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Research Article

Non Solar and Non Electric Portable Stove for Heating Meal and Making Tea/Coffee

Shyam S Nandwani*

Retired Professor, Researcher and Promotor of Solar Energy, Costa Rica

***Corresponding Author:** Shyam S Nandwani, Retired Professor, Researcher and Promotor of Solar Energy, Costa Rica.

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Abstract

In the absence of both Solar and Electricity for heating water and meal, author preferred to find the simple solution to make coffee and heat lunch. Used tripod and a portable burner, Can of Ethylene Glycol and paraffin wax as burning fuels. The variation of water and meal temperature and amount of fuel consumed was measured with time with both fuels. The two cups of pasteurized tea/coffee could be made in 12 to 15 minutes and 300 g of typical breakfast (pinto) could be heated to 70 °C in 20-30 minutes. The burning efficiency of fuels and some costs etc. are reported.

Keywords: Heating Water; Heating Meal; Handy Fuels; Ethylene Glycol; Paraffin Wax

Introduction

Author did his Ph.D. in Physics on theoretical aspects of Mossbauer Spectroscopy during 1969- 1973 at Indian Institute of Technology, Roorkee, India. Although got Degree, published 13 research papers in international journals including at International conference of Mossbauer Spectroscopy, in France in 1974 [1]. Inspite of this I was not very satisfied. Thus in 1976/1977/changed my interest to do experimental research, promotion and practical uses of Solar Energy at Indian Institute of Technology, Delhi India. Then in June 1978 got an offer to work on Solar Energy at Universidad Nacional in Costa Rica. Most of the people, including myself, were using electricity for cooking, because about 75% of electricity was generated with clean hydroelectricity. Started challenges. In Feb. 1979, due to less hydro potential but summer (more sunny days) Electric Utility Company imposed electric rationing 2 days a week, from 7 am to 5 pm. I took as first challenge to use solar energy for heating meal cooked previous night. The device, Solar Food warmer made first time in Costa Rica was published in May 1979 in local English News Paper [2]. Next was to cook meal on Sunny day, the device Hot box Solar Oven was designed, studied and published in 1981 in the journal [3,8] and also got patent in 1982. Next step was Cooking meal on partially sunny day using Hybrid Solar/Electric Oven [4] and many more models [5,7,9,10]. Some model used at our home are shown in Photo 1. The first oven with electric cable, Multipurpose Solar/Electric Hybrid Oven is authors favorite device [6].

Photo 1: Some Solar Cookers/Ovens designed/studied and used by author at home.

In summary during last 45 years, in addition to work on various applications of Solar Energy author uses solar oven to cook different meals [5] has also done dissemination of solar cookers for heating lunch students at educational centers [9].

Then came another challenge. My wife and myself like morning herb/black tea/coffee at about 8 to 9 am. Solar intensity at this time even on sunny day is not sufficient to heat water at 70°C (pasteurizing temperature) for making 2 cups of tea/coffee (400-500 ml). Now imagine no electricity due to some problem with electric utility company. Although I can walk 500-600 meters to get coffee at bakery place, but she does not like to walk. bakery shop. She has to go to neighbor house to heat water on her gas stove. Considering that electricity failure in Costa Rica is not very common, I did not like to spend/invest in Gas Range. Being a applied physicist I thought of using just some simple and portable burner, especially for this period (No electricity and insufficient solar energy) and study different aspects. That is the main objective of this paper.

Materials

In the market I saw various types of solid, liquid and gaseous compact portable fuels as shown in Photo 2.

Photo 2: Different types of compact fuels available in the market.

For this study I decided to use two fuels, Handy Wick Chafing fuel (Liquid) and paraffin Wax (Solid), as shown in Photo 3 and commonly available.

For preliminary study, I used the system as shown in Photo 4, commonly used at some marriages, baby shower activity etc.for maintaing cooked meals hot, and tried to heat 300-500g of water (about 2 cups).

Photo 3: Liquid and Solid Fuels used in the present Study.

It could heat water to 70-80 °C (pasteurization temperature) in 8-10 minutes and even boiled in 15-20 minutes. In this way at least I could make my/our tea Coffee and also heat breakfast. Although my problem of enjoying morning tea/coffee was solved, even in the absence of both Sun and Electricty. Then the objective was more scientific. How much water coffee could be made, maximum temperture attained in what time and quantiy of fuel used, cost, burning efficiency and the carbon dioxide emission, etc.

Experimental set up

In one of the liquid fuel, made by STERNO, Ethylene glycol ($C_2H_6O_2$) and diethylene glycol ($C_4H_{10}O_3$) are used for heating meals in portable stoves [11].

As indicated on the Can, the fuel is a mixture of Ethylene Glycol and Diethylene Glycol. It also mentions that Can has volume of 7.41 Fl. Oz. or 219 ml. Total weight of Can with fuel= 282g. A pack of 12 Cans cost around US$26 and one Can of fuel can burn for 6 hours.

Photo 4: Preliminary set up for heating water for making tea/coffee.

For experimental study I set up the necessary simple instruments like thermometer, balance/weighing machine, watch etc., as shown in Photo 5.

Experiments

Although many experiments were performed using Ethylene Glycol and Paraffin Wax, we will inform only some of these.

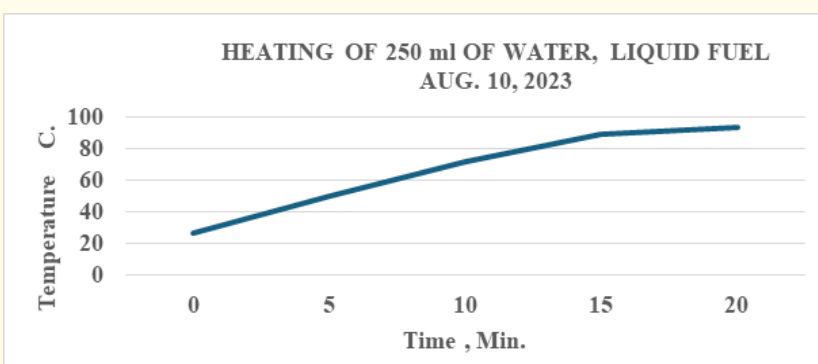
Ethylene glycol

Expt. E1. Aug. 10, 2023

Initial weight of Can plus fuel 282 g. Plan was to heat 250 ml water in Aluminum pot (120 g). Initial water temperature was 27 °C.

Photo 5: Set up of Tripod, Fuel, Water pot, Thermometer, Weighing balance, IR thermometer etc.

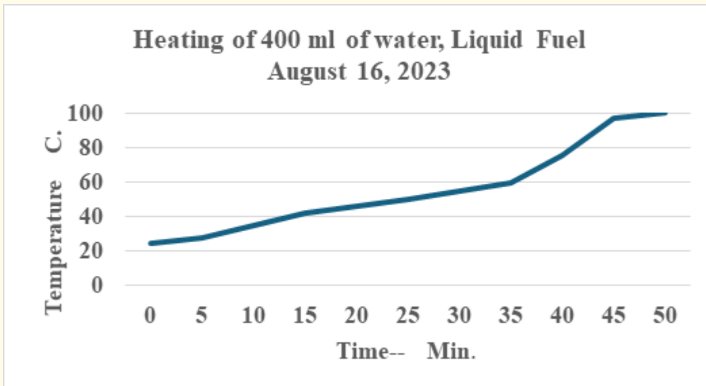
The experiment was started at 2:30 pm. Measured water temperature every 5 min and total fuel left after water got pasteurized or boiled. The results are shown in the graph 1. The water temperature reached to 70 °C after 10 minutes and reached 94 °C, in about 20 minutes. At the end, the weight of the Can with fuel was 271 g. Thus, fuel burned was only 11 g.



Graph 1: Variation of temperature of 250g of water with time measured on Aug. 10, 2023.

Expt. E2. Aug. 16, 2023. 1:20 pm

Continued experiment with previously used Can to heat 400 ml of water in steel pot where the temperature sensor could be introduced in the water. Being steel pot it has less thermal conductivity, as compared to aluminum. Weight of Can plus fuel is 271 g. Again measured the water temperature every 5 min and the fuel left once water reached near boiling temperature. Results are shown in Graph 2.



Graph 2: Variation of temperature of 400g of water with time measured on Aug. 10, 2023.

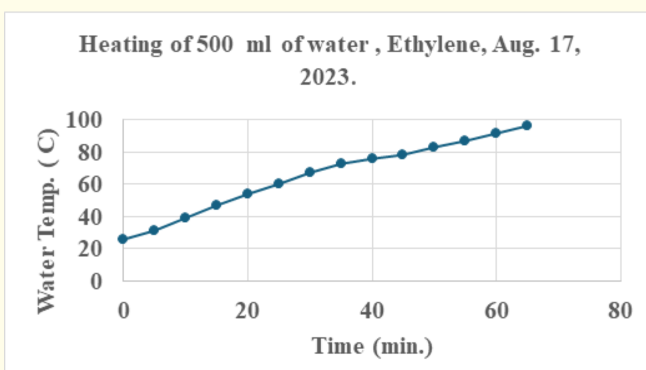
Water temperature reached 70 °C after 38 min and reached to boiling temperature after 50 min. The Can weight was 251 g. Thus, fuel burned is 271-251 = 20 g.

Expt. E3. Aug. 17, 2023, 4:40 pm

Continued with used Can with Fuel (223 g) to heat 500 ml of water again in steel pot.

The variation of water temperature with time is shown in graph 3.

Initial water temperature was 27 °C. and after 35 min temperature reached to 70 °C and. reached to 96°C, after 65 min. The Can weight was 211 g. Thus, fuel burned is 233- 211= 22 g.



Graph 3: Variation of temperature of 500g of water with time measured on Aug. 17, 2023.

In summary we can see that the water could be pasteurized in 10 min (250 ml), in 38 min (500 ml) and water was almost boiled in 20 and 60 min respectively.

Similar experiments were continued on Aug. 16, 17, 18 and 20, 2023, with different quantities of water at different times, until the fuel in the can was finished.

Total fuel burnt in one Can since beginning was 238 g and took 670 minutes.

Some results

Burning efficiency

Total water heated with one Can is 5.650 g. Rise in water temperature (97-25) °C, is approximately, 72 °C.

Total Useful heat: 5.65 kgX 1 (kcal/kg.°C) X 72 °C = 406.8 kcal -----(1)

To know the applied energy, Total fuel used/burned = 238 g.

According to the label on the Can, it says fuel contains Ethylene glycol and Diethylene glycol. When these two compounds are mixed, the calorific value of the mixture will be a weighted average based on their respective proportions in the mixture [11].

Calorific value of Ethylene glycol (10) = 23.5 MJ/kg

Calorific value of Diethylene glycol (10)= 26.3 MJ/kg

If we assume the Can fuel is a mixture of 50% ethylene and 50% diethylene glycol by mass, calorific value of the mixture will be= (0.5X23.5 +0.5X26.3) MJ/kg = 24.9 MJ/kg.

Therefore heat contained in 0.238 kg of fuel used = 0.238 kg X 24.9 MJ/kg = 5926 kJ/kg = 1411 kcal. (heat supplied) ---(2).

From Equations 1 and 2, burning efficiency of fuel = (406.8/1411) = 0.288 or 28.8%.

It is low as lot of heat is lost from the wick to the container. If required, the losses could be reduced by covering the pot with some insulating material, then efficiency will be increased.

Cost/simple economy

Cost of Box of 12 fuel packs is about 12995 Colones (local currency) or US$26.

Cost of one can will be US$26/12 = US$2.1, Normally one cup of coffee 8Oz (8X29.6 =236 ml).

Excluding the cost of coffee/tea/sugar, with one Can one can make/heat 5650 ml/236 ml = 24 cups of tea/coffee. Fortunately, Costa Rica is a producer of coffee, sugar and milk.

Thus, cost of making two 8 oz coffee = $2.1/12 = $0.18. In case we had to go to nearest cheap coffee place we had to pay, $4/- for two cups of simple coffee.

We did also experiments for heating breakfast, like Gallo pinto (mainly Rice and black beans) on two days using the same fuel as shown in Photo 6.

Photo 6: Heating of Pinto with Ethylene Glycol in Aluminum (left) and Steel (right) pot.

Citation: Shyam S Nandwani. "Non Solar and Non Electric Portable Stove for Heating Meal and Making Tea/Coffee". *Acta Scientific Applied Physics* 5.1 (2025): 23-32.

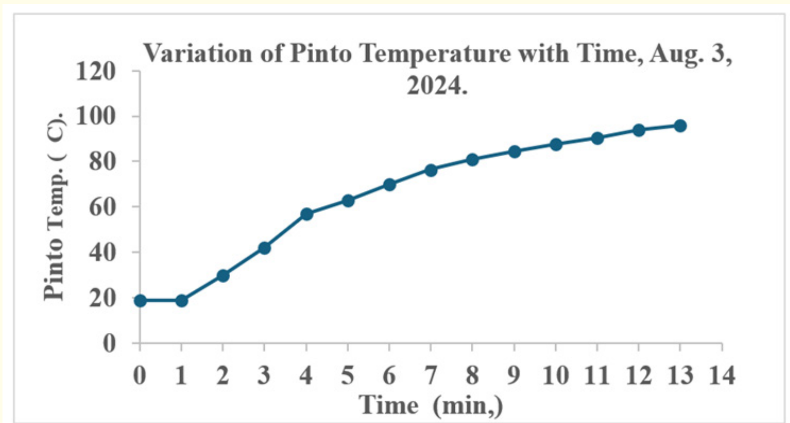
E4. Friday, Aug. 3, 2024, 2:45 pm

Three hundred grams of pinto was heated in Aluminum (Al) pot and temperature was measured each 2 minutes, until reached to about 96 °C. Results are shown in Graph 4.

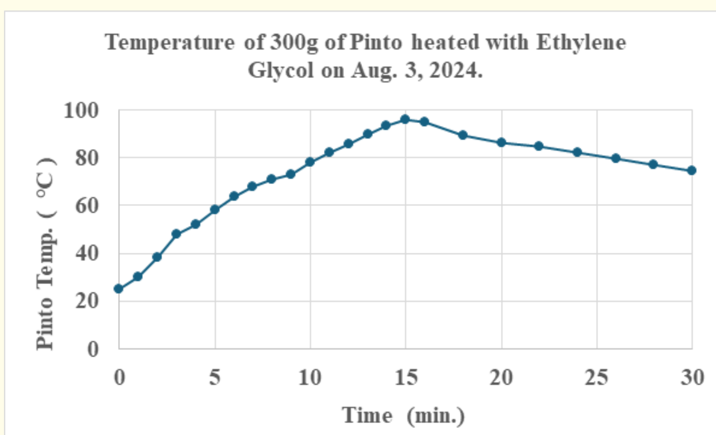
Thus 300 g of pinto could be heated to 70 °C in only 6 minutes and to 96 °C in 13 minutes., using only 10g of fuel.

E5. Aug. 3, 2024. 4:45 pm

Again three hundred grams of pinto including some chicken pieces was heated in steel (SS) pot. Meal temperature was measured each 2 minutes until reaching to about 96 °C.



Graph 4: Variation of pinto temperature with time on Aug. 3. 2024.



Graph 5: Variation of pinto temperature with time again on Aug. 3. 2024.

After heating for 15 minutes the Ethylene burner was removed. And the fall of pinto temperature was measured for another 15 minutes. Graph 6 shows the variation of pinto temperature with time.

We can see that 300 g of pinto could be heated to 70 °C in only 8 minutes and to 96 °C in 15 minutes., using only 10g of fuel. Also the steel pot maintained the meal hot, reducing to 70 °C in another 15 minutes.

Table 1 shows the experimental heat gain and fuel consumed and thus burning efficiencies for heating pinto in both measurements.

Slightly better efficiency using aluminum pot as compared to steel pot could be due to better thermal conductivity of Aluminum.

As planned now we also did similar experiments with another compact fuel, wax.

Date Meal	Temp. Rise °C	Heat Gain Kcal	Fuel used g	Heat Supplied, kcal	Effic. %
3/8/24 (Pinto)	95.8-18.7= 77.1 (Al)	22.82	10	59.51	38.3
3/8/24 (Pinto with Chicken)	96.0-24.7= 71.3 (SS)	19.25	10	59.51	32.3

Table 1

Experiments with paraffin wax

The primary purpose of a candle is to produce light. The vaporized wax burns, producing a steady flame that emits light. While the light output is relatively low compared to modern electric lights, it is enough to illuminate a small area. However, the candle can provide also heat, like incandescent bulb.

A typical candle used for lighting/heating is primarily composed of the following basic materials.

- **Wax:** The main component, usually made from paraffin (a petroleum byproduct), beeswax, soya wax, or stearin (animal fats and vegetable oils). Paraffin wax is the most common in commercial candles.
- **Wick:** Typically made of braided cotton, the wick is designed to absorb the melted wax and allows it to burn providing a steady flame.

A candle can be used to heat water, but it is generally not very efficient. If more candles are used, more heat will be generated, but it is not practicable for quickly boiling or heating large quantity of water. We wanted to try if we can make at least tea/coffee and heat lunch box using bucket of paraffin wax. Photo 7 shows wax bucket and the experiment Setup for measurements of water/meal temperature.

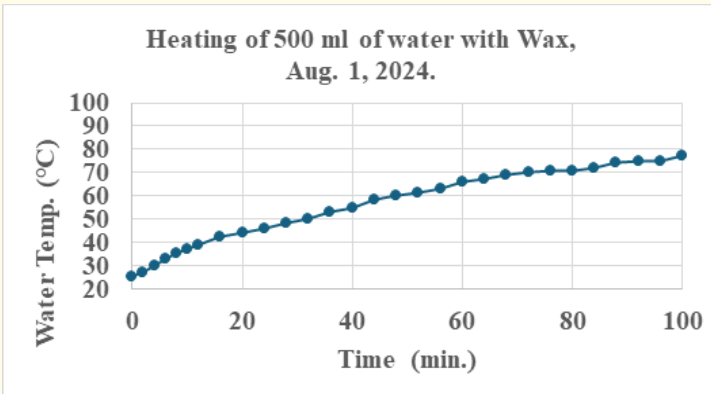
As part of the study, we tried to heat water at least to 70 °C for heating water. For this instead of one or more candles, we used a small bucket of wax (377 g, including weight of bucket), available in the market as shown in photo 7. And stainless-steel pot with possibility of measuring water temperature. As in previous cases, measured the temperature of known quantity of water with time until reach at least 70 °C, and at the end measured the quantity of wax left and thus, weight of fuel (wax) used.

Photo 7: Wax bucket and experimental set up and some measuring devices.

Expt. W1 Aug. 1, 2024

Experiment was started at 4 pm. Weight of the wax with bucket was 377g. Five hundred ml of water was heated, and its temperature was measured every 2 to 4 minutes, up to pasteurization temperature. Results are shown in Graph 6.

One can see that 500 g of water could be pasteurized in 72 minutes. Fuel burned 7g. Losses are from flame, all sides from pot. To reduce heat losses, again one can enclose the pot with insulating material.



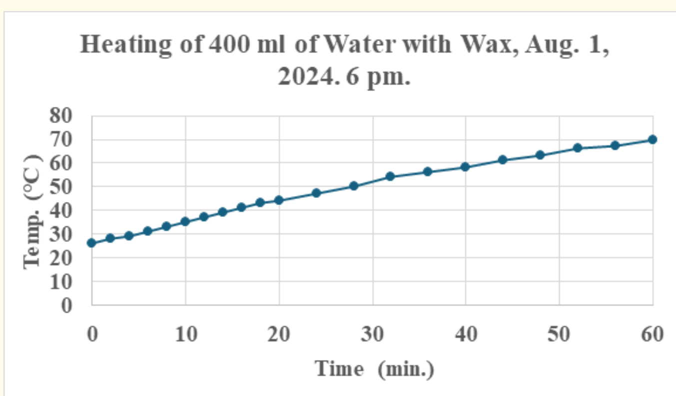
Graph 6: Variation of temperature of 500 ml of water with time. On Aug. 1, 2024.

Expt. W2. August 1. 2024

Experiment was repeated at 6 pm. Bucket and Wax: 370g. Now 400 ml (2 cups or 16 Oz) of water was heated with wax and its temperature was measured every 2 to 4 minutes up to pasteurization temperature. Results are shown in Graph 7.

Thus one can see that 2 cups (400 ml) of water could be pasteurized in 60 minutes.

Weight of Bucket and Wax. 367 g. Loss of fuel is 3g. Ambient temperature 23-24 °C.



Graph 7: Variation of temperature of 500 ml of water with time. On Aug. 1, 2024.

Three more experiments were done with 300 and 400 ml of water. In the case with 300 g of water, (August 2, 2024) it got pasteurized only in 29 minutes.

Calculation of burning efficiency

Based on 5 studies, total water heated was 1.9 kg, up to pasteurization temperature (70 °C). Average rise of temperature is about 48 °C. Total fuel burned is 23g in total 300 minutes.

Total useful heat energy: M(kg) X Specific heat (kcal/kg °C) X Change in Temp. δT (°C)

= 1.9kg X 1 (kcal/kg X °C)X48 °C = 91.2 kcal ------(3)

Calorific Value of paraffin wax (11)= 44 MJ/kg. = 10470 kcal/kg.

Total Heat input (supplied) = 0.023 kg X 10470 kcal/kg = 240.8 kcal --------(4)

From Eq. 3 and 4, burning efficiency with paraffin wax = 91.2/240.8 = 37.9 %. Very similar with Ethylene Glycol. One of the advantages with this fuel is that candles are made in Costa Rica.

Economics of two fuels

We will like to make some comparison of two fuels, glycol and wax used in the present study.

Wt. of Single glycol Can (only fuel). 238 g.

Price of Single Can: Col. 12995/12= Colones 1083 (US$2)

Price of 1 kg of Stern Fuel: Col. (1083/238) X1000= Col. 4550 (US$9)

Calorific Value of Fuel, 24.9 MJ/kg = 24900 kJ/kg = 5951 kcal/kg

Regarding solid paraffin wax, price of Wax depends on simple Candel, Colored Candel or Perfumed Candel, etc. We have used simple colored candle.

Weight of only Wax 605- 252 (bucket) = 353 g, Cost = Colones 1875 (US$3.6).

Price per kg of Wax, = (1875/353) X 1000= Colones. 5311 (.US$10.3)

Calorific Value of Wax. (paraffin) = 10470 kcal/kg**.**

Although wax cost (per kg) is about 13% more than Stern Liquid fuel however Calorific Value of Wax is about 43% more than Glycol Liquid Fuel. Also Wax is more commonly available and manufactured in Costa Rica.

Conclusions

In addition to conventional Electric Oven, author has studied and used Solar Ovens, Hybrid Sol/electric Oven etc. for about 45 years for cooking and heating meals. However, when there is No electricity or sufficient Solar Energy, then the last option for the heating will be conventional and stored fuel in Cans/bottles, like ethylene, methylene and even wax etc., although somewhat polluted. As electricity failure is not very common in Costa Rica thus instead of buying LPGas range and tank, used two types of stored fuels to heat water to make just tea/Coffee and heat breakfast and lunch cooked already. The measured data shows that the water could be heated to 70 °C in 12-15 minutes and even can be boiled in 20- 40 minutes.

We found that these fuels although are somewhat polluted, but are not expensive for our purpose, portable and secured fuel. Security of any fuel is more important than cost. Millions of mobile phones are being sold at variable prices for different uses, but all can make call at any time and in any climate. My challenge was to get my morning tea/coffee and heat lunch on no electric and no sunny day, comfortably and at reasonable cost. Although the work done is not advanced research but at least can solve practical problem for some readers like me.

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