SHE Technical Report no. TR-33

Thermal Performance of Some Mexican Cooking Pots

Paul Arveson

Director of Research, Solar Household Energy

Oct. 9, 2017

Citation: Technical Report no. TR-33, Solar Household Energy, Inc., (Oct. 9, 2017)

Solar Household Energy (SHE) strives to unleash the potential of solar cooking to improve social, economic and environmental conditions in sun-rich areas around the world. SHE Technical Reports are intended for use within the solar cooking community, for the rapid dissemination of findings related to solar cookers. They may contain information that is based on limited data, and/or conclusions and recommendations that are solely the opinions of the author, not of the organization. Please contact the author for further correspondence.

Thermal Performance of Some Mexican Cooking Pots

Paul Arveson
Solar Household Energy, Inc.
Oct. 9, 2017

In Sept. – Oct. 2017, we used clear days to make side-by-side comparison tests of several types of cooking pots that are available at low cost in Mexico. The following report provides a log of our experiments and findings.

These are not intended to be standard performance tests in accordance with ASAE S.580.1 or other standards. The load is 1 liter of water in all pots. The reflector in all cases is the Haines MPET reflector, with polycarbonate sleeve attached tightly around the pot, and the polycarbonate cone or outer cover.

The spacing sleeve between the reflector and the bottom of the pot was set to approximately 3 inches (7 cm) in all cases, in order to allow sunlight to reach the bottom of the pots.

Pot descriptions:

The photo shows Margarita Battle and Gigi Mounkala with the four types of pots that were tested.

All pots were weighed and their brim capacity measured. Here is the data:

Description	Capacity, liters	Height, cm	Inside Dia., cm	Pot weight, g	Lid weight, g
Cinsa Biotech light blue enameled steel with wire handle; 230 pesos	5.7	16	22.7	599	278
Duracero by Vasconia steel with dark blue enamel, 199 pesos	5.0	12	24	816	355
Speckled gray Yajad Italian aluminum pot with handles, small, with glass lid, 249 pesos	3.75	9	24	584	594
Speckled gray Yajad Italian aluminum pot with handles, large, with glass lid, 299 pesos*	5.6	10.1	28.2	716	744
Haines Dutch oven (for comparison)	4.0	9	24	367	580

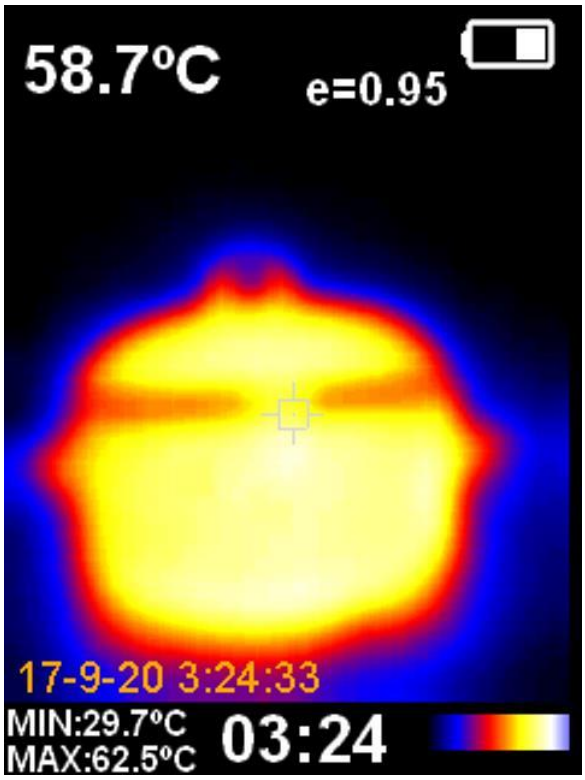
*Handles were removed from the large speckled Italian pot to accommodate the sleeve.

Heat loss experiment

Heat loss of each pot was assessed by measuring the reduction in temperature after 1 liter of boiling water was poured into the pot and the lid placed on. Here are the results:

Description	Temperature drop after 15 min., deg. C
Cinsa Biotech light blue enameled steel with wire handle	68
Duracero by Vasconia steel with dark blue enamel	65
Speckled gray Italian aluminum pot with handles, small, with glass lid	66
Speckled gray Yajad Italian aluminum pot with handles, large, with glass lid	63
Haines Dutch oven (for comparison)	71

The smaller the drop, the better is the performance. Heat loss generally takes place mostly around the top rim of the pot, where heat leaks through the lid gap. An infrared image of the Duracero pot illustrates this effect:



The heat loss is higher where the pot is cooler (red on this color scale). (The pot's outline is red because emissivity at near-grazing angles is reduced for most nonmetallic materials).

In terms of heat loss, the differences between the four types of pots is rather small and any of them should be usable based on this test. It was interesting to note that the large Yajad pot had the largest rim, but its heat loss was lowest. This indicates that its rim, although metal without a rubber seal, was well made and fairly tight.

Heating experiments

On days with nearly clear skies, solar heating experiments were conducted on all the Mexican pots, using a Haines Dutch oven pot as a basis of comparison. But before conducting the tests, two general questions about cooking pots arose. Finding answers to these questions will give us general guidelines on the selection of a cooking pot. That way, rather than measure a large number of pots, we can have general selection rules to narrow down the types of pots that are most likely to perform well.

Glass vs. opaque lid?

Two of the pots to be tested have glass lids, and two have metal lids. One general question of relevance is: does a clear glass lid perform better than an opaque lid?

This question could be answered quickly using a comparison test with four identical Haines Dutch oven pots. The experiment did not use reflectors, so that there would be no variation attributable to reflector differences. Instead, only a shiny fabric sheet was laid out on the ground under the pots. (In the photo, the reflective fabric looks dark because it is reflecting the sky.)

Four different lid conditions were compared in this experiment (9/27/2017):

1. Clear glass lid
2. Lid covered with aluminum foil on the outside
3. Lid covered with black painted aluminum foil on inside of lid
4. Lid painted black on the outside

The results showed that the clear glass lid heated 39% faster than a black opaque lid. The aluminum covered lid heated even slower than the black lids. This finding makes sense, as the clear glass lid creates a greenhouse effect inside the pot, enhancing its cooking speed. The conclusion is that a clear glass lid is desirable from a heating perspective, as well as for viewing the food. Consequently, this experiment emphasizes the importance of focusing light from reflectors into the pot from above.

Sealed vs. unsealed lid?

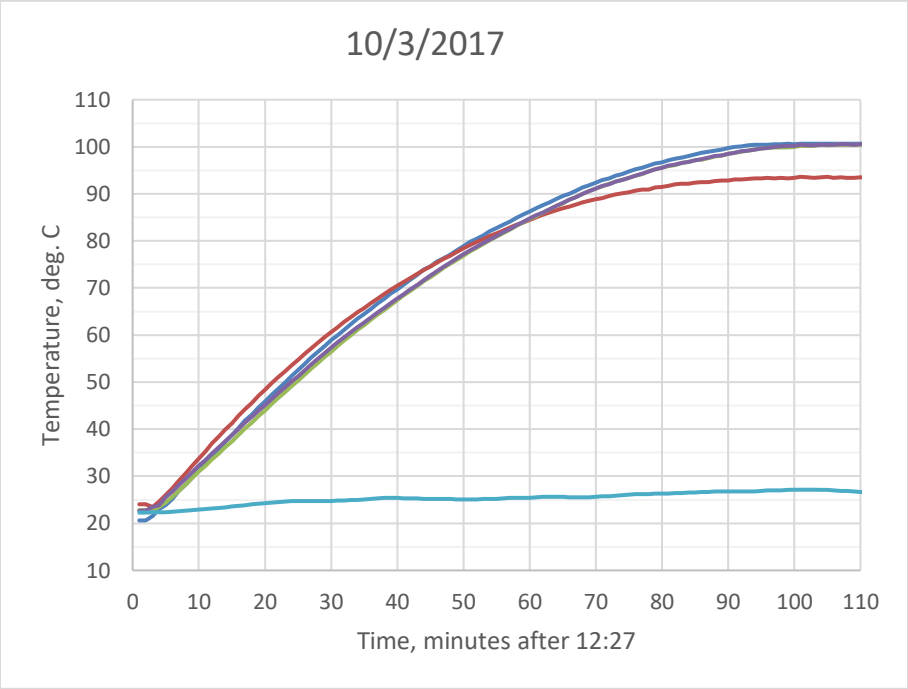
The Haines Dutch oven, which is a well-performing pot, has a silicone rubber lid that provides a good seal and greatly reduces heat loss. None of the Mexican pots have such a seal. So the question arose, do we need to require a rubber seal or not?

To investigate this question, we conducted an experiment with the two small Yajad Italian pots on 9/28/2017. One was sealed tightly around the rim with aluminum adhesive duct tape. This simulates the condition with a high-quality silicone seal. (The glass lids have a steam vent, so there was no concern about pressure buildup.) The other had no seal. The top lid knob was removed on both pots, but the screw was left in the lids to maintain a tight seal in the hole. There was only air in the pots.

To avoid possible variations due to the reflectors, this test was also done with the pots only, sitting on a reflective surface on the ground, with insulated pads under the pots.

Two thermocouples were placed in the pots for redundancy. The comparison showed that the sealed pot was about 5 deg. C hotter than the unsealed pot after 1 hour. Although temperature differences may vary, the general conclusion is that a sealed pot is better than an unsealed pot.

On 10/3/2017, a day where the sky was clear, a comparison experiment was done with the small and large Yajad Italian pots, along with the Haines Dutch oven for repeatability checking. The smaller Yajad pot was sealed watertight with metal tape (but the steam vent was kept open). All pots had a 1-liter water load. The results were as follows:



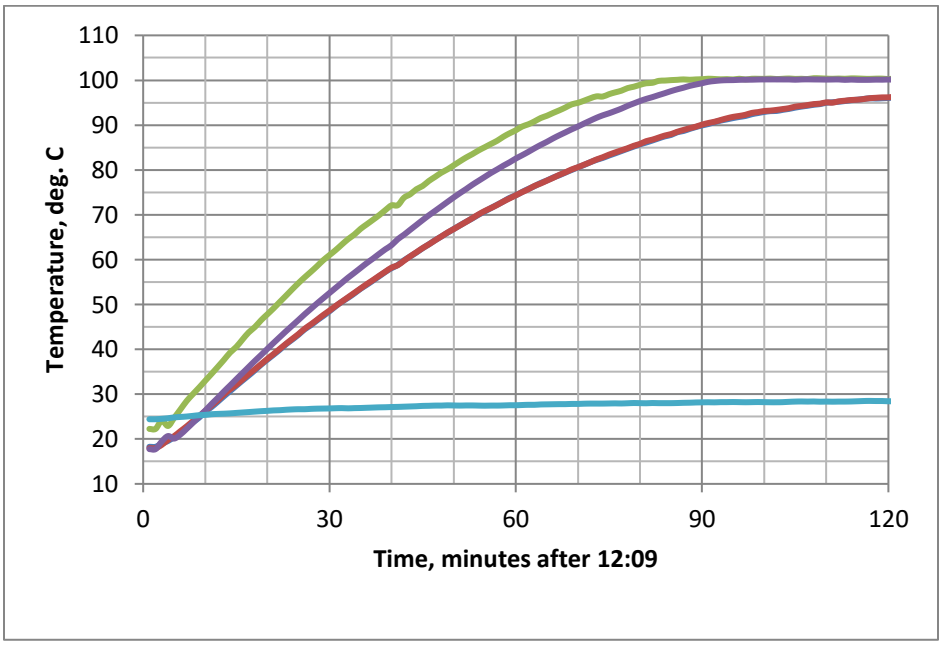
The plot labels are as follows:
Dark blue – small Yajad pot, sealed, in polycarbonate sleeve, with Haines reflector #1
Purple – Haines Dutch oven with sleeve, Haines reflector #3
Red – large Yajad pot, unsealed, in sleeve, with Haines reflector #2
Light blue – ambient

The unsealed large pot (red) initially heated faster, possibly because it had a larger glass lid that could accept more sunlight. But at higher temperatures, where more water vapor is generated, it never quite came to a boil, and vapor could be seen escaping from the lid gap:

The small sealed Yahad pot performed almost the same as the Haines Dutch oven (which has a tight silicone rubber lid seal). Both of these came to a full boil after 100 minutes.

The conclusion from this experiment is that pots with a good lid seal perform better than pots without a seal, even if they are larger and can capture more sunlight.

On 10/4/2017, another clear day, an experiment was conducted with the large Yajad Italian pot, a Haines Dutch oven, and the blue Duracera pot. All pots had a 1-liter water load and a 6-inch plastic sleeve. The chart showed the following results:



Green – large Yajad Italian pot, sealed watertight with metal tape, in sleeve, reflector #2
Purple – Haines Dutch oven #3 in sleeve, reflector #3
Red – Duracera blue pot, unsealed, with sleeve and Haines #1 lid in reflector #1
Light blue – ambient

The large Yajad pot apparently got a bit of a head start in heating, but it reached 95 degrees C at 71 minutes. The T4 (Haines) Dutch oven reached 95 deg. at 80 minutes. The blue Duracera pot reached 95 deg. at 110 minutes. The conclusion is that with a good watertight seal, the large Yajad Italian pot can perform slightly better than the Haines Dutch oven. It should be noted that the inside of the Yajad pots are gray, not black like the Dutch oven. The outside of these pots was spray painted black with Krylon Ultra-black (initially they were bright aluminum on the bottom).

Again, the conclusion is that with a tight lid seal, other pots can perform as well as the Haines Dutch oven, but without such a seal, they lose too much water vapor at higher temperatures and the heating time is extended.

These findings – that glass lids are preferable, but the lid gap in unsealed pots is the major cause of heat loss – are consistent with previous findings.

Recommendations

Of the pots that were examined in this series of experiments, the large Yajad Italian aluminum pot, with its glass lid, appears to be the most promising pot to use in a panel cooker with reflectors similar to the one in the Haines solar cooker. Because it is made of aluminum there is no possibility of rust. However, there are some improvements that are needed to get the maximum performance from these pots:

1. A food-grade silicone gasket should be added to the lid of the pots. We are developing a device to apply such a gasket, and when this process has been perfected, further heating experiments will be done to verify improved performance.

2. Some decision has to be made regarding the pot handles. In the experiments with a Haines reflector with its polycarbonate cover, the pot handles had to be removed in order to accommodate the sleeve. In any case the handles may become too hot to hold, defeating their purpose.

3. The glass lids also have a handle. These may not be durable enough after heating within the covered reflector, so they may need to be replaced with silicone handles (at added cost). Also, it is important to maintain a tight seal around the handle where it is attached to the lid.

4. The polycarbonate sleeve needs to have notches to accommodate the pot, and its height needs to be optimized.

5. The pots need to be painted black on the outside with a flat black paint and sufficient baking at 450 deg. F to drive off all volatiles before the pots are used for cooking.