Technical science and innovation

Volume 2021 | Issue 1 Article 7

3-27-2021

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Recommended Citation

Usenov, Azamat; Sultanova, Shaxnoza PhD; Safarov, Jasur Dr., Professor; and Rahmanova, Tojiniso (2021) "EFFICIENCY OF A HELIO HEATING COLLECTOR," *Technical science and innovation*: Vol. 2021: Iss. 1, Article 7.
DOI: https://doi.org/10.51346/tstu-01.21.1-77-0105
Available at: https://btstu.researchcommons.org/journal/vol2021/iss1/7

UDC 66.047-912

EFFICIENCY OF A HELIO HEATED COLLECTOR

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Abstract. *A study of several industrial heat requirements has identified several industries with favorable conditions for solar energy use, the most important industrial processes using heat at moderate temperatures are: sterilization, pasteurization, drying, hydrolysis, distillation and evaporation, rinsing and cleaning and polymerization. The study describes some important processes and the temperature range required for each of them.*

The aim of this study is to develop and experimentally study a model of a solar water-heated drying device for drying ginger (Zīngiber) root and other medicinal plants. Models are available for separate subsystems of the drying system, but there is currently no completesystem model for controlled, defined heliological drying for ginger root and other medicinal plants. In this paper, a model of a solar water-heated drying device for drying ginger (Zīngiber)root and other medicinal plants has been developed and studied experimentally. Using the model, the useful energy and temperature coming from the solar collector were analyzed. The appliance consists of a transparent solar flat collector, a drying chamber and an exhaust pipe. The plant was developed and tested for drying ginger root (Zīngiber). By creating a separate subfunction for a product, the overall model does not depend on the type of product used in the experiment, and the product can be user-defined. The sub-functions of product drying provide the initial conditions for the product itself, air and moisture flow in the air. This allows relative humidity to be re-passed through each zone and is critical for accurate modeling of the drying curves of each product. Variable product and air constructions are included in the product drying function to monitor the moisture content of the product on the pallets. However, the importance of modeling in optimizing results was highlighted. To display the conditions in the dryer, the system displays conditions such as temperature, humidity, and flow over time. To simulate drying curves, the moisture content of the product is determined internally. Graphs of relative humidity and heat exposure are plotted. The optimal operating mode of the solar collector has been developed. The advantages of other types of dryers have been studied. The efficiencies are presented in the form of equations. The graphs were compared with the experimental results. The solar collector model was analyzed to determine the outlet temperature and relative humidity, ambient temperature and relative humidity.

Keywords: *thermal conductivity, temperature, collector, solar energy, modeling, efficiency, Zīngiber, humidity, temperature.*

INTRODUCTION. Energy is considered to be a major agent in wealth creation and an important factor in economic development. The importance of energy in economic development is well recognized, and historical evidence suggests that there is a close relationship between energy availability and economic performance. Achieving solutions to the environmental problems facing humankind today requires long-term potential actions for sustainable development. In this regard, renewable energy sources are one of the most efficient and effective solutions [1].

Solar energy hits our planet in just 8 minutes and 20 seconds after it left the giant furnace, the Sun, which is located at a distance of 1.5 * 1011 m.The Sun has an effective black body temperature of 5762 K. The temperature in the central region is much higher and estimated from 8 * 106 to 40 * 106 K. In fact, the sun is a reactor with continuous fusion, in which hydrogen is converted into helium. The total energy generated by the sun is 3.8 * 1020 MW, which corresponds to 63 MW / m2 of the sun's surface. This energy is radiated outward in all directions. Only a tiny fraction of 1.7 * 1014 kW of all emitted radiation is intercepted by the ground. However, even with this small fraction of 30 minutes of solar radiation falling to the ground, it is equal to the global energy demand in one year [2,3].

All forms of energy in the world as we know it are of solar origin. Oil, coal, natural gas, and wood were originally produced through photosynthetic processes accompanied by complex chemical reactions in which decaying vegetation was exposed to very high temperatures and pressures for extended periods of time. Even the energy of wind and tides is of solar origin, as they are caused by differences in temperature in different regions of the Earth [4].

The biggest advantage of solar energy over other forms of energy is that it is clean and can be supplied without any pollution. Over the past century, fossil fuels have provided most of our energy because they are much cheaper and more convenient than energy from alternative energy sources, and until recently environmental pollution was not a major concern [5].

MATERIAL AND METHODS. The first scientific work was devoted to the production and experimental study of a model of a solar water heating construction devicefor the construction of ginger (Zīngiber) root and other medicinal works. Allows automation of control as a result of modeling.

Efficient use of solar energy is a topical issue today. based on this, we analyzed the efficiency of the solar water heater

Solar collectors mainly differ in their movement, i.e. stationary, uniaxial and biaxial, as well as operating temperature. Stationary solar collectors are investigated first. These collectors are permanently fixed and do not track the sun. Three types of collectors fall into this category [6]:

1. Flat collectors;
2. Stationary composite parabolic collectors;
3. Evacuated pipe headers.

1. Efficiency of a stationary solar collector

The expression for the efficiency of a stationary solar collector with a developed structure is presented in the form:

$$\eta = \frac{\alpha_{\text{солн.}}}{1+\frac{h_r}{\epsilon \rho C_p V_{\text{в}}}} \tag{1}$$

where $\alpha_{\text{сол}}$. - solar absorption capacity of the absorber surface; h_r - coefficient of radiation heat losses from the surface of the absorber to the environment; ϵ - efficiency of heat exchange of the collector surface; $V_{\text{в}}$ - absorption rate; ρ - air density; C_p is the specific heat capacity of air.

Suction rate equation:

$$V_{\text{в}} = \frac{V}{A_{\text{к}}} \tag{2}$$

where V is the volumetric flow rate of the system; $A_{к}$ - collector surface area. The equation for hr is:

$$h_r = \varepsilon_{\text{п}} \frac{\sigma\left(T_{\text{п}}^4 - T_{\infty}^4\right)}{T_{\text{п}} - T_{\infty}} \tag{3}$$

where ε_n is the emissivity of the absorber plate; σ - Stefan-Boltzmann constant; T_n - plate temperature; T_∞ - ambient air temperature.

The solar absorption of the plate and the emissivity of the plate are usually determined by independent measurement or the experimental data are fitted to the model equation (1). By fitting the experimental data to the efficiency model, the calculated values are $\alpha_{\text{солн.}}=\varepsilon_{\text{п}}=0{,}687$ for the structure used in the system. Extensive testing of the material of the absorber is necessaryfor greater confidence in the material properties. The plate temperature is also not known for this system. To determine the temperature, it was assumed that the initial temperature would be approximately 50 ° C higher than the ambient temperature, and the loop iteration was used until the temperature converged. The model for the plate temperature is assumed to be a target temperature above the manifold outlet temperature (about 10 ° C). The model started from the assumed initial temperature of the absorber and was repeated until the change in the temperature of the absorber between iterations became less than 0.01 ° C. Convergence criteria are user-defined to provide varying degrees of accuracy based on model requirements.

2. Plate front, plate holes and plate back side efficiency.

To develop an efficiency model, we divide the overall efficiency into three components: efficiency at the front of the plate, through the holes in the plate, and at the rear of the plate. Equations (3-6) show the definition for each efficiency:

$$\epsilon = \frac{T_o - T_\infty}{T_п - T_\infty} \tag{4}$$

$$\epsilon_п = \frac{T_{o1} - T_\infty}{T_п - T_\infty} \tag{5}$$

$$\epsilon_о = \frac{T_{o2} - T_{o1}}{T_п - T_o} \tag{6}$$

$$\epsilon_з = \frac{T_o - T_{o2}}{T_п - T_{o2}} \tag{7}$$

where T_{o1} is the average volumetric air temperature when it enters the hole; $T\infty$ - ambient air temperature; $T_п$ is the temperature of the absorbing plate; T_{o2} - average volumetric air temperature at the outlet from the hole; T_o - average volumetric temperature of the internal part of the collector; ϵ_n - efficiency for the front of the plate; ϵ_o - efficiency through the hole; $\epsilon_з$ - efficiency on the back of the plate.

Combining equations (3-6), the overall efficiency is:

$$\epsilon = 1 - (1 - \epsilon_п)(1 - \epsilon_о)(1 - \epsilon_з) \tag{8}$$

We simulate each efficiency model based on the speed Reynolds number at each absorber stage. The model is based on empirical experience and the constants are solved by fitting the model to experimental data taken from a variety of different plate configurations. For efficiency in the front of the plate:

$$\epsilon_п = \frac{1}{1 + Re_s\,\text{мин}\left[a * Re_w^{-\frac{1}{2}}, f\right]} \tag{9}$$

where *a* and *f* are constants and equal to 1.733 and 0.02136, respectively; Res is the Reynolds number based on the suction rate; Rew - Reynolds number based on wind speed [15].

The value for wind speed was accepted as there was no experimental data for wind speed on the test day.

The efficiency through the hole in the plate is shown as:

$$\epsilon_о = 1 - e^{-4\left(c\frac{P}{D} + \frac{3{,}66\,t}{\Pr Re_h D}\right)} \tag{10}$$

where *P* is the pitch of the holes; *D* is the diameter of the holes; *Pr* is the Prandlt air number; Re_h is the Reynolds number based on the velocity through the holes; t is the thicknessof the plate [7-10].

$C\frac{P}{D}$ takes into account the non-uniform temperature at the entrance to the hole in the absorber plate. The constant c was set to zero because the simulated transparent reservoir is so small that the hole efficiency is negligible

RESULTS. Finally, the efficiency at the back of the plate is shown as:

$$\epsilon_з = \frac{1}{1 + e * Re_b^{\frac{1}{3}}} \tag{11}$$

where $e = 0.2273$; Re_b - Based on the suction rate divided by the porosity of the plate [10]. Combining formulas (8-10) with equation (7) gives the overall reservoir efficiency, which is used to determine reservoir efficiency using equation (1).

To determine the temperature leaving the manifold, a useful heat gain was found:

$$Q_u = \eta I_c A_к \tag{12}$$

where I_c is solar insulation.

Finally, the outlet temperature was found using:

$$T_{вых.} = \frac{Q_u}{\dot{m}\, c_p} + T_\infty \tag{13}$$

Equations (11) and (12) are widely used to determine the useful energy and temperature at the outlet of solar collectors.

The collector model underestimates the collector outlet temperature according to our experimental data.

Two rounds of experimental data have been successfully obtained. Each stage was carried out in a complete drying chamber of the ginger root, which were dried for two days. These days were sunny with occasional very light winds. A longer period of cloud cover and stronger breezes occurred on the first day of the experiment. An error was introduced into the data due to breezes when measuring the weight of the trays. To minimize this error during the second experimental test, a heavy cooking tray was used as a base on the balance to make the trays morestable during weighing.

Figure 1 shows the efficiency of the reservoir over time. Efficiency mostly stays between 40% and 70%, however there are a few emissions. Most of them are associated with the fact that the system has a heat accumulator, but a steady state model was adopted. When a cloud or other object blocks the sun for a short time, the solar flux decreases very quickly. However, the temperature in the system does not decrease as quickly due to the thermal mass of the system. This results in high temperatures reported for low solar fluxes. This especially explains the last point, which exceeds 100% efficiency. This also explains the low efficiency for a couple ofpoints in the period [11-18].

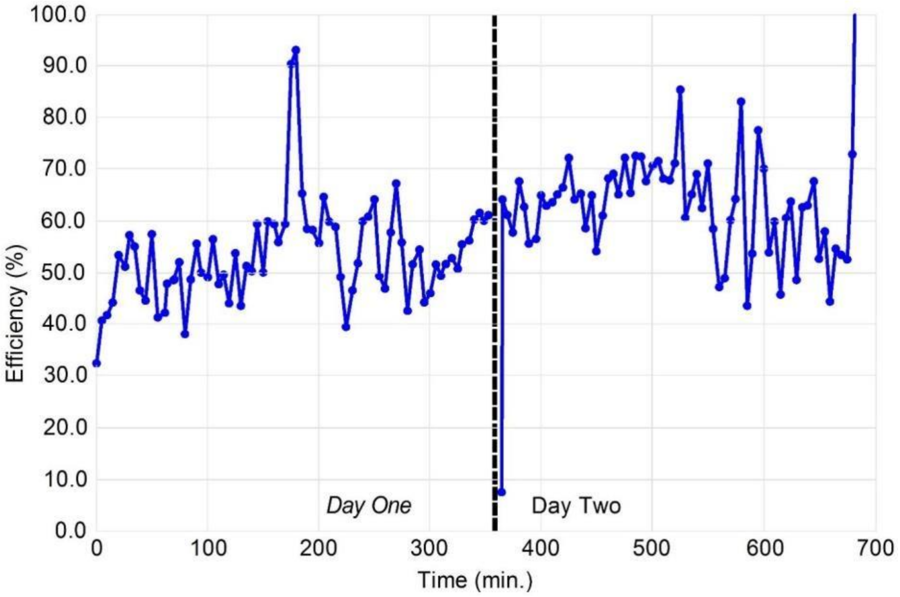

Figure 1. Collector efficiency versus time for the first and second day

The reservoir efficiency model predicts efficiency well in relation to the average efficiency observed in the experimental data. The efficiency is expected to be more dependent on temperature and flow. Using experimental flow rates, simulations show a large variance over time. The amplification of the flow pattern can greatly affect the entire system, since each subsystem is dependent on the volume flow.

The ginger root was dried over a two-day period with an average initial moisture content of 73% and dried to an average of 8%. The ginger root on the top pan did not dry as quickly as the ginger root on the first pan. 4 kg chopped ginger roots per square meter of collector absorber area were dried at an average volumetric flow of 0.015 to 0.020 m^3/s.

Figure 2 shows the volumetric flow rate over the period of experiments. The speed is somewhat consistent with the solar flux. There is an initial start-up period at the beginning of the day and the flow rate decreases with solar flow at the end of each day.

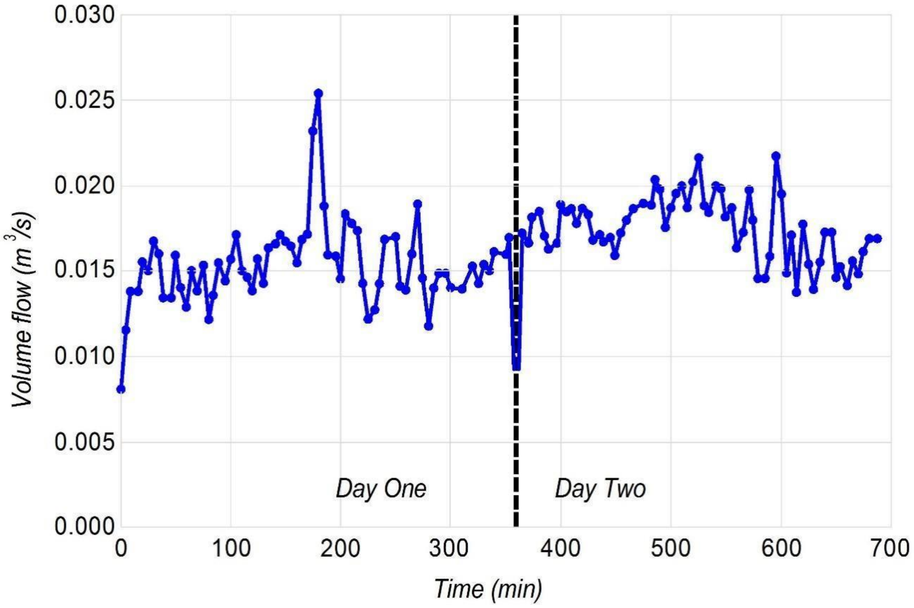

Figure 2. Drying volumetric flow rate over time for the experiment conducted on the first and second day.

CONCLUSION. The following results can be obtained from the proposed generalized mathematical models and theoretical expressions:

1) The collector efficiency regularly exceeded 50% with an average temperature riseof over 20 ° C. The dryer actively added moisture during the entire drying process, which was manifested in an increase in the air humidity coefficient. Since the first dataset did nothave ideal environmental conditions and the lead times between experiments were significantly longer than overnight, the second dataset was the main analysis and simulation.

2) The model shows that the humidity at the exit of the dryer is slightly higher, which indicates a slightly higher prognosis for the overall rate of moisture removal.

3) This model of solar water heater is a tool for predicting the performance of the drying system of ginger (*Zīngiber*) and other medicinal plants in different climatic conditions, designing and optimizing the operation of the solar water heater, and learning alternative concepts.

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