\beta_2} \right) + \frac{HL}{\sin\beta_2} + \frac{HL}{\sin\beta_1} + 2 \cdot \frac{H^2}{2}\left(\frac{tg\beta_1 + tg\beta_2}{tg\beta_1 \cdot tg\beta_2} \right)$$

- the area of the enclosing surface of the installation. (6)

Substituting the value of expression (2) - (6) into expression (1), we obtain the formula for determining the utilization factor of the bottom of the chamber

$$\text{I:} \ \alpha = \frac{F_{дно}}{F_{огр.}} = \frac{HL\left(\frac{tg\beta_1 + tg\beta_2}{tg\varphi_1 \cdot tg\varphi_2} \right)}{HL\left(\frac{Sin\beta_1 + Sin\beta_2}{Sin\beta_1 \cdot Sin\chi_2} \right) + HL\left(\frac{tg\beta_1 + tg\beta_2}{tg\beta_1 \cdot tg\beta_2} \right) + H^2\left(\frac{tg\beta_1 + tg\beta_2}{tg\beta_1 \cdot tg\beta_2} \right)}. \qquad (7)$$

Where, $H -$ height, $L -$ the length of the chamber I of the solar drying plant.

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We select the initial data of the angles of the inclined surface of the installation $\beta_1 = 38^o$, $\beta_2 = 52^o$ and set the dependence of the utilization factor of the bottom of the chamber I α from H and L:

$$\alpha = \frac{F_{дно}}{F_{огр.}} = \frac{2{,}06}{4{,}94 + 2{,}06\frac{H}{L}}. \quad (8)$$

By formula (8) it follows:

- upon choosing the condition: $H = 0$, chamber I takes the shape of a parallelepiped (with quadrangular bases), i.e. instead of chamber I, only chamber II can be used, then the maximum value of the bottom utilization factor is set $\alpha_{мак} = 0{,}417$;

- upon choice of condition: $\frac{H}{L} = 1$ or $H = L$ set the minimum value of the bottom utilization factor

$\alpha_{мин} = 0{,}294$;

- upon choosing the condition: $\frac{H}{L} > 1$, or $H > L$, the value is set $\alpha_{мин} < 0{,}294$;

Thus, the value of the utilization factor of the bottom of the proposed chamber I of the dryer is set in the interval $\alpha = 0{,}294 \div 0{,}417$.

For example. we will order a direct type solar dryer (Fig. 3 a)) with an average utilization rate $\alpha_{ср.} = 0{,}36$ and height $H = 0{,}75 м$, then by formula (8) we determine the value L:

$$L = \frac{2{,}06 \cdot \alpha_{ср.} \cdot H}{2{,}06 - 4{,}94 \cdot \alpha_{ср.}} = \frac{2{,}06 \cdot 0{,}36 \cdot 0{,}75}{2{,}06 - 4{,}94 \cdot 0{,}36} \approx 2{,}10 м. \quad (9)$$

Camera width I N as a segment AC drying installation, using Figure 2, we find as follows:

$$N = AC = AD + DC = \frac{H}{tg52} + \frac{H}{tg38} = \frac{0{,}75}{1{,}28} + \frac{0{,}75}{0{,}78} = 1{,}55 м. \quad (10)$$

Определим площадь поверхности дна камеры I сушилки с высотой $H = 0{,}75 м$ и длиной $L = 2{,}1 м$, где размещаются осушаемые материалы :

$$F_{дно} = L \cdot M = 2{,}1 м \times 1{,}55 м = 3{,}255 м^2. \quad (11)$$

If the materials to be dried have their own average dimensions $36 мм \times 33 мм \times 30 мм$, then one apricot at the bottom of chamber I occupies the area $f = 1188 мм^2 = 1188 \cdot 10^{-6} м^2$. Number of apricots (n) occupying the surface area of the bottom of chamber I $F_{дно} = 3{,}255 м^2$ defined like this:

$$n = \frac{F_{дно}}{f} = \frac{3{,}255 м^2}{1188 \cdot 10^{-6} м^2} \approx 0{,}003 \cdot 10^6 = 3000 шт.$$

If the average weight of one apricot $m_o = 23г \div 26г$, then the weight of the material to be dried in the amount $n = 3000 шт$ will be equal $m = n \cdot m_o = 3000 \cdot 25г = (75 - 80)кг$.

Thus, on the surface area $F_{дно} = 3{,}255 м^2$ chambers I of the dryer can be placed $m = (75 - 80)кг$ dried apricots.

Air supply chamber II of the dryer.

The air supply chamber II of the dryer is chosen in the form of a parallelepiped, with the bases of a quadrangle. The dimensions of chamber II are chosen as follows: width M and length L (which are equal to the width and length of chamber I); chamber height I h is defined as follows.

To set the size of the height h chamber II, we agree that the volume of chamber I (V_I)equal to the volume of chamber II (V_{II}), т.е.:

$$V_I = V_{II}. \tag{12}$$

From Figure 2 a) it is necessary to determine the volume of the chamber I (V_I):

$$V_I = L \cdot S_{ABC} = \frac{H^2}{0{,}968} = \left| H = 1м^2, L = 2{,}18м \right| = 2{,}25м^3. \tag{13}$$

From Figure 2 b) the volume of chamber II should be determined (V_{II}):

$$V_{II} = L \cdot M \cdot h = \left| L = 2{,}18м, M = 2{,}07м \right| = 4{,}51 \cdot h \cdot (м^3). \tag{14}$$

From conditions (6) we set the size of the height h cameras II:

$$2{,}25 = 4{,}51 \cdot h,$$

$$h = \frac{2{,}25}{4{,}51} = 0{,}49{,}9 \approx 0{,}5м.$$

We recommend installing two dampers in the side walls of chamber I of the direct type solar dryer, one oriented to the west and the other to the east. The other two dampers are in the side walls of chamber II of this dryer, one is oriented to the west, and the other to the east.

Dampers installed in the side walls of chamber II are designed to allow air from the environment to enter into chamber II. Dampers installed in the side walls of chamber I are designed to release the vapor-air mixture from chamber I. into the environment.

Taking into account the geographical latitude of the regions where it is planned to install a direct-type solar dryer, a method for choosing their shape has been identified. As an example, a parallelepiped shape with non-isosceles triangular bases was chosen for a solar dryer. The working surfaces, from which solar radiation comes on the surface of the material to be dried, are inclined at angles of 38 and 52 degrees, according to 38 degrees north latitude.

In this article, concepts have been selected, on the basis of which a computational computational method has been developed for determining the geometric dimensions of the elements of a solar dryer. The ratios of the dimensions of the height to the length and, accordingly, to the width of the direct-type solar dryer have been established, and a method for determining the dimensions of the dampers has been developed, intended 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 into the environment.

This method of sizing solar dryer elements creates an optimal mode of their operation, and also creates natural convection air circulation inside its chamber.

In order to make a direct type solar dryer, building materials are required: wooden blocks with cross-sectional dimensions; polyethylene films; wooden trays for placing the materials to be dried into the drying chamber.

Literature.

1. https://solarsoul.net/orientaciya-i-ugol-naklona-solnechnyx-kollektorov. Ориентация и угол наклона плоских солнечных коллекторов. Опубликован 27 декабря 2016 г.

2. https://core.ac.uk/download/pdf/39691439.pdf. Курейчик Е.П. Закономерности распределения солнечной радиации по поверхности Земли. Белорусский национальный технический университет. Автор: ЕП Курейчик - 2013.

3. Абунде Неба Ф. Джиокап Ноно Й. Моделирование и имитация дизайна: новая модель и программное обеспечение гибридной сушилки солнечной биомассы. Comput. Chem. Англ., Т. 104, с. 128-140, 2017.

4. Мадхлопа А. Нгвало Г. Солнечная сушилка с тепловым аккумулятором и резервным нагревателем биомассы. Sol. Энергия, т. 81, нет. 4. С. 449-462, 2007.

5. Ratti C. Mujumdar A.S. Солнечная сушка пищевых продуктов: моделирование и численное моделирование. Sol. Энергия, т. 60, нет. 3-4, pp. 151-157, 1997.

6. Яссен Т.А. Аль-Кайем Х.Х. Экспериментальное исследование и оценка гибридной солнечной тепловой сушилки в сочетании с дополнительная сушилка для рекуперации. Sol. Energy, том 134, стр. 284-293, 2016.

7. Бахер Махмуд А. Амер. Хоссейн М.А. Готтшалк К. Конструкция и оценка производительности новой гибридной солнечной сушилки для бананов. Energy Convers. Manag., Том 51, № 4, стр. 813-820, 2010.

8. Акинола А.О. Фапету, О.П. (2006). Эксергетический анализ солнечной сушилки смешанного режима. Журнал технических и прикладных наук, 1, 205–210.

9. Шафик Х. Экван М.Р. Экспериментальное исследование прямого и косвенного солнечного осушителя биомассы. Департамент машиностроения, Национальный университет Тенага, Каджанг, Селангор, Малайзия. 2017 IJSRSET | Volume 3 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN: 2394-4099 Themed Section: Engineering and Technology.

10. Пранав К. Фадке. Валке П.В. Криплани В. М. Прямой тип природная конвекция солнечная сушилка: обзор. International Journal Of Advance Research In Science And Engineering http://www.ijarse.com IJARSE, Vol. No.4, Issue No.02, February 201.ISSN-2319-8354(E).

11. Атул Шарма. Чен С.Р. Нгуен Ву Лан. Системы осушения солнечной энергии: обзор. Обзор возобновляемых и устойчивых источников энергии 13 (2009) 1185–1210.

12. Огастес Леон М. Кумар С. Бхаттачарья С.С. Комплексная процедура оценки производительности солнечных сушилок для пищевых продуктов, Обзоры возобновляемой и устойчивой энергетики 6 (2002) 367

13. Содха М.С. Данг А. Бансал П.К. Шарма С.Б. Аналитическое и экспериментальное исследование сушилки на открытом воздухе и сушилки шкафного типа. Управление преобразованием энергии 1985; 25 (3): 263–71.

14. Ezekwe C.I. Сушка урожая с помощью солнечных нагревателей в тропической Нигерии. ISES, Форум «Солнечный мир», Брайтон, Великобри-тания. Оксфорд: Pergamon Press; 1981, стр. 997– 1005.

15. Diemuodeke I. Проектирование и изготовление сушилки с прямой естественной конвекцией для тапиоки. Электронный журнал практик и технологий Леонардо ISSN1583-1078; Выпуск 18, январь-июнь 2011 г. с. 95-104.

16. Сингх С. Сингх П.П. Дхаливал С.С. Портативная солнечная сушил-ка с несколькими полками. Возобновляемая энергия 2004; 29: 753–65.

17. Шобхана Сингх. Субодха Кумара. Сравнительное исследование тепло-вых характеристик солнечных осушителей косвенного и смешанного режима. Центр энергетических исследований, Индийский технологический институт, Дели, Индия. Международный журнал устойчивого развития энергетики (МЖУРЭ). Том 1. Выпуск 1. Июнь 2012.

18. Гибин И.С. Котляр П.Е. Модели абсолютного черного тела. Успехи прикладной физики. 2019.Т.7. №2 с.188.