TEACHING FACILITIES OF SOLAR ENERGY IN SECONDARY SCHOOLS

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Abstract

The purpose of my article is to present some extra curricular material prepared by me related to the solar energy. In my activities 15-16 years-old students parttaken who has totally different range of interests. During the lessons the students made some simple observations related to the effects of solar radiation.

In particular we studied the functioning of solar food dryer during extra lessons with some inquisitive students. The appliance was prepared by the students and we also made some measurements inside and outdoor as well. In this article we give a method to define to efficiency of the dryer. This way it can be compared to similar instruments.

1. Introduction

Nowadays healthy eating is considered to be important by a lot of people and more and more people are getting interested in renewable energy. Our students can hear about sustainable development a lot. I would like to assist this thinking during physics lessons, too, so I suggested my students an idea of a solar dryer construction. I started an environmental physics extra lesson two years ago, where we have been talking about the use of solar energy and we have been observing, measuring, respectively making appliances.

The solar food dryer is a simple construction, which can be made easily at home. The main points of its function are the following: first capturing the sunshine, then with the help of the collected energy we have to heat the air and fruits. It's very important to help reduce the moisture content of fruit (from 80 percent to 20 percent) that is why we have to provide that the moist leaves from the dryer cabinet. That's why we blow on soup, so the evaporation can be faster. So we have to concentrate on these two important things.

Our students were making a solar dryer during extra lessons last year (Fig. 1.a). We made the plan and built up our own invention to which we used recycled materials. The whole instrument cost only 5 Euros – we just had to pay for the aluminium. It has got two main parts: the collector and the cabinet.

Figure 1.a My students with the solar dryer 1.b Cabinet's levels

We used wood, some glass plates (they were parts of an old shelf), mosquito net, polystyrene (as insulation) and aluminium plate. Of course, we needed some bolts and glue. The useful surface of the collector is around 0.5 m^2 and the basic area of the cabinet is 0.1 m^2. The cabinet has got four levels (Fig. 1.b).

2. Solar food dryer in physics teaching

Solar food drying is a great way to learn more about the sun and solar energy [1]. I believe, we can demonstrate a lot of physical phenomena with this construction. For example: radiation (where does energy come from, electromagnetic waves, spectrum), the Sun's path, reflection, transmission, internal energy, evaporation, diffusion, greenhouse effect. There are similar physical phenomena in collector than for example in atmosphere and these can be observed more simplier.

During basic lessons the phenomena can be discussed on qualitative levels and complexity can be demonstrated. Obviously, quantitative thinking is also important: some physical parameters can be measured for example the radiant energy or the temperature inside the collector. (What does this measuring instrument indicate? What's the difference between Lux and W/m^2?)

During the study circles we can do series of different measurements and we can find connections within the results. If we modify a parameter (for example the number of holes in the collector – see also), how will another measured quantity change (for example the temperature of the air in the collector).

Of course, basic lessons do not have the possibility to deal with this thing in details but students can make many interesting observations about the topic. This year we spent double lessons outdoors with some classes. Students worked in five groups and they got to know topics in connection with solar energy. Students got a research diary, in which it was written purpose of the measuring, what to do, available tools and they had to write the results.

One of the groups had to fill 4 glasses with equal amount of water then covered 3 glasses with different materials (foil, black and yellow cardboard). Students put them in sunlight, measured the temperature of water in each glass and how much water evaporated at the same time. They used a sensitive digital scale.

The reflecting- absorbing abilities of the different materials could be seen by the students. They also had the task to observe the reflecting radiation spectrum from the cardboards and the foil. They used a manual spectroscope and Luxmeter. Here the difference could be seen as well.

The other group's task is introduced by one of my students. "Our group did an experiment involving the greenhouse effect. We got two cardboard boxes, one with a big opening on top, the other without one. (…) Both temperatures were quickly rising. Our final conclusion was that the box with the window had a higher temperature, since the clear foil let the sun´s rays in more easily, but it also kept them trapped in the box, thus proving the greenhouse effect right. We have all learned about the greenhouse effect in science class and could picture it a little bit in our heads, but now we saw it happen (in a smaller version) right in front of our eyes. I think these kinds of experiments are very useful."

Due to the huge amount of drying food it is necessary to make the industrial processes efficient. Lot of experiments deal with this topic and the drying of various fruits and vegetables are examined. For example Rajkumar Perumal carried out some observations with tomatoes. He compared the behaviour of different thickness of tomato slices. According to Perumal's measurements the physicochemical parameters such as colour retention, rehydration capacity and ascorbic acid retention were comparatively higher in vacuum assisted solar dryer than in solar cabinet and open sun drying methods [2].

We don't have very good technical possibilities but we can carry out many observations. Now I would like to sum up the results of the measurements used with the collector and the dryer. First of all, I am going to write about the measurements with the collector.

During the winter we worked with a lamp of 300W in a classroom. The benefit of these measurements was to get to know the functioning of the collector. It's important to mention that these observations can be repeated precisely. We put the lamp 50 cm far from the collector and it reached the surface in 90 degrees. We used few and small-sized holes during the laboratory measurements. Basically, we observed the role of the aluminium: we studied the effect of the black paint and we changed the place of the aluminium plate in the collector. We measured the temperature of the flowing hot air in the upper part of the collector.

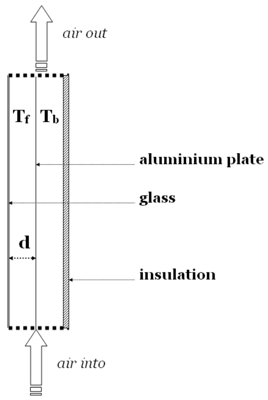


Figure 2. Line diagram of the collector

The following graph shows these results. On the horizontal axis we can see the time and the vertical shows the temperature. The line with ♦ sign is the situation of the unpainted plate, the other one with Δ is the measurement when the aluminium is 2.5 cm far from the glass. The thirds line with sign • belongs to d = 4 cm (Fig. 3.).

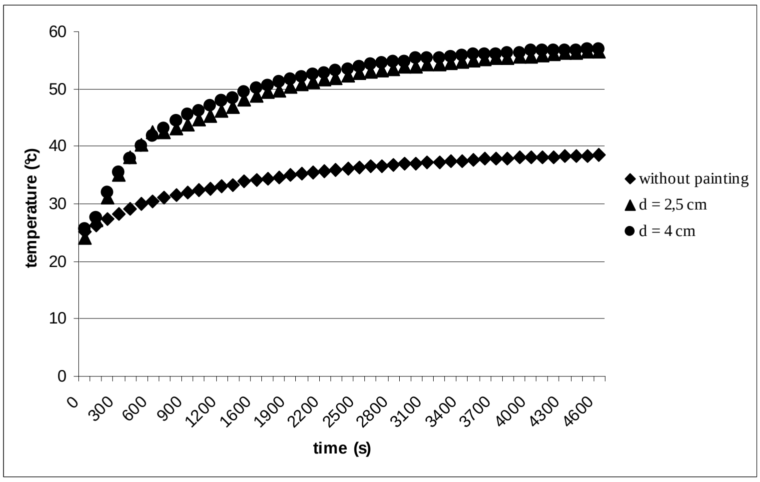


Figure 3. the temperature of the flowing hot air in the upper part of the collector

After the measurements we can state that the painting made the collector more efficient but the position of the aluminium did not change the temperature of the flowing air.

If you have ever measured something outdoors, you know how many difficulties you can face with. We had problems with the environmental parameters which changes minute by minute: For example sunshine is not available in the same way during measurements which lasts for many days. I am going to introduce the series of results that we carried out thanks to the lucky weather.

Everybody knows that grape is planted on the southern slope of the northern hemisphere because there is plenty of sunshine. It is advisable to set the collector in this direction. Around noon we were observing the shadow of a pole. According to zone time it was the shortest at 12.45. The end of the shadow described a straight line on which we draw a perpendicular. This showed the North-South direction. The peak time was important to fix the beginning and the ending of our task. We were working from 11.45 to 13.45.

We changed two parameters: the place of the aluminium plate (d_1=2,5 cm, d_2= 4 cm, d_3 = 5,5 cm - for three days) and the number of holes at the upper part of the collector. Meanwhile we were measuring the temperature between the aluminium plate and the glass, and also behind the aluminium plate. I summarized the outcome in three charts (5.a,b,c).
The columns of all the three tables differ in the number of holes and the lines belong to the different aluminium positions. The first chart contains the temperature of the air in front of the aluminium plate. The darker fields belong to the lower temperatures and the lighter to the higher ones.

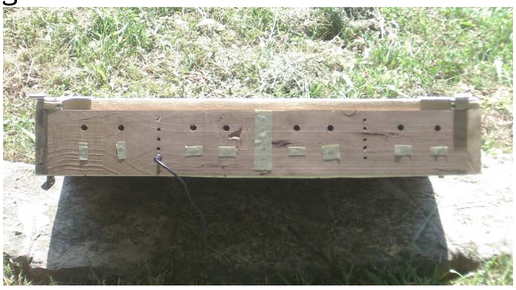


Figure 4. Holes at the upper part, of the collector

Number of holes						
d_1	98,8	110	113,3	115,1	117	116,7
d_2	100,8	108,2	114,3	116,1	116,1	116
d_3	100,5	106,5	108	110,2	112	113,5

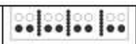
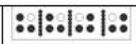
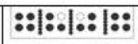
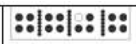
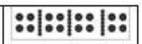
5.a Temperature of air between aluminium plate and glass (T_f in °C)

You can see if we stick down more and more holes than higher temperature will be measured. If there are less holes the flowing air will be slower. It's heated by the sun for a long time. T_f does not depend on d. The difference of values in the columns are not significant, maybe higher temperature belongs to d_1 because in this case there is less mass of air between aluminium plate and glass.
The second chart shows the temperature behind the aluminium plate. You can see in lines a similar trend as in previous chart. In line d_3 there are the biggest values because there is the least space for air behind the aluminium.

Number of holes						
d_1	86	92,5	100,3	97,4	96,5	102
d_2	95,5	96,7	101,5	104,8	103,8	99
d_3	104	107,8	106*	110,7	111,2	112,8

5.b Temperature of air between aluminium plate and insulation (T_b in °C)

The third chart can be interesting as well. I gave the difference of the two temperatures in each cell. We can state as a conclusion that in d_3's case there is no difference between the T_f and T_b and this is the best position of aluminium plate back of the collector.

Number of holes						
d_1	12,8	17,5	13	17,7	20,5	14,7
d_2	5,3	11,5	12,8	11,3	12,3	17
d_3	-3,5	-1,3	2	-0,5	0,8	0,7

5.c Difference of temperatures between T_f and T_b

If we wanted to measure the efficiency of the collector we should measure the temperature of the flowing air as well. Unfortunately, we did not have the appropriate techniques. We tried to work with the help of a wind velocity measuring instrument but the measuring range was not suitable. The efficiency of the collector can be approached by formula (1) where c is specific heat, ρ is density, v is velocity of flowing air, A is the cross section of holes and ΔT is the temperatures difference of incoming and outcoming air.

$$(1) \qquad P_{coll} = c\rho v A \Delta T, \qquad \eta = \frac{P_{coll}}{P_{solarrad}}.$$

I have to mention here that a separate efficiency rate would belong to each cell of the former charts, because it can be seen that T changed and v is going to change, too. The functioning of the collector is well outlined by the efficiency, but the quantity of the whole instrument is more significant for us.

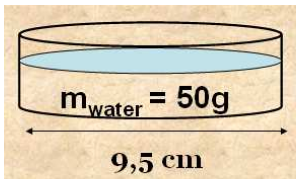
I am going to outline the efficiency of the dryer with an arbitrarily defined quantity. This way it can be compared to similar instruments. Evaporate a given amount of water from a standard bowl (see picture) for an hour. Give the mass of the evaporating water. This is called evaporating capacity. We measured the quantity of the evaporating water three times: in the drying area which was connected to the collector, in sunlight and in shade. We repeated this measurement another day, too. First 2,6g was given for the evaporating capacity of our dryer. Solar radiation was about 1100W/m^2. In the second case 2,2 g was. The solar radiation was about 900 W/m^2. Another four massdata are just informative. (Fig. 6.)

	shade	*sunlight*	*dryer*
Measurement 1. (rh%=50; 1110 W/m^2)	**1 g**	**3,9 g**	***2,6 g***
Measurement 2. (rh%=15; 900 W/m^2)	**1,7 g**	**2,8 g**	***2,2 g***

6. Evaporating capacity of our dryer

I have to mention that the relative humidity wasn't the same during the measurements. You can see the efficiency of the dryer (2) where L is evaporation heat of water, m is the mass of evaporated water, P is the solar radiation, A is the useful surface of collector and Δt is the length of time. (The efficiency of the dryer can be estimated if we take into consideration the amount of energy that reaches the collector.)

$$(2) \qquad "\eta_{dryer}" = \frac{L_{water} m_{evapor}}{P_{solar} A_{coll} \Delta t}$$



Both of measurement gave quite low rates (≅0,3%), obviously they were low because the evaporating surface was low, too. I have to remark that it is not a typical data either, because more water would have evaporated from two bowls. Anyway our instrument can be compared with others. Our main task is to improve removing the moist. So our dryer functions well, but it is not perfect yet.

We have some further plans for the future. We would like to take some records with termocamera. I hope we get some useful informations about our dryer. We will also try an adjustable venting system with solar cell. Obviously we will observe the process of drying.

3. Conclusions

The purpose of my lecture was to present some extra curricular material related to the solar energy. In my activities 15-16 years-old students were involved who have totally different range of interests. During the lessons the students made simple observations related to the effects of solar radiation.

In particular we studied the solar food dryer during extra lessons with some inquisitive students. The instrument was prepared by the students and we also made some measurements inside (using a lamp) and outdoor (with solar energy) as well. I was going to highlight some important and revealing results in my summary about the characteristic times, physical processes, efficiency of the dryer and about how to embed it into high school teaching of physics.

The whole project has been realized as a part of a big and complex programme in the framework of environmental physics and its next unit is going to be the theme of environmental flows. I believe the topics of environmental physics help the young people to form scientific ideas about nature and also these topics are great to show the strength of empiric observations for students during the extra and normal lessons.

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