A Parabolic Solar Cooker for Unattended Cooking

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Introduction

A parabolic reflector concentrates sunshine onto a cookware. It is efficient, if properly aligned. Since the sun moves over the sky at about 15° per hour, frequent adjustment is needed. The adjustment (typically two to four times an hour) inconveniences the user. Mechanism for the adjustment drives up the cost. In this article, we describe a parabolic cooker tolerant to misalignment. It has no moving parts, and cooks unattended. There is no need to vent, stir, or to follow the sun. With a crude reflector (home-made out of cardboard and aluminum foil), it can be made for under $10. Six prototypes have been tested extensively for a year in San Jose, California (37.6°N), with excellent results.

The Cookware

The cookware should be large and tall, so that it stays in-focus long enough for unattended cooking. Consequently, the pot will usually be less than half-full. It should be dark on the outside, and preferably dark on the inside as well. For uniform heating, it should be made of thick, good heat conductor. In developed countries at least 2 mm of aluminum, either hard-anodized or nonstick, is preferred. In developing countries 2 mm of black-coated aluminum, or 5 mm cast-iron, is recommended. For a family of four, we recommend a pot with a diameter d between 200 and 250 mm (8 to 10 inch), and a height h between $0.6d$ and $0.9d$.

The cover can be either transparent, or dark on both sides. The former is more efficient. However hot spots may appear on the top layer of food. The latter is less efficient. But it eliminates the hot spots. A dark cover should be made of aluminum or cast iron. A transparent cover is preferably made of tempered glass. Regardless of its material, a cover should be nearly airtight, to minimize heat loss in the form of steam.

Handles of the pot and the lid block sunlight. They should not be too large. Transparent handles are best. Dark handles are too hot to touch. Shiny handles may harm your eyes.

The Potholder

In the absence of handles, an ideal potholder would be a transparent sphere circumscribing the pot (fig. 1). It can hold the pot horizontally, and always in-focus, regardless of its own inclination. The radius of this sphere is c =. For example let d = 200 mm and h =150 mm. Then c = 125 mm. This parameter will be used in the design of reflector and potholder.

The sphere would also serve as a greenhouse, which is desirable in windy or cloudy days. However in the presence of handles, a greenhouse must be larger than the circumscribing sphere. An additional structure is needed within the greenhouse to hold the pot.

A greenhouse is not always desirable. It is fragile or costly. It fogs up during cooking. It also hinders access to the cookware. Therefore in calmer and sunnier regions, the potholder is designed without a greenhouse. Since the cooker will be designed to tilt about one axis only, a spherical potholder is not necessary. A pair of arched rails is adequate. Obviously the rails represent a subset of the circumscribing sphere (fig. 2).

Each rail contacts the pot at two points. For maximum stability, four contact points should define a square. Therefore the rails should be spaced about $0.7d$ apart. The radius of each arc describing the rail should be . Although the contact points are usually less than 100° apart on each rail, the rails should measure between 160° and 180°. The margin allows the rails to tilt over a range between ±30° and ±40°

The Reflector

The focal length f of a parabola is defined as the distance between its vertex and its focal point. To be insensitive to misalignment, and to keep the pot clear of the reflector, f should be slightly greater than c. For example when $c = 125$ mm, f should be about 130 mm.

The outer diameter D of the parabola should be approximately four times the diameter of the pot ($D \approx 4d$). A larger D yields greater cooking power. However the power declines more rapidly with misalignment. Also, the reflector becomes taller and bulkier.

A high-precision parabolic surface is neither necessary, nor desirable. As a rule of thumb, the diameter of "hot spot" around the focal point should be slightly less then $d/2$. A sharper focus creates greater fire hazard. A fuzzier focus reduces the cooking power. A homemade reflector is rarely too sharp in focus. However an industrial reflector may have to incorporate facets whose diameters are slightly less than $d/2$.

The reflector can be made out of a sheet by cutting, folding and gluing. Details will be described in a separate article. Bare cardboard crumbles permanently in the morning dew. With Latex paint it can stand the dew and light rain. Sheet metal is either too heavy or too thin. Fiberglass-filled epoxy works best. Regardless of the sheet material, aluminum foil should be applied on the interior of the reflector after the latter is formed.

The Frame

A frame holds the reflector axi-symmetrically at its bottom-side (fig. 3). It can be cut out of the top of a jumbo-size tomato-cage, for example. Legs of the frame are bent and cut into unequal lengths, so that the frame will be tilted with respect to the base. The free-end of each leg is further bent to create a loop, to receive a mounting screw.

The Base

The base of the cooker is a piece of rectangular plywood or other inexpensive solid. It supports both the potholder and the reflector, without any mechanism for adjustment.

Assembly

The reflector is intentionally tilted with respect to the base (fig. 4). The axis of tilt is parallel to the shorter edges of the base. The tilt angle ϕ from the base to the optical axis bisects the expected range of solar elevation. For example in San Jose (37.6°N), the elevation of sun can be as high as 75° in a summer noon, and as low as 29° in a winter noon. If we wish to cook between 25° and 75° elevation of the sun, then $\phi = (25° + 75°)/2 = 50°$.

Once the reflector is fixed to the base, locate the focus. Position the rails such that their circumscribing sphere is centered at the focus, and that their cords are parallel to the longer edges of the base (fig. 5).

The rails can be cut out of the lower section of the tomato-cage. Each rail should have two legs in this case, because the cage consists of rather thin wire. The legs run through the reflector, and are affixed to the base (fig. 5).

The base can be placed on the ground at any azimuth angle. Usually one of its two short edges remains on the ground. The other short edge is plopped up by common objects (such as bricks, a rock, or a stool), to accommodate up to ±30° change in the sun's elevation (fig. 6). Fancier supports, whether stand-alone or attached to the base, are optional.

Finally make an alignment mark as follows. Aligne the optical axis vertically. The base will be tilted at this time. Drill a hole on the reflector, above a lower corner of the base. Locate a point O on the base, directly below the hole. Measure the distance l between point O and the hole. Let $b = 0.27l$ and $a = b/\sin\phi$. Draw an ellipse with center O, major axis $2a$ parallel to the longer edges of the base, and minor axis $2b$ parallel to the shorter edges of the base. The vertex nearest the short edge of the base represents 6 o'clock am. Starting from this vertex, every 15° of arc represents an hour. The time increases counterclockwise on the ellipse. Draw and label ticks in the usable period, for example 8 am through 4 pm (fig. 7).

Usage

Warning: Direct or concentrated sunlight can damage your eyes! Always wear dark sunglasses when looking into the reflector.
Caution: The pot and food can be very hot!

The solar cooker is now ready to use. Simply place the solar cooker on a sunny, flat ground. Turn the base on the ground. Then plop it up with bricks, etc. to face the sun. A bright spot should appear under the reflector. Adjust the base orientation such that the spot falls on the ellipse, at a point corresponding the present time. Place a pot of food on the rails. Cooking begins, at about 80% of the full power. The spot travels toward the center of the ellipse, and reaches there in one-hour. The solar power will peak then. The spot will continue onto the opposite side of the ellipse; and the solar power will drop to the present level in another hour. Most food will cook unattended in this two-hour period, and stay warm for hours afterwards. There is no need to stir or vent.

If a shorter cooking time is desired, let the bright spot fall within the ellipse. If less power is desired, let the spot deviate from the present time. If maximum cooking power is desired, and if the user is willing to adjust the alignment frequently, the spot should stay in the center of the ellipse at all times.

No greenhouse is needed in a calm, sunny day. If it is windy or cloudy, loosely wrap the pot in a clear HDPE bag before placing it on the rails. Most plastic shopping bags from the supermarket are HDPE. If a bag bears store logo or advertisement, the printed area may overheat and melt. This area should be tugged under the pot, away from strong sunlight. The bags also tend to melt over dark handles and dark cover, but not on shinny or transparent surfaces.

Variations

A funnel reflector can be used in place of the parabolic reflector. A funnel is easier to make, but about 20% less efficient than a parabola of the same diameter. A funnel also requires more material than a parabola. The optimal apex angle of the funnel is 60°. It should be truncated at half-height. The flat bottom surface must be reflective, and preferably shiny instead of mat. It is also preferably strong enough to support the potholder.

A funnel reflector has no focal point. The center of the pot should be at, or slightly below the intersection of diagonals, which run from the top edge to the bottom edge (fig. 8).

The top of a reflector, whether parabolic or funnel, can be trimmed at both ends of the horizontal diameter. These ends are least efficient, because they are facing a sharp corner, instead of a round edge of the pot (fig. 9). A trimmed reflector requires less material. It provides better access to the potholder, and is easier to store and transport.

The frame and the potholder can be integrated, so that there is no need to align the rails during assembly.

The cooker described above is intended for use at a permanent residence. It can be made collapsible and portable. However the number of parts will increase.

Summary

A parabolic solar cooker suitable for unattended cooking is described. It features a short focal length, a tall and slightly oversized pot, a self-centering potholder with a pair of arched rails, an alignment mark, and a tilted frame. The cooker contains no moving parts. It weighs only 4 kg (9 lbs). Since it is insensitive to misalignment, the reflector can be very crude and cheap. With ample power, it requires no greenhouse in good weather. Plastic bags can be used as a greenhouse in windy and cloudy days.