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Research Article

Vacuum Tube Solar Water Heater for Cooking Meal

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Abstract

Author has designed, studied, used at home and published for more than 40 years the performance of various hot box solar cookers, including hybrid and multipurpose solar ovens. The objective here is to study two vacuum solar water heating tubes, for heating air, water and for cooking meals and pasteurizing water etc., to see its thermal performance and make some comparison with conventional hot box solar oven. Air, water, meals temperature and solar intensity is measured. On sunny day, maximum air temperature reached to about 220 ^{0}C and water temperature to about 96 ^{0}C. Different vegetables, lentils and including pork pieces were cooked. In addition, for first time author used cheap, portable, battery operated smart camara and mobile phone to measure solar intensity and temperature remotely, even at coffee shop.

Keywords: Hot Box Solar Oven; Vacuum Tube Collector; Vacuum Tube Solar Oven; Smart Camara; Smart Phone; Remote Measurements

Introduction

Author in addition to researcher and promotor has been using different Hot Box Solar ovens (Photo 1) at home for last 44 years for heating and cooking meal and pasteurizing water and dehydrating domestic agricultural products and other uses [1-10]. Also got a national patent on Solar Oven in 1984. In addition, we are using at home also Conventional Solar Water heater using black metallic plate and tubes (Photo 2). However, for last about 10 years, many vacuum tube Solar Water heaters have come in market in many parts of the world (Photo 3). Being having vacuum in between two concentric tubes (Photo 4), in general heating efficiency is better, although has some limitations too, like fragile etc. Thus, sometime sellers give extra tubes to the buyer to replace if broken any tube.

Photo 1: Some Solar Ovens at author's house.

Photo 2: Some Solar Devices at author's house.

Photo 3: Vacuum type Solar Water Heater.

Fortunately, one of the local solar companies RILESA donated me two tubes, during the EXPO Construction exhibition in Feb. 2023. I thought of using this tube for cooking and make some comparison with Hot Box Solar Oven.

Solar water heater with vacuum tubes is shown in Photo 3. The tubes are normally 180 cm long and 6 cm of external (and internal 4.5 cm). diameter. The number of tubes varies depending on the capacity of water to be heated. One of the companies had smaller sample tube (length 55 cm, but same diameter) for demonstration to the possible clients. A known friend and President of the company RILESA, donated me two tubes for my research study. These vacuum tubes are opened on one side and closed on the other side (Photo 4). Its OK for water heating. I thought of using these tubes for cooking, Thus I had to think of some modifications.

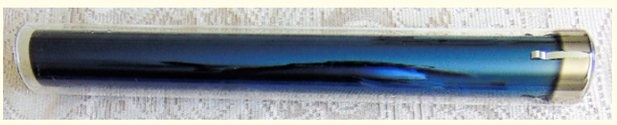

Photo 4: Vacuum glass tubes.

Experimental set up

As explained earlier, the tube as such cannot be used for cooking, thus one has to find the ways to introduce crude meal to be cooked and take out cooked hot meal. The final set up is shown in Photo 5. It is a flat wooden (could be metallic) base, with proper rubber cover and metallic clamp to make it tight. The base could be inclined for both tubes (normally from zero to .20 degrees). depending on the study. I have also introduced one stem thermometer in each rubber tube cover to measure temperature inside the vacuum tube.

Photo 5: Set up of two vacuum glass tubes with thermometer for this study.

Objective of study

The objective of the study was to see the maximum air and water temperature attained in the vacuum tube collector with solar radiation, and some comparison with hot box solar oven. In case the external tube is broken (means tube will be without vacuum) what will be the corresponding air and water temperatures in broken (Normal tube) and unbroken (vacuum) tube, and finally some comparison with conventional hot box solar oven. In all these cases, in addition to air, water, ambient and meal temperature, solar Intensity was also measured each 15-30 minutes.

Experimental studies

Different studies are made, during April 6, 2023 to July 15, 2023, as explained below.

Air and water temperature

This experiment was done on April 9, 2023 with two vacuum tubes. One tube had air and other tube had 700 ml (tube capacity) of water. Both tubes were at same inclination 25 degrees. The day was sunny. Photo 6 shows variation of air and water temperature with solar intensity, from 9 am to 1 pm. The maximum air temperature reached to 220 ^{0}C after 2 hours and water temperature reached to 96 ^{0}C in four hours. Water can be pasteurized in 135 minutes as it is pasteurized at about 65-70 ^{0}C.

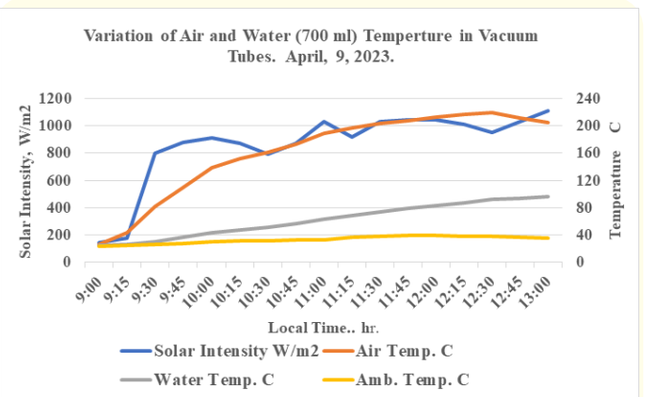

Photo 6

The same experiment is repeated on April 26, 2023, with air and 700 ml of water. Both tubes were kept almost horizontal (around 5 degrees inclination). Photo 7 shows the variation of temperature and solar intensity during 8 am to 4 pm. Day was not very sunny. Until 9:15 am, tubes were not receiving much solar radiation. As can be seen, maximum air temperature reached to 212 ^{0}C after 3 hours and maximum water temperature reached to 89 ^{0}C. in about 4 hours. Again, water could be pasteurized in about 150 minutes.

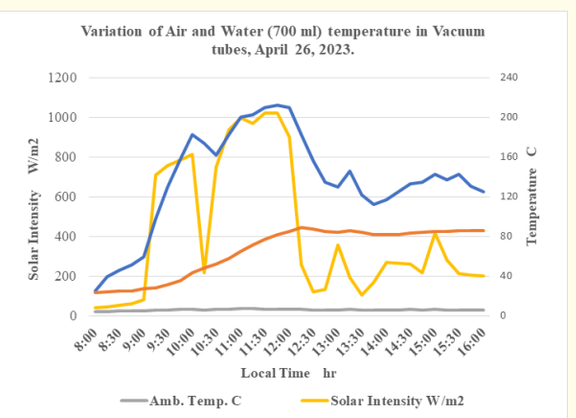

Photo 7

Heat losses in vacuum tubes

Heat losses can be studied, just by cooling hot air and hot water with time. Here air and water once heated with solar energy, the complete base with both tubes were brought inside the room (no solar radiation) and temperature of air and water is measured after every 15-30 min.

Photo 8 shows the temperature of hot air and 700 ml of hot water, with time on April 8, 2023, during 13:15-17:00 hr. Water temp, dropped from 87 ^{0}C to 38 ^{0}C in 4 hrs. And air temp. dropped from 121 to 28 ^{0}C, in 4 hrs. The ambient temperature during this period was around 24-26 ^{0}C.

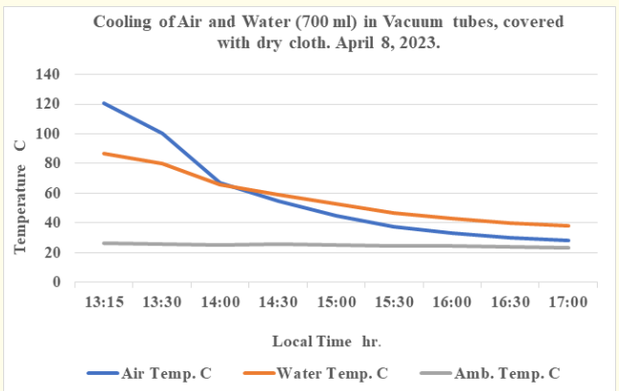

Photo 8

The experiment was repeated on April 9, 2023, from 1 to 6 pm. gain, one tube had heated air and another had 700 ml of hot water. Two tubes had same inclination. Here also both tubes were covered with some dry cloth, as if the user want to maintain the food hot for longer period, The results are shown in Photo 9. In this case water temperature dropped from 97^0 C to 64 ^{0}C in 5 hrs. and air temp. from 204 ^{0}C to 27 ^{0}C, in 5 hrs., much better as compared to previous study.

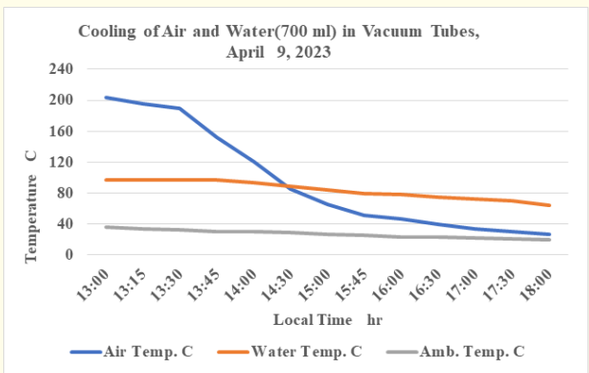

Photo 9

Vacuum glass tube vs. normal glass tube

Unfortunately, in one of the vacuum concentric tube, outer tube was broken at the bottom. It can be happened to any user. The inner tube was fine. (Photo 10). Now this tube has no Vacuum inside. The second tube was OK. Thus, we can compare the temperature variation in Normal and Vacuum tube.

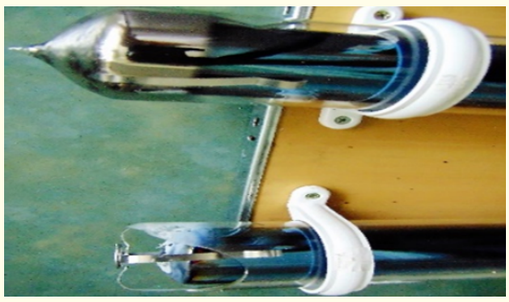

Photo 10: Broken (bottom) and Complete (upper) Vacuum tube.

Here both tubes had air. Experiment was done on May 13, 2023, from 8:30 to 10:30 am. Photo 11 shows the variation of air temperature in both tubes with Solar Intensity. Day had good solar intensity. Maximum air temperature in vacuum tube was 180 ^{0}C. whereas in broken tube (no vacuum tube) was only 80 ^{0}C, under the similar climatic condition.

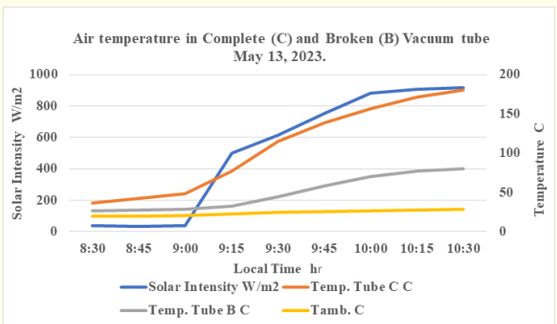

Photo 11

With the infrared thermometer, temperature of outer glass was measured in both tubes. The broken (unvacuumed) tube was hotter (more losses) than vacuum tube. It is justified due to vacuum.

The experiment was repeated on May 13, 2023, during 10:45 to 14:00. Here both tubes had 700 ml of water. Solar Intensity was good. The results are shown in photo 12. Maximum water temperature was 110 ^{0}C in Vacuum tube (higher than 100 ^{0}C, whereas in broken (without vacuum) tube was 72 ^{0}C. That shows that even with normal glass tube, one can make tea and pasteurize water.

Temperature of more than 100 ^{0}C in Vacuum tube could be due to mix up of air/water. Fortunately, I got another Vacuum tube. Thus, next studies are made with both vacuum tubes.

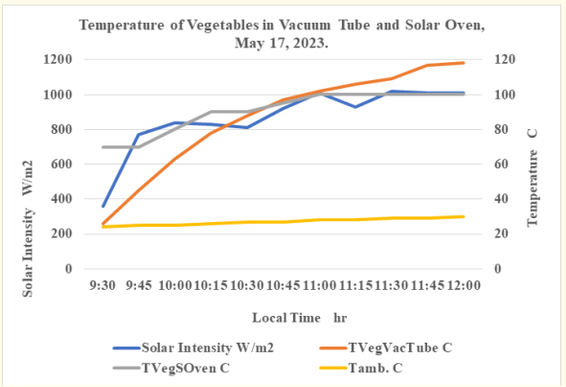

Photo 12

Cooking

Different types of meals are cooked in vacuum tube to see the performance. Only some results will be mentioned.

Cooking of Broccoli and Potatoes in Vacuum tube and Solar Oven.

We put only cut vegetables garlic, spices and some oil (but no water) in vacuum tube on May 17, 2023. (Photo 13, left). The temperature variation of meal with solar intensity is shown in Photo 14. Quantity of vegetable in Vacuum tube was 320g.

On the same day, similar quantity of Broccoli and potatoes were also put in Solar Oven (May 17, 2023), during 8:30 am to 12:00 md. (Photo 13, right) Solar Intensity was good.

Photo 13: Potatoes with Colliflower cooked in Vacuum tube (upper) and Solar Oven (lower).

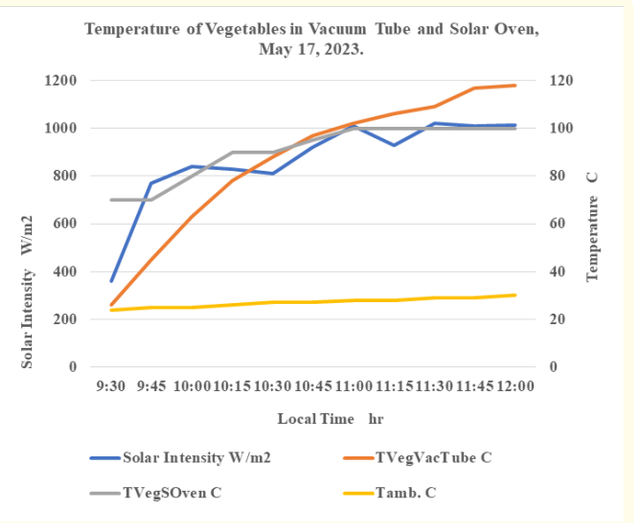

Photo 14: Potatoes with Colliflower cooked in Vacuum tube (Upper) and Solar Oven (lower).

Maximum temperature of vegetables in vacuum tube was 118 ^{0}C and in solar Oven was 100 ^{0}C. Although in solar oven one can cook 3-4 items. The area of solar oven is about 3-4 times the area of one vacuum tube.

Experiment was done during 09:30-12 :00. Both vegetables were cooked.

Weight of Cooked meal in vacuum tube was 316g whereas in Solar Oven was 289 g. The reason of similar weight in Vacuum tube (320 to 316 g) and reduced weight in Solar Oven (325 to 289g) is due to fact, in vacuum tube vapors/water remain inside the tube, whereas in solar oven, part of the vapors is evaporated. Thus, vacuum tube is not good for roasting or drying, fine for cooking and frying.

Cooking of Potatoes and Carrot. June 8, 2023, Weight of only cut potatoes, cut carrot, garlic, spices, some oil but no water was 465g, as shown in Photo 15.

Experiment was performed during 9 am to 12 mid-day. Solar Intensity was good. Photo 16 shows the temperature of meal and solar intensity, In 2 hours the meal temperature reached to 90 ^{0}C although maximum temperature reached to 100^0 C in three hours. Vegetables were cooked.

Cooking of pork pieces. May 8, 2023.

Although I planned to cook chicken pieces, but on the day of experiment could not get it. But got pork pieces. Experiment was done during 9:15 to 13:30 Put Pork pieces plus garlic, spices but no oil (453g) in the vacuum tube at 10 am. Photo 17a.

Photo 15

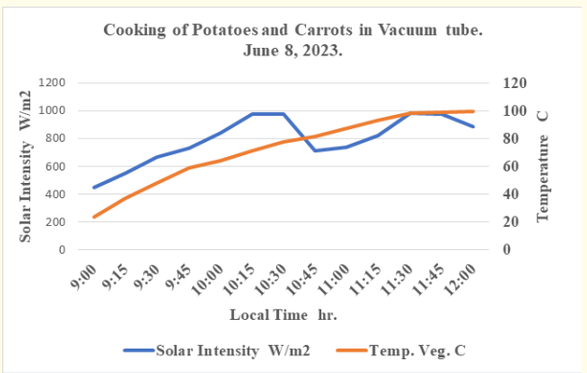

Photo 16

Photo 18 shows the temperature of pork and solar radiation with time. Checked at 12:30 was not fully cooked. But at 13:00 It was fully cooked. (Photo 17b) Maximum temperature in Pork, was 159 ^{0}C. Its worth mentioning, the pork pieces could be put in stainless steel rod (skewer, like used for BBQ) as shown in Photo 17c.

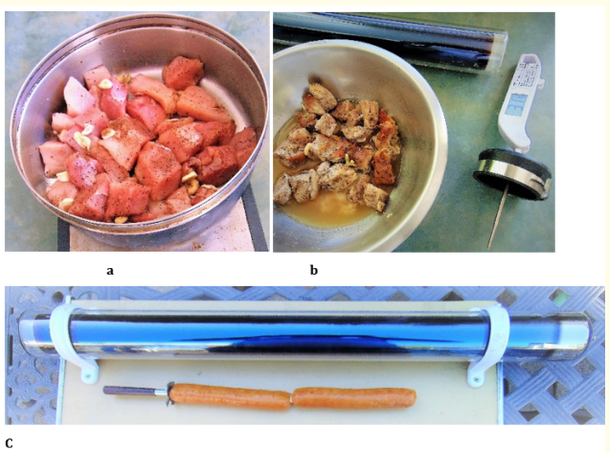

Photo 17

Cooking of pork pieces in Vacuum tube with Solar Energy., a (crude), b (cooked) and c (steel skewer).

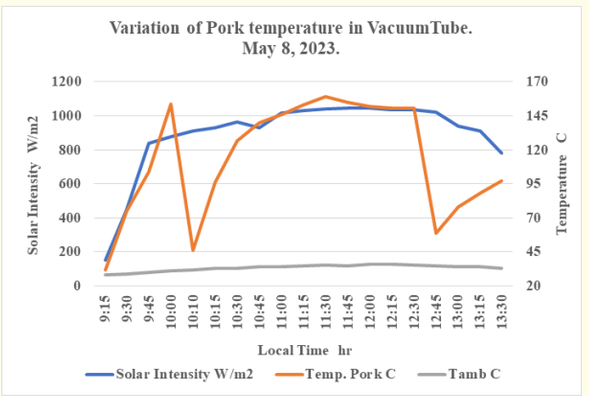

Photo 18

Cooking of lentis

On July 15, 2023, 150g of lentil was soaked in water (1.5 times in volume) from 9-10 am. Then at 10 am put soaked lentil in vacuum tube (Photo 19, left). Tube was inclined about 20 degrees to reduce the dipping of water.

Lentil attained maximum temperature of 95 ^{0}C. Checked at 1 pm. It was well cooked (Photo 19, right). Total weight of cooked lentil was 472g.

Photo 19: Cooking of Lentil (Crude, left and Cooked, right) in Vacuum tube.

Photo 20 shows the temperature of lentil with solar radiation.

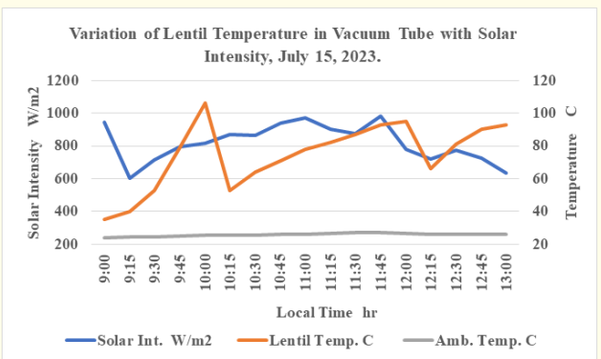

Photo 20

In all the cases, once taken out the cooked meal, Tube has to cleaned before it gets dried. For cleaning the tube, one can put water in tube and keep in Sun to heat water. Then shake the tube well, the tube will be almost cleaned. No long brush is required to clean and also not recommended.

Remote measurements

Being a retired professor since 2013, I am doing the experiments/measurements at home, having some portable instruments, like thermometer and portable pyranometer to measure solar radiation, but not the constant measuring data/data logger. During the experiment sometime I have to go out for 1-2 hours and do not want to miss the data. Then I thought of small and cheap battery camara (NEXXT Home), and put in front of thermometer as well as Solar radiation meter (Photo 21). Downloading the application of camara, I could see meal temperature and solar intensity in mobile phone, at my study table and also on road or coffee place outside.

Photo 21: Battery operated portable camera and smart phone for measuring solar radiation and temperature.

Conclusions

Initial conclusions

Different studies have been made to know the performance of vacuum tube collector, for heating air, water, cooking different vegetables etc. and compare with conventional hot box oven. Although the performance look better in Vacuum tube, and also can be carried during your journey. however, in Solar Oven, one can cook 3-.4 pots simultaneously. Also Vacuum tube is somewhat fragile. In case you are cooking vegetables without water, the tube can be kept horizontal. In case you are cooking meal with water, like rice, lentils, potatoes with water, the tube should be inclined 15-20 degrees, so that meal is dipped in water.

Limitation

For cleaning tube from inside, it is not very simple, however one can heat water in Vacuum Tube with Solar Energy, shake well, the tube will be almost cleaned. No Long brush is required and not recommended.

Revised conclusions

Different studies have been made to know the performance of vacuum tube collector, for heating air, water, cooking different vegetables etc. and to compare with conventional hot box oven. Although the performance looks better in Vacuum tube, however in Solar Oven, one can cook 3-.4 pots simultaneously. Also Vacuum tube is somewhat fragile. In case you are cooking vegetables without water, the tube can be kept horizontal. In case you are cooking meal with water, like rice, lentils, juicy potatoes with water, the tube should be inclined 15-20 degrees, so that meal is dipped in water. For cleaning vacuum tube from inside after meal is cooked, one can heat water in tube with Solar Energy, shake well, the tube will be almost cleaned. No Long brush is required and not recommended. From now this Vacuum Cooker will be new addition to my previous five Solar Cookers´/Ovens in use since May 1979. Hopefully some readers may also like to use this type tube Cooker.

Acknowledgement

I am thankful to Eng. Esteban Solis, President of the Solar Company RILESA for donating me two vacuum tubes for this study, normally used for solar water heating.

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