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Development and calculation of technological schemes of vacuum-solar dryers

B P Shaimardanov[1], A P Tajimuratova[1], P Berdimurodov[1], M Q Asrorova[2] J B Khujamkulov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent Uzbekistan
[2]Gulistan State University

E-mail: a.tajimuratova@polito.uz

Abstract: the article contains the results of research on methods of construction of drying installations for drying vegetable products. The developed technology and design of the vacuum-heliodilator and process of drying food products. Substantiated parameters of the design and drying regime.

1. Introduction

Drying is one way to preserve vegetables. During drying, most of the moisture contained in them is removed, concentration of cell juice increases and osmotic pressure increases several times, as a result of which development of microorganisms becomes impossible, biochemical processes stop. Moisture content in vegetables is reduced to 12-14% [1].

Main nutrients are well preserved in vegetables with correct drying technology and their calorie content increases (the dry matter content reaches 88%). All types of vegetables can be dried, but the most often used are cabbage, carrots, beets, onions, green peas.

Vegetables to be dried must be of good quality, standard; it is preferable to use varieties with a large amount of dry matter. The drying speed also depends on the degree of grinding. Basically, products are prepared, as well as for thermal sterilization: they are sorted, calibrated, washed, inedible parts, scales, skin are removed and crushed.

Blanching is of great importance in preparation for drying. Blanching speeds up the drying process inactivates enzymes, as a result of which the color of vegetables changes slightly, and the loss of vitamins is reduced. Cabbage, carrots, beets are blanched almost until tender. We can blanch before and after grinding. When blanching chopped vegetables, the losses increase, when blanching with steam, the losses are lower than when blanching in hot water. Vegetables rich in essential oils do not blanch. These include onions, garlic, parsley, parsnips, celery, all spicy herbs [2].

Thus, Savoy and Brussels sprouts are unsuitable for pickling, but are used for drying. Before drying, Savoy cabbage is cleaned, crushed (chopped). Heads of Brussels sprouts are cleaned of spoiled leaves, washed, cut in half, blanched for 2-4 minutes. Cabbage is dried at a temperature of 50 - 60 ° C with the obligatory use of ventilation. Dried cabbage should have a moisture content of no more than 14%. Dried cabbage is hygroscopic and should be stored in a cool and dry place.

Along with artificial drying in areas with high air temperatures (Central Asia), solar drying is used for melons and watermelons. Sometimes shade drying is carried out (under a canopy). The material prepared for drying is placed on trays and placed on the ground of the platform or on low racks, can be dried on roofs or in special containers made in the form of a bookcase and closed from insects with a nylon mesh or gauze. Drying speed increases if vegetables are placed in well-ventilated areas. The initial stage of drying is the most critical. Care must be taken to ensure that the vegetables do not grow moldy or rot. The first stage of drying should take place in a shorter time.

Packaging and storage of dried vegetables. Dried vegetables are best stored at low temperatures, close to 0 ° C; it should be remembered that dried vegetables are hygroscopic and must be protected from moisture (relative humidity not higher than 60-65%). It is best to store dried vegetables in a metal sealed container. It can also be stored in plywood drums. From the inside, the drums are lined with parchment or waxed paper. The container must be clean, dry, and free of foreign odors, disinfected from pest eggs that damage dry vegetables.

Drawing up a technological scheme of a vacuum-helium dryer. The oldest, simplest and most common way of harvesting fruits and vegetables for future use is drying them. We can dry fruits and vegetables in the sun, in the air, in ovens, in ovens, as well as in specially equipped devices.

When dried, they release most of the water contained in them and significantly decrease in mass and volume. The concentration of sugar and other nutrients increases. Properly dried fruits and berries are extremely valuable and persistent food products. We can consume them at any time of the year. However, their aroma and color are often lost.

Solar-air drying is the cheapest way of harvesting fruit for future use. This method can be used to dry all cultivated and wild fruits, vegetables, spices, medicinal raw materials, etc. Only the drying regime and preparation of raw materials differ. At low temperatures and slow drying, nutrients and aromas are better preserved. At the same time, the quality of the finished product is slightly worse than with artificial drying, since the process takes several days, and the product is contaminated with dust [3].

At night or in rainy weather, trays and trays with fruits and vegetables are removed under a canopy, stacked, covered with foil, and, if necessary, dried in ovens, dryers, ovens.

If there are rainy days during the sun-air drying, then mold may appear on the fruits, or they begin to rot. To avoid this, before drying, the fruits are treated with a saline solution (200 grams of salt per bucket of water) or fumigated with sulfur dioxide. Fumigation speeds up drying, the fruits brighten and are not contaminated by insects.

Air-shade drying is carried out in a well-ventilated area, and in good weather - outdoors, but in the shade, under a special canopy. It is mainly used for drying grapes, drying plums, cherries and other fruits before drying, for drying fruits, as well as for drying medicinal raw materials.

Heat drying with artificial heating provides for a specific temperature regime for each type of fruit and vegetables. Basically, they are dried at a temperature of 70-90 ° C. Before drying, the fruits must be sorted, removing poor-quality ones, washed, blanched and fumigated.

Blanching destroys the bulk of microbes, removes wax deposits, which significantly speeds up drying. Fruits and vegetables decrease in volume, which makes it possible to use special containers more economically, become softer, and easier to stack, because air is partially displaced from the tissues. [4, 5]

During blanching, the natural color is retained, but part of the food components - sugar, vitamins, minerals, etc. are lost. Such losses are reduced when blanching with steam. The quality of finished products from blanched fruits is always higher also because dried fruit pests can not contaminate them.

Prepared fruits are placed in a colander, dipped in boiling water or in a special solution. So that the water does not cool down instantly, which will reduce the blanching effect, its volume should be 3 times the volume of the submerged fruits. Depending on the type, the fruits blanch from a few seconds to 20 minutes. Then they are taken out and immediately doused with cold water. When the water drains, we lay it out to dry.

Sugar is sometimes added to the water during blanching (for example, for pears), as well as salt or baking soda (for plums, grapes, etc.).

Fumigation with sulfur is used for drying mostly whole fruits (less often halves), which have a fairly dense pulp. For this, wooden, adobe, concrete and other rooms and chambers are prepared, the walls of which must be impervious to gas (they can be coated with clay again). We can also use tents made of thick tarpaulin impregnated with a gas-waterproof compound. The room must be hermetically sealed. After loading it with fruits, put on a gas mask, install the braziers in the intended place and pour sulfur-free arsenic (200 grams per 100 kilograms of fruit) on the preheated coal in a uniform layer. When the sulfur flares up well, the door of the room is tightly closed, the remaining cracks are sealed with paper or covered with clay. We can also fumigate in cellars, if they are sealed, or in smoking chambers.

When sulfur burns out, as can be seen through viewing window, room is left closed for a while, so that sulfur dioxide gas penetrates well enough into all boxes and has a preserving effect on the fruits. Apples and pears stand 15-18 hours, cherries, sweet cherries, dogwood - 14-16, apricots, strawberries - 4-10 hours, etc. After fumigation, they are immediately laid out for drying. [6,7].

We can enter the room only 2-4 hours after airing and only wearing a gas mask, because the gas remains in the lower part of the chamber for a long time. Ventilation is accelerated by a fan installed in front of the door [8, 9].

A variety of simple devices are used for drying: trays, trays, sieves, sieves, nets made from thin dry boards, plywood, cardboard, tin, sanded willow rod, etc.

Most popular are wooden and plywood trays, sieves and trays. For air circulation, the bottom is made of lattice slats with a clearance of 3-4 centimeters. We can also stretch metal mesh, burlap, or rare fabric by attaching it with straps to prevent sagging.

On the garden plot, We can build the simplest drying area by choosing a well-ventilated and sunlit area, hammering several stake-pillars into the ground, onto which slats are stuffed from above with a slope to the south. Trays are placed on them or they are upholstered with sacking. At night, the fruits are covered with foil.

Sheet metal can be used to make a solar dryer with a pipe, door and sieve insertion attachments. The box is painted black.

Drying frames are very convenient, on which they stretch up to 15 rows of wire, stringing up to 15 kilograms of apples on them. Many more rows of wire can be made on a wooden frame wall. [8]

Citizens often dry apples and eggplants by cutting them into circles and stringing them on a line or string, on windows or balconies. In apartments, the fruits can be dried in gauze bags by sewing them along the length of the heating battery. Apples cut into slices or circles are poured into such a bag, tied, and then straightened on the battery so that the thickness of the apple layer is no more than a centimeter.

A faster way to prepare dried fruit is to use ovens and ovens. There are dryers with a permanent stove - an oven next to the firebox. It is convenient to drown them with sawdust. Along with smoking meat products, smokehouse-dryers can be used to dry vegetables, fruits and mushrooms. [9]

Description of the technological process of heliodrying

The product we offer for drying is a melon. In this work, we will dry the melon mass with jam. From one ton of melon, 300-350 kg of melon mass is obtained. The resulting mass is considered natural, since no crystalline sugar is added to it, it contains about 60-70% of dry matter, of which 40-50% is sugar. The colors are yellow, orange and dark orange.

We recommend installing a mini-shop at the places where melons are grown, i.e. in the countryside.

To save electricity, we propose to use solar energy, since the ripening and processing season coincides with the period of the greatest intake of solar radiation.

General view of the schematic diagram of the technological process

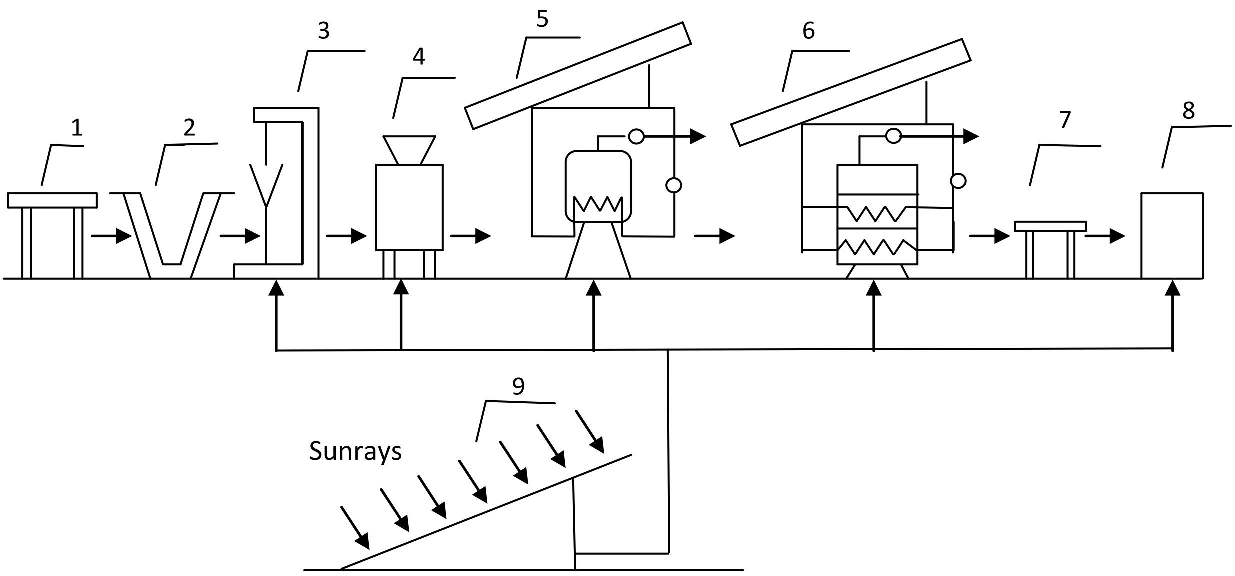

Figure 1. Technological diagram of the heliodrying process. 1-Acceptance of raw materials; 2-Cleaning, sorting, inspection of raw materials. 3-Separating the pulp from the seeds and rind using cutting and rubbing; 4-Obtaining a homogeneous dispersion by the homogenization method; 5-Removal of moisture and harmful substances by evaporation of the resulting pulp; 6-Vacuum drying using solar energy of a pasty semi-finished product; 7-Packing and packing of finished products; 8-Storage for finished products; 9-Collector.

Description of the technological process:

Reception of raw materials - raw materials are transported from the field in tractor trolleys and collected near the proposed mini-workshop. For the reception of raw materials, the organoleptic characteristics of the raw materials are determined. Organoleptic indicators are determined in the following sequence: appearance, color, smell, texture and taste.

Cleaning, sorting and inspection of raw materials - we offer trough water conveyors for washing raw materials. They clean the raw materials from sands and other harmful substances. After cleaning, the raw materials are sorted.

The most time-consuming technological operations in the melon processing technology is the peeling of the fruit, followed by the isolation of seeds and the separation of the pulp. For this purpose, specially designed machines are used with low energy consumption (3.2 ... 3.5 kWh / t). The machine can process up to 7 tons / hour of fruit.

The resulting pulp is converted into a homogeneous dispersion using a homogenizer. This process is very beneficial for us, since bound water loses its strength and is easily dehydrated.

The dispersion mass is placed in an evaporator and moisture and harmful substances are removed. Our proposed scheme of the evaporator is powered by solar energy. The water is heated to 70 ° C and enters the evaporator through a heat exchanger.

We put the resulting mass in a hot state on special pallets and put it in a solar vacuum dryer. To rationalize the energy supply, it is proposed to use the preliminary heating of the material before the vacuum is switched on. In this case, the temperature of the heaters should not exceed 50 ° C in order to avoid the activation of oxidative processes.

To improve the drying process, we use a vacuum pump, which will improve the quality of the dried product and the drying process. In the dryer, pasty masses are dehydrated to 10%.

Dried products are packed in special sealed containers and the finished products are sent to storage [11].

Calculation of the technological scheme of a vacuum-helium dryer. Calculation of the solar water heater. Much attention is paid to the method of optical and thermal calculations, as well as to the analysis of factors affecting the efficiency and operating mode of solar water heaters. The heat balance of a solar water heater is determined by the formula:

$$Q_{fal} = Q_{pass} + Q_l + Q_{li} + Q_g$$

where Q_{fal} - the solar energy falling on the surface of the installation;

Q_l, Q_{li}, Q_g - energy losses during the passage of solar radiation through the cover of the installation, a layer of dust and glass; Q_{pass} - solar radiation passed through the glass cover, which is equal to

$$Q_{pass} = Q_r + Q_h + Q_{t.l} + Q_u$$

Here Q_r is the loss of radiant energy due to the reflection of solar radiation from the boiler surface; Q_h - heat of installation; $Q_{t.l}$ - thermal losses of the installation; Q_u - useful energy received by the coolant, which is calculated by the formula:

$$Q_u = G_c(T_{out} - T_{in})$$

Where G and c - consumption and specific heat of the heat carrier (water); T_{out} and T_{in} - the temperature of the water entering and leaving the solar heater.

The use of PS-4 foam plastic, glass wool as thermal insulation, and for stationary solar heaters - foam concrete, timber, foam-fiber plates with a thickness of no more than 8 cm is most expedient. The use of a selective coating, first proposed by G. Taylor, reduces radiant losses and improves efficiency of heater [12]

For correct calculation and design, as well as for determining the technical and economic feasibility of using solar water heaters, it is necessary to know the heating capacity of the installation. The results of a year-round test of a solar water heating installation with a working surface of 545 m^2 in conditions from the foothill regions of Central Asia are shown in Table 1.

Table 1. Results of a year-round test of the Charvak solar water heating plant

Month	Average number of days of the solar plant operation	Duration of sunshine (30-year average), hour	Average daily ambient air temperature, °K	Average daily ambient air temperature, °K	Total radiation incident on the surface of the installation	Useful energy generated by the solar plant	Efficiency of installation	Ratio of monthly to annual productivity, %
					106 J (m^2mon)			
January	14	116	269,0	315,0	370,53	133,98	0,36	6,0
February	13	125	276,1	320,2	383,09	146,54	0,38	6,6
March	16	165	284,5	327,5	412,40	173,33	0,42	7,8
April	17	229	290,0	332,0	452,17	198,87	0,44	8,9
May	19	312	297,1	334,2	427,05	205,15	0,48	9,2
June	23	359	302,8	338,5	412,40	210,18	0,51	9,4
July	26	390	304,9	343,2	414,91	224,00	0,53	10,1
August	28	371	301,9	341,9	431,24	237,39	0,55	10,7
September	25	304	297,2	335,5	456,36	228,18	0,50	10,2
October	22	233	291,6	328,4	414,91	198,46	0,48	8,9
November	17	156	284,2	321,9	385,19	159,10	0,41	7,1
December	14	110	276,0	312,1	351,69	113,04	0,32	5,1
For the year	234	2870	290,3	329,0	4911,94	2228,22	0,45	

It is easy to calculate, even with an efficiency of fuel installations of 0.4, each square meter of a solar water heater will save 0.19 t conv. in year. The angle of inclination of the unit to the horizon (50 °) is selected so that it can be effectively operated all year round.

At the Physico-Technical Institute. S.V. Starodubtsev Academy of Sciences UzSSSR developed and investigated various designs of solar water heaters with steel, aluminum and plastic boilers. In 1974, the production of a small series of steel solar water heaters was organized, which passed acceptance and production tests in various farms of the republic [17].

In 1977, the serial production of solar water heating elements of four standard sizes with a working surface of 1.62 is planned; 2.16; 2.70 and 3.24 m2. These units are designed in a predetermined way to supply hot water and heat residential and public premises.

Calculation of the developed solar water heater

The average angle of incidence of direct solar radiation on the surface of the PSO system (degrees) is at an angle of inclination of 90 ° and an azimuth of the surface of 0.0.

For thermal calculations of dryers, it is necessary to know the thermophysical characteristics of the dried materials, some results are shown in Table 2.

Table 2. Light transmission transparent in different parts of the spectrum and depending on the area of operation and the time of exposure to light weather

Material	**Time of exposure to light weather, days**	**Transmissions**	
		Visible light (0,4-0,75)	**Near infrared spectrum (0,75-2,5 µm)**
Glass	Reference	93	78
	10	78	73
	20	72	69
Polyethylene film	Reference	86	78
	10	82	74
	20	76	72
Glass	Reference	93	78
	10	76	78
	20	68	71
Polyethylene film	Reference	86	78
	10	76	73
	20	70	71

Here are the data of the solar water heater:

Given:

l = 1600 mm = 1.6 m

h = 600 mm = 0.6 m

$\alpha = 35^o$

Q_{fall} = 431 • 106 J per m2 month August

Q_{pass} = 70% of the incidence of solar radiation with polyethylene film, 1 micron

To dry 1 kg of fruit product, 1.27 m2 area of the solar water heater is required

Q_{abs} =?

Decision:

1) Find the area of the solar water heater.

$S=l\cdot h=1,6\cdot 0,6=0,96\ m^2$

2) Having found the area of the solar water heater, we can determine the absorption of solar radiation from the solar water heater

For $1\ m^2 Q_{pass=} 431\cdot 10^6$ J we find for 0.96 m^2

$1\ m^2 - 431$

$0.96\ m^2 – x$

$$x = \frac{0,96\cdot 431}{1} = 413,76\cdot 10^6\ J$$

To get the “Hot Box” job, we covered the solar water heater with plastic wrap. Film thickness is 1 micron. Films conduct solar radiation up to 70%

From this we find

413.76 J - 100%

x-70%.

$$x = \frac{413,76 \cdot 70}{100} = 289,632 \cdot 10^6 J$$

Hence, from this we can conclude that if the surface of the solar water heater is 0.96 m^2 then in August the month of absorption of solar radiation is equal to

3) From the calculations given, we know that for dehydration of 1 kg of pasty mass, 1.27 m2 of a solar water heater is needed. Knowing these parameters, we can find the mass of the drying object.

1kg - 1.27 m2

x- 0.96 m2

$$x = \frac{0,96 \cdot 1}{1,27} = 0,75 \text{ kg}$$

This means that 0.75 kg of pasty mass can be dried in the developed vacuum dryer.

Method to calculate the drying plant. On basis of the research carried out, following procedure for calculating a drying plant for pasty masses of fruit and vegetable products of any productivity can be proposed [17].

To calculate the thermal calculations of drying plants, it is necessary to know the thermophysical characteristics of the materials to be dried. Some results of studies of thermophysical characteristics are given in the table 3.

Table 3. Basic thermophysical characteristics of agricultural products

Product	Content of dry substances,%	Density, kg/m^3		Degree of porosity,%
		true	bulk	
Apricot	17,5	1050	650	62
Grapes	16,8	1045	650	62
Melon	15,2	1040	650	63
Tomato	8,6	1010	550	54,5
Apples	14,2	1015	600	59

Initial data:

1. Amount of loaded material G, kg.
2. Type of material.
3. Initial temperature of the material t_i.
4. Initial moisture content of the material W_i,%
5. Final moisture content of the product W_f,%.
6. Specific load q, kg/m^2 (4.6 ... 9 kg/m^2).
7. The limiting temperature of the material at the end of drying is t_{lim} (58.4 ± 1°C).
8. Pressure in the drying chamber p_d (13.17 ... 20.2 kPa).

Calculation:

1. Thickness of the dried layer

$$h = \frac{q}{\rho_b} = \frac{4.6}{650} = 0.0071, \text{ m}$$

ρ_b - bulk density (Table 3), kg/m^3.

2. Duration of drying

$$\tau = \frac{2,3\lg \dfrac{\overline{W_b}}{W_{con}} h^{0,75}}{K_1 t_{con}^{0,5} p_c^{0,2}} = \frac{2,31 \cdot 0.75 \dfrac{50}{10} \cdot 0.024}{3.14 \cdot 58^{0.5}} = 8.73, \text{ h.}$$

K_1 - reduced coefficient of drying speed, for fruits K_1 = 3.14·10-3 m3 / (h·deg);

3. Required loading surface

$$F = \frac{G}{q} = \frac{0.75}{4.6}, \text{ m}^2$$

4. Calculation of the required area of the solar heater

$$S = S_{heat} \cdot G = 1.27 \cdot 0.75 = 0.96, m^2$$

Where S_{heat} is the area of the solar heater for each kilogram of feedstock, m^2/kg.

4. Conclusion

1. The calculation of the solar water heater developed in laboratory was made. According to calculations, it is possible to dry 0.96 kg of pasty mass of fruit and vegetable products

2. The application of proposed installation with solar water heaters, which reduce energy consumption by 65 ... 70% compared with use of electricity, allows obtaining an economic effect of 497,210 thousand soums per year per installation.

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