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Solar-powered fruit and vegetable dryer

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Abstract

This work investigates drying of fruits and vegetables, highlighting the advantages of using solar energy for this purpose. This method not only reduces energy costs but also helps retain the optimal levels of essential nutrients in the raw materials. The main drawback of solar-powered drying devices is the complexity of accurately orienting the solar energy receiving surface to align with the sun's changing position throughout the day. This causes the drying devices to operate at lower capacity. A new construction of drying machine is presented whose solar energy heat-receiving apparatus is made in the shape of a convex hemisphere casing. This provides the constant exposure of the casing surface to the sun rays during the day regardless of the particular position of the sun, and, therefore, provides the use of the sun rays heat during the whole day.

Keywords: Vegetables; Solar Energy; Drying Chamber; Heat-Absorbing Apparatus, Drying, Fruit

1. Introduction

The issue of lowering energy costs is of great importance nowadays. One way of realizing it is to utilize the alternative energy sources, including the solar energy. In light of the above, the search for the ways of using solar energy and implementing it takes place in many industries, especially in Power Engineering. The use of solar energy collectors allows for a significant economy of the energy; furthermore, it has practically no harmful impact on the ecology of the environment. It has also been calculated that even in the conditions of Northern Europe (where the solar radiation is comparatively lower) solar systems can cater for the 50-70 % of hot water requirements, whilst in Southern Europe (where solar radiation is much higher) 70-90 % of hot water needs can be satisfied.

The efficient use of solar energy is also possible in fields such as food industry. It should also be mentioned that the use of solar energy in food production, apart from lowering the regular energy costs, has another positive feature: the possibility to increase the quality of the products.

In particular, in case of utilizing solar energy in drying fruit and vegetables, compared to other methods, the process of drying is milder. This leads to the vitamins, microelements, and minerals being optimally retained in the raw material, which is unfeasible by using other methods of drying the same raw materials. It is true that the productivity of the drying process utilizing solar energy is lower compared to other methods; however, this downside is compensated by the high quality of the products and the decrease of energy costs.

2. Materials and methods

We were studied to develop to develop a heat-absorbing device design that ensures the heating of the working agent (air) using solar energy for as long as possible while also preventing the mixing of unheated or cold air with the already heated air supplied to the drying chamber.

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For this purpose, various types and designs of "tracking" mechanisms are used in practice to orient flat heat-absorbing devices toward the sun rays. However, these mechanisms are characterized by complex construction and significant energy consumption.

To maximize the efficiency of solar radiation utilization, a new design of the heat-absorbing device has been developed, the principal diagram of which is presented in pictures 1, 2, 3.

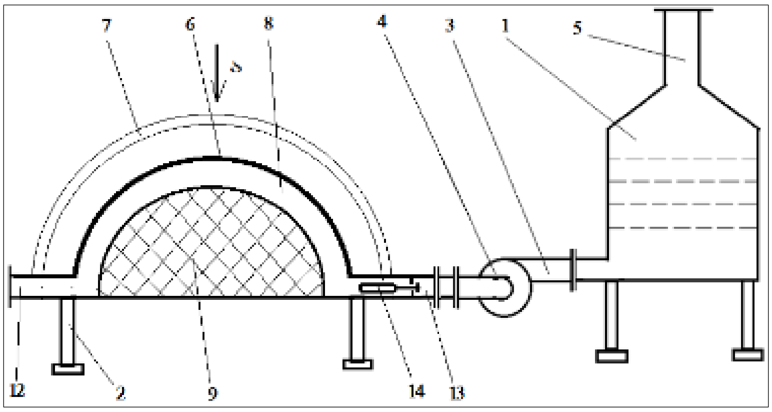

Figure 1 The principal diagram of the fruit and vegetable dryer

A fruit and vegetables drying machine is composed of a drying chamber 1 and a heat-absorbing apparatus 2, interconnected by piping that carries the working agent 3. An air fan can be installed on the piping 4. However, in order to lower the energy costs, as an alternative to a fan, the proper rarefaction of the working agent can also be ensured by increasing the length of the air exhaust pipe 5 above the chamber.

The heat-absorbing apparatus is a convex hemisphere casing, the exterior surface of which is made from a material with good heat-absorption capability (for instance, black-painted copper) 6.

The protective shield 7, made of glass, is positioned coaxially around the surface of the heat absorber 6. Inside the heat absorber, a hemispherical inner casing **9**, made of thermal insulation material, is positioned coaxially to the surface of the outer casing with a constant-sized gap **8**. The gap **8** between the outer surface and the inner casing **9** is divided into isolated channels **11** by parallelly arranged walls **10**. These channels are equipped with air inlet **12** and outlet **13** pipes on both sides of the casing. Furthermore, inside each channel **11**, on the side of the air outlet pipe, bellows **14** are positioned. The bellows are equipped with valves **16** mounted on a rod **15**, which can close the air outlet openings **17** of the channel. The bellows are filled with a volatile liquid, the boiling temperature of which is selected according to the air heating temperature in the device.

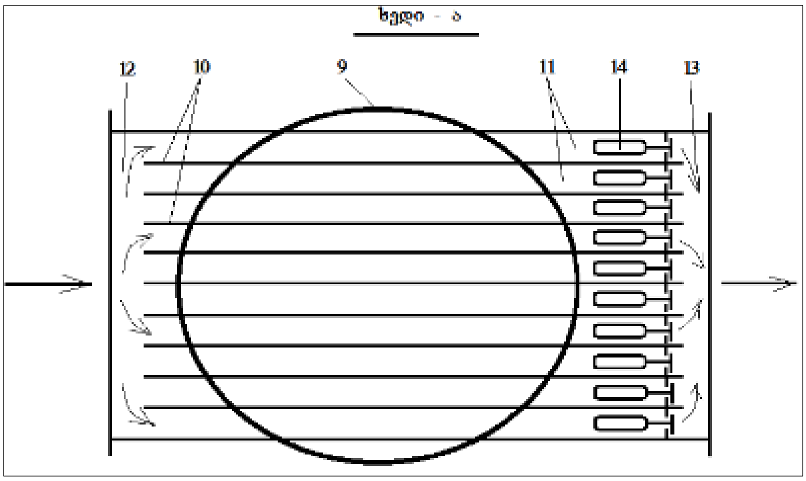

Figure 2 Top view of the heat-absorbing apparatus

2.1. The machine operates as follows

In compartment 1, the drying product is loaded, and the drying process begins using the air heated by solar radiation in the heat-receiving apparatus 2. The sunlight that reaches the heat-receiving apparatus penetrates the glass shield and heats the casing 6. The surrounding air enters the device through the pipe 12 and reaches the channels 11. At this time, the air comes into contact with the casing 6, which has a good heat absorption capacity, absorbs heat from it, and continues moving as heated air toward the hot air outlet pipe 13. Here, the inner casing 9, made of thermal insulation material, helps maintain the temperature of the heated air. The hot air from the pipe enters the drying compartment 1 through the pipeline 3 and dries the loaded product. After the drying process, the used air exits into the atmosphere through pipe 5. The movement of the air is ensured either by the rarefaction created due to the height of pipe 5 or by the fan 4 installed on the pipeline 3.

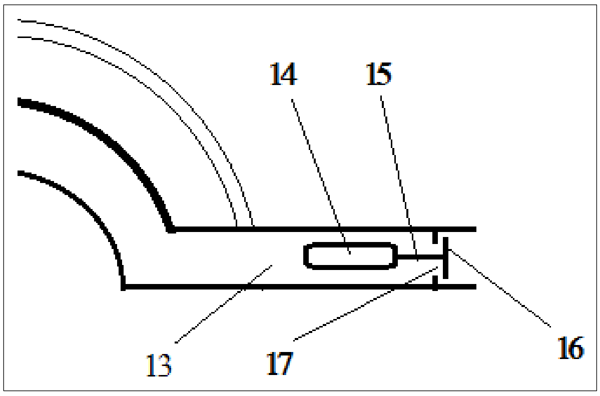

Figure 3 Diagram of the hot air outlet with a bellows pipe

The heat-receiving apparatus consists of a convex, hemispherical-shaped casing made of a material with good heat absorption capacity. As a result of this design, the surface of the casing is always exposed to sunlight throughout the day. Regardless of the sun position relative to the Earth, some of the rays always remain perpendicular to a certain part of the casing, ensuring maximum efficiency in utilizing the thermal energy of the sun. Furthermore, the air passing through the device channels heats unevenly: channels positioned perpendicularly or at a small angle to the sunlight become hotter and transfer more heat to the passing air, while channels inclined at a larger angle to the sunlight heat up less, resulting in comparatively cooler air passing through them. The mixing of cold and hot air is prevented by the bellows 14 located inside each channel 11 on the side of the air outlet pipe 13. These bellows are equipped with valves 16 attached to a rod 15. These bellows are filled with a highly volatile liquid. As a result of this structural design, when the air passing through a given channel reaches a sufficiently high temperature, the highly volatile liquid inside the bellows boils, expands in volume, and consequently increases the size of the bellows. The latter, with the help of the rod, opens the valve 16 and allows the hot air to pass toward the pipe 13. If the temperature of the air passing through any channel 11 decreases, the highly volatile liquid inside the bellows condenses, causing a reduction in the volume of both the liquid and the bellows. The reduced-size bellows, with the help of the rod, closes the valve 16 and prevents cold air from passing toward the pipe 13. This prevents the delivery of a mixture of cold and hot air into the drying compartment, thereby avoiding complications in the drying process. Supplying only hot air to the drying chamber increases the efficiency of the heat-receiving device and improves the drying conditions.

3. Results and discussion

In practice, flat heat-absorbing devices are most commonly used to heat the working agent in fruit and vegetable drying equipment powered by solar energy. These devices heat the passing air using the thermal energy of sunlight. On the other hand, it is known that the efficiency of heat transfer through radiation is determined by the direction in which the heating rays fall on the heat-absorbing surface. The transferred heat is maximized when the rays and the heat-absorptive surface are positioned perpendicularly to each other. Considering the fact that the Earth revolves around the sun, the sun constantly relocates in relation to the heat-absorbing device. Practically, the flat heat-absorbing device is positioned facing south, in the direction of the sun. However, it is still impossible to position the flat air heater in such a way that the sun's rays are always perpendicular to it. As a result, the distribution of the heating of the air inside the device is unequal and the maximum heating result is reached during quite a small period of time (mainly, at midday). It is also worth mentioning that only part of the heat-absorbing surface is active in air heating (the one to which the sun rays are either perpendicular or at an angle close to perpendicular). The air in contact with the other parts of the surface does not heat up sufficiently and is supplied to the chamber filled with the product only after mixing with the heated air, thereby reducing its working temperature. Consequently, the imperfect design of the heat-absorbing surface, on the one hand, fails to ensure the proper heating of all the passing air, and on the other hand, it cannot prevent the reduction of the already heated air's temperature. As a result, it practically decreases the efficiency of solar energy utilization.

4. Conclusion

The presented design of the heat-receiving device in the solar-powered fruit and vegetable drying apparatus enhances the efficiency of air heating, because the change in the sun inclination angle throughout the day does not affect the amount of heat absorbed by the device. Regardless of the position of the sun, its rays are always directed perpendicularly to some part of the convex hemispherical casing, thereby maximizing the heating of that section. There is no longer a need to optimally orient the heat-absorbing device toward sunlight. Moreover, the device prevents the supply of cold air mixed with hot air into the drying chamber, thereby avoiding a reduction in the drying process efficiency. The bellows, individually placed in each hot air outlet channel, ensure the passage of air heated only to the required temperature, while the supply of insufficiently heated air is blocked with the help of valves connected to the bellows. A high-efficiency heat-absorbing device and the supply of air heated only to the required temperature in the chamber ensure an overall increase in the efficiency of the fruit and vegetable drying device.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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