August 27, 2014

To: Naama Haviv, Jewish World Watch

From: Pat McArdle

Subject: Solar cooker tests

Contents:

Summary and recommendations

Over the past eight months I have tested a variety of solar panel cookers as well as combinations of materials that could replace the plastic bag currently used with the CooKit. I submitted a preliminary report in January after conducting the first series of tests. In May, July and August, I conducted additional comparative temperature tests. I have included in each of these tests a Tchad Solaire solar cooker (with a plastic bag greenhouse) to serve as a baseline measurement (since we know this design works well and is an accepted cooking technology in the camps in Chad). I would be happy to come to LA for the day to demonstrate my findings and recommendations.

The plasticized versions of the CooKit I tested were able to heat pots as efficiently as the cardboard models, however none of them were flexible enough to be folded into a 12"x12" square like a traditional CooKit. This made them more difficult to transport and store and resulted in their eventually becoming bent and distorted if they were not stored completely flat in a sufficiently large space. This could pose a problem in the huts and tents of the refugees where space is at a premium. I'm continuing to search for a durable, rigid, plastic material with a fully bonded reflective surface that can be scored and folded like a cardboard CooKit.

The one new design I tested was the Haines Solar Cooker. (See a detailed description in section 3.) The Haines (in most cases) reached the highest temperatures even in windy conditions. It is currently being tested in a Rotary-funded pilot program in Kenya, but it is being distributed with a black metal pot and glass lid (which would not be practical for refugee camps.)

I've also tested a number of durable replacements for the plastic bag. The most effective material I have found (polycarbonate) allows the pots to reach interior temperatures slightly higher than those reached with a pot inside a plastic bag. The arrangement includes a thin, flexible, transparent strip of polycarbonate plastic wrapped around the pot and an 8 mm rigid, twin-wall polycarbonate disc clipped over the lid. This material is 12 times lighter than glass, will not film over after long exposure to sunlight; has a hollow, twin-walled construction, which provides great heat retention; is fire resistant with a combustion temperature of 1,166˚F.; and it has a 10 year warranty. With the polycarbonate greenhouse combination, pots reached or exceeded the temperature of pots inside

a plastic bag. The wrap and disc lid are easy to set up, and since the disc is clipped right to the lid of the pot it is also easy to open the pot after cooking without spilling the food. I've sent samples of the polycarbonate materials to Trust in Education, which will be testing them in October in Afghanistan with displaced families, who are also using CooKits.

Cob Box Solar Oven

Our attempts to reach 300 degrees F internal temperature with this oven have so far not succeeded. We have doubled the insulation and painted the interior black. Our next step will be to dismantle the top layer of cob and reinstall the frame with a sheet of the 8 mm twin-wall polycarbonate, which may provide greater insulation.

Recommendations:

1. Send samples of the polycarbonate disks and strips to Chad to allow the refugee women to use and evaluate them with the CooKits they are currently using.

2. In the absence of a viable plastic version of the CooKit, send samples of the Haines Solar Cooker (minus the glass lidded pot) to Chad for the women to test with their own pots (using the polycarbonate disc and strip arrangement described above instead of their plastic bags).

3. We will continue to experiment with the cob solar oven at our own expense and will provide you with more information when we are able to reach the desired temperature.

Tests

On May 5 in Borrego Springs (latitude 33°N) in the Anza-Borrego desert I tested six panel solar cookers, each with two liters of cold water and one egg. The ambient temperature on both days was 97°F, but the skies were hazy due to blowing dust and wind gusts up to 15 mph. With the exception of the Tchad Solaire CooKit (with the pot in a plastic bag), the pots were wrapped in strips of polycarbonate and topped with a disc of single-layer poloycarbonate (I had not yet discovered the 8 mm twin-wall polycarbonate, which is far more effective for insulating the pot lid).

Type of solar cooker	Water 2 pm	Pot 2 pm	Water 3 pm	Pot 3 pm	Egg
Haines	160°	244°	196°	254°	Thoroughly cooked
Tchad Solaire CooKit	138°	150°	153°	153°	Not cooked
SCI CooKit	147°	160°	165°	180°	Partially cooked
Rundle CooKit	140°	163°	149°	160°	Partially cooked
Rundle two pot CooKit	127°/138°	131°/136°	144°/164°	140°/160°	Partially cooked
McArdle two pot CooKit	127°/134°	126°/133°	147°/160°	140°/172°	Not cooked

At one pm on July 31, in Oceanside, California, at latitude 33°N, under clear skies with the temperature around 75 degrees F. (after having discovered the 8 mm twin-wall polycarbonate) I made a disc with this material and tested it first with a Hot Pot reflector. I heated three liters of water in three 12 inch, aluminum, traditional African cooking pots using: a Haines Solar Cooker;

a Tchad Solaire CooKit (with plastic bag); and a HotPot (with the cooking pot wrapped in a strip of polycarbonate and topped with a disc of the 8 mm twin-wall polycarbonate clipped to the black metal lid). Temperatures were measured at 2 pm and 3 pm.

Type of solar cooker	Water 2 pm	Pot 2 pm	Water 3 pm	Pot 3 pm
Haines	160	204	180	230
Tchad Solaire CooKit	147	189	172	204
HotPot with polycarbonate	167	220	183	221

On August 4, in Vista, California, at latitude 33°N under clear skies with the temperature around 75 degrees, I conducted another comparison test, cooking a cup of corn meal and a cup and a half of water in four ten-inch African pots using: a Tchad Solaire Cookit with the pot inside a plastic bag; a Haines Solar Cooker; and two Hot Pot aluminum reflectors (one with the pot inside a plastic bag and another with the cooking pot wrapped in a strip of polycarbonate, topped with a disc of 8 mm twin-wall polycarbonate clipped to the black metal lid). Temperature probes in the cornmeal reached internal temperatures between 174 -178 F. After one hour of cooking, the cornmeal was fully cooked. The exterior pot surfaces measured with a laser thermometer registered between 183 and 190 F. Although the difference among all the pot temperatures was only a few degrees, the hottest pot and cornmeal were in the Hot Pot reflector wrapped in a polycarbonate strip and covered with the 8 mm twin-wall polycarbonate disc. The lowest pot and cornmeal temperatures were recorded in the Hot Pot and the CooKit (both heating pots inside plastic bags).

Type of solar cooker	Cornmeal temp	Pot Temp
Haines	174	189
Tchad Solaire CooKit	175	188
HotPot with bag	174	185
HotPot with polycarbonate	178	190

On August 22 in Oceanside, California at 33°N under blue but slightly hazy skies I heated an SCI Cookit, two Tchad Solaire Cookits (one with a plastic bag and one with the polycarbonate) and my homemade ‘two-pot’ CooKit.

Type of solar cooker and greenhouse	Temperature empty pot
SCI CooKit with polycarbonate disc and wrap	235
Tchad Solaire CooKit with plastic bag	205
Tchad Solaire CooKit with polycarbonate disc and wrap	221
Two pot Cookit with polycarbonate disc and wrap	208/210
Hot Pot with polycarbonate disc and wrap	230
Haines solar cooker with polycarbonate lid and wrap	230

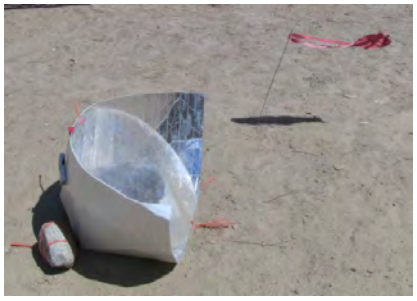
Types of Solar Cookers Tested

(*Some were eliminated after earlier rounds of testing in January and May due to poor performance.*)

1. The **Solar Cookers International (SCI) CooKit,** designed by French physicist Roger Bernard, and modified in the early 1990s by SCI members, is an open source, panel solar cooker that has been used and made by tens of thousands of people around the world. SCI's current version, which is sold for $29 (currently out of stock) is made of cardboard and foil and has pictogram instructions on the back that explain positioning and cooking times for different foods. It is not waterproof and the foil will separate from the cardboard if it gets damp.

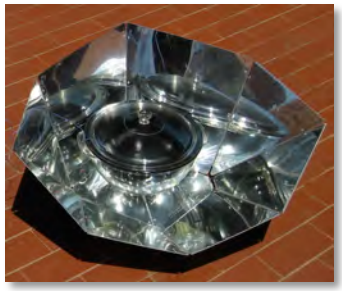
2. The **Tchad Solaire CooKit,** assembled by Sudanese women in Touloum and other refugee camps in eastern Chad, is made with thin cardboard, which is die cut and delivered to the refugee camps in large bundles. Refugee women glue a sheet of thin aluminum foil (the thickness of cigarette packaging foil) to the cardboard, pound in four grommets, coat the back with a waterproofing substance, put strapping tape around the edges, fold it into a square and place it into a hand-sewn carry bag for distribution to refugee families along with the heat resistant plastic bags, in which the pots are placed during the cooking process. Despite the waterproof backing, the foil, if it gets damp especially from hot liquids, will begin to bubble and separate from the cardboard. Termites are another issue since they can chew through the cardboard and devour it from the inside. There is still debate—some rather contentious—about how long these cookers last. Refugee women interviewed during an international survey conducted for Tchad Solaire in 2009 estimated four months to one year, but it was not possible to know if this was correlated to daily usage. If the CooKits are cleaned after each use, always kept dry and stored properly, the survey team concluded that they could last for up to a year. The plastic bags last only for a few weeks since there is not enough water to wash them out. **The issue of durability is a significant concern to UNHCR, which currently provides durable biomass cookstoves (like the German-made Save 80 Stove -$100) to many refugee families.**

3. The **Haines Solar Cooker** developed by Roger Haines of Del Mar, California, is a 2x4 ft piece of cross-linked polyester foam insulation bonded with reflective metalized polyester film. The reflective polyester is waterproof, will not oxidize, cannot be scratched off, and has a high melting point. Haines reports that, according to the manufacturer, this material is environmentally safe through the whole production and recycling process. In the U.S. this material is used to make high-end auto windshield sunshades. In bulk, this material can be purchased for about $3.60 USD per square meter (the size of one cooker). A polycarbonate, cooking sleeve insulates and elevates the black cooking pot, eliminating the need for a plastic bag. A second layer of insulation is provided by a circular polycarbonate windscreen, which stabilizes the cooker and creates "oven-like" conditions around the cooking pot. The windscreen also provides extra stability in windy conditions as illustrated in this photo taken in Borrego Springs with 15 mph wind gusts. This solar cooker is currently being sold and evaluated as part of a Rotary San Diego-sponsored project in Kenya. The estimated wholesale price with all parts included is $15 USD per cooker.



NOTE: *Haines uses metal clips to hold the cooker, the windscreen and the cooking sleeve in place. I have strongly recommended that he use string instead since the metal clips can be easily lost in the sand and are difficult to replace. For the tests I conducted in Borrego, I replaced all of the clips with string. The result was a much more wind resistant cooker.*

4. The **Hot Pot reflector** is an aluminum, panel-hinged, modification of the original CooKit. It is manufactured in Mexico and was designed in 2004 for the Washington, D.C.-based NGO Solar Household Energy by Energy Laboratories, Inc. in Jacksonville, Florida. The complete Hot Pot kit includes a three-liter, tempered glass bowl with a glass lid and a black metal bowl that nests inside. The polished aluminum reflector is durable and folds flat for easy storage. It can last for years if kept clean and folded correctly for storage. It is designed for the tropics. The U.S. distributor has said he can provide Hot Pot reflectors in bulk for $40 each. One modification that would be required for desert use is some way to attach strings to anchor the reflector to rocks [as shown in this photo]. Solar Household Energy tested fifty Hot Pot kits in Gaga refugee camp in Chad. The women loved the reflectors, which are beautiful and efficient but they had to attach string to anchor it against the wind. They also loved the glass bowl and lid since all you have to do is lift the lid to get to the food. The problem with shipping the bowls and lids into refugee camps is their weight and fragility. One option would be to purchase the aluminum reflectors since they work just like a CooKit



and can be used with a traditional cooking pot and plastic bag. The pot gets even hotter when wrapped in a clear strip of polycarbonate, with a disc of 8 mm twin-wall polycarbonate clipped over the lid.

5. The **Rundle CooKit** is a version of the CooKit made with waterproof plastic flute board (instead of cardboard). It has foil glued to the plastic. It is fairly stiff and cannot be folded into a 12”x12” square like traditional CooKits. The **double Rundle** is a slightly (10%) larger version of the CooKit, which can hold two pots at once. I discontinued tests on this model due to its inability to fold into a 12”x12” square. Also when the foil was moistened with hot water it began to separate from the plastic.

6. **(Pat’s double CooKit)** I built this 10% larger version of the CooKit several years ago (using heavy duty cardboard and foil) after reading about a U.S. Army private based in Kuwait, who made one so that he could simmer chili with a large cast iron pot. I tested this CooKit with a large pot and later discovered that it could also cook two pots at a time (each in a plastic bag). It also worked well with the 8 mm twin-wall polycarbonate disc and wrap. The purpose of this test was to demonstrate that a larger version of the cooking can heat two pots at a time.

7. **Rollins CooKits** were designed by the late Matthew Rollins of the United Kingdom. They are made with waterproof plastic flute board and have a highly reflective surface glued to the flute board. One of the cookers has a curved back reflector, which creates a focal point that can quickly boil a small container of water like a parabolic solar cooker. While this may be useful for boiling water it is not practical for cooking since it heats only a small area on the cooking pot and will burn the food. The other is a traditional CooKit with a highly reflective aluminum coating. The plastic used in both cookers is too stiff for them to be folded like a typical CooKit into a 12”x12” square. Not practical for refugee camp situations. Tests on these models were discontinued. ##