Experimental comparison of two specialised cooking pots during partly cloudy conditions using parabolic dish solar cookers

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Abstract

Solar cookers perform well during sunny days, but their performance during cloudy periods is poor. Most of the solar cooking tests presented in recent literature, including the test protocols, are for ideal clear sky sunny conditions with little or no clouds. Very little work has been reported on solar cookers in partly cloudy conditions. This work compares two specialised cooking pots using 1.5 m parabolic dish solar cookers to evaluate their performance during partly cloudy conditions. A 4-litre pressure-cooking pot is compared to a 4-litre heavy base cooking pot under partly cloudy conditions to see if it is possible to boil water in variable high and low solar radiation conditions caused by cloud cover. With an average partly cloudy solar radiation value of 549 W/m^2 for the heating period up to boiling, the pressure-cooking pot can boil 4 litres of water in 1.1 hrs. This is faster than the 1.3 hrs the heavy base pot takes at an average solar radiation of 570 W/m^2. The average thermal (water heating) efficiency is 33 % for pressure-cooking, greater than the heavy base pot of 26 %. Two additional experimental tests performed with 2.0 and 4.0 kg of water also show better performance for the pressure-cooking pot than the heavy base pot. The results obtained support the use of the pressure-cooking pot during partly cloudy conditions.

Keywords: Experimental; Partly cloudy conditions; Parabolic dish solar cookers: Specialised cooking pots; Thermal efficiency

1. Introduction

To reduce the use of fossil fuels for cooking in developing countries, which have negative health impacts on humans, solar cookers without greenhouse emissions can be used (Aramesh et al., 2019; Arunachala et al., 2020; Paneru et al., 2024; Alonso et al., 2025; Adavi et al., 2025). Solar cookers are devices that capture solar radiation and use it to cook food. Solar cookers can be used to improve the livelihood of women in the developing world since more time can be allocated to other activities instead of searching for firewood, which is detrimental to their health since greenhouse gases are emitted when using firewood for cooking (Padonou et al, 2022). The most common types are solar box cookers, panel cookers, and concentrating solar cookers. Concentrating solar cookers like parabolic dish solar cookers are the most efficient type of cookers, achieving high temperatures in short time intervals for almost all types of cooking such as roasting, baking, frying, and boiling (Lentswe et al., 2021; Abedigamba et al., 2023; Mawire et al., 2024; Gil et al., 2025; Mahmoudi et al., 2025). However, concentrating solar cookers perform poorly during cloudy periods and cannot be used efficiently. Options to improve their

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performance during cloudy periods are integrating storage or using specialised cooking pots (Bhave et al., 2020; Mawire et al., 2020). Most solar cooking tests with parabolic dish solar cookers presented in recent literature, including the test protocols, are for ideal clear sunny conditions with little or no clouds (Saxena et al., 2025). Very little work has been reported on using solar cookers in partly cloudy conditions, and people still need to cook in such conditions. To address this problem, this paper presents an experimental comparison of two specialised cooking pots under many variations in solar radiation during partly cloudy conditions. The aim is to determine whether these specialised cooking pots can boil a large load of water (4 kg) under variable solar radiation conditions. Two solar parabolic dish solar cookers with diameters of 1.5 m are tested with pressure and a heavy base cooking pot. The results will add to the knowledge of solar cooking with specialised cooking pots under variable high and low solar radiation conditions, a grey area with very little work presented.

2. Experimental method and analysis

The two specialised cooking pots painted with high-temperature black enamel engine paint are shown in Fig. 1. The pots were painted black to increase the absorption of solar radiation. The pots were purchased locally from Takelot in South Africa (Heavy Base Cooking Pots, 2025; Stainless-Steel Pressure-cooking Pot, 2025) and have capacities of around 5 litres, although the pressure-cooking pot is sold as a 7-litre pot. The instruction manual indicates that the pressure-cooking pot cannot be operated above 4 litres. Both pots are made of stainless steel. The difference between the pots is that the pressure-cooking pot has a lid with a silicone seal for pressurised water. It has a specialised lid handle to ensure a tight fit seal during cooking.

On the other hand, according to the manufacturer, the heavy base pot has a 3 cm thick encapsulated stainless-steel layer to allow for cooking and storage of thermal energy and additional cooking after the heat source is removed. All the cooking pots are ready with induction cookers. The heights of both pots are around 14 cm. The pots also have comparable outer base diameters of 21.2 and 21.4 cm, respectively, for the heavy base and pressure-cooking pots. The internal diameters are around 24 cm for both pots. The mass of the heavy base pot with the lid was 1.792 kg, whereas for the pressure-cooking pot, it was 2.846 kg.

Fig. 1: Photographs of (a) the heavy base cooking pot, and (b) the pressure-cooking pot used in the experimental tests.

Fig. 2: A photograph of the 1.5 m parabolic dish solar cookers with the two specialised cooking pots just before experimental tests

The average thermal/water heating efficiency is calculated from the ratio of the average input solar energy to the thermal energy gained by the heated water, and it is expressed as (Saxena et al., 2025):

$$\eta = \frac{mc_w(T_f - T_i)}{I_{av}A_c\Delta t} \quad (1)$$

, where *m* is the mass of the load, c_w is the specific mass of water, T_f is final steady state temperature at the start of boiling, Ti is the initial temperature of water before heating, I_{av} is the average solar radiation from the beginning of water heating to the commencement of boiling, Ac is the solar capture area of the parabolic dish solar cooker, and Δt is the time interval between the start of water heating and boiling..

The pots were placed on two identical 1.5 m parabolic dish solar cookers, shown in Fig. 2, and manually tracked during the experimental period. 4 litres of water were used in each test. Two K-type thermocouples with accuracies of ±2.0 ºC were placed in identical central positions just above the base of the inner surface were used to measure the temperature. Another K-type thermocouple measured the ambient temperature. The solar radiation was measured with a CMP 11pyranometer. The thermocouples and the voltage output of the pyranometer were connected to the SEFRAM DAS240 datalogger, which recorded data in its internal memory at 10 s intervals during the experiments. The experimental tests were conducted in Mahikeng (25.8582° S, 25.6210° E), South Africa.

3. Results and discussion

The solar radiation profiles during a partly cloudy period from 9:00-10:30 hrs on 12 April 2025 are shown in Fig. 3 (A). The first initial period between 9:00 and 9:23 hrs shows very low solar radiation values. This was followed by a relatively sunny period from 9:23-9:45 hrs with occasional clouds between that period. The last period from 9:45 to 10:30 hrs was generally cloudy with patches of solar radiation here and there. The average solar radiation for the whole 1.5 hrs of the experiment was 599 W/m^2 with a maximum solar radiation just below 800 W/m^2. The temperature profiles of the cooking pots are shown in Fig. 3(B). Due to the initial low solar radiation values between 9:00 and 9:30 hrs, the temperatures of the two pots are almost identical and marginally rise to just above 30 ºC. After this, the pressure-cooking pot shows a faster temperature rise and achieves the boiling temperature after around 1.1 hrs (at 10:08 hrs) of the water heating. This is likely attributed to the pressuring mechanism, which efficiently traps heat more effectively than the heavy base pot, which has no pressuring mechanism. The heavy base pot only achieves the boiling point after 1.3 hrs (10:22 hrs), although it is much lighter than the pressure-cooking pot. With an average partly cloudy solar radiation value of 549 W/m^2 for the heating period up to boiling, the pressure-cooking pot achieves an average water heating efficiency of 33 %. This efficiency is greater than the heavy base, which achieves an average water heating efficiency of 26 % at an average solar radiation of 570 W/m^2 for its more extended water heating period. The results suggest that a pressure-cooking pot is a more effective solution for cooking during partly cloudy conditions than the heavy base pot. Even with the drops in the solar radiation after the boiling point has been achieved for the pressure cooker, the temperature does not seem to show any pronounced drop.

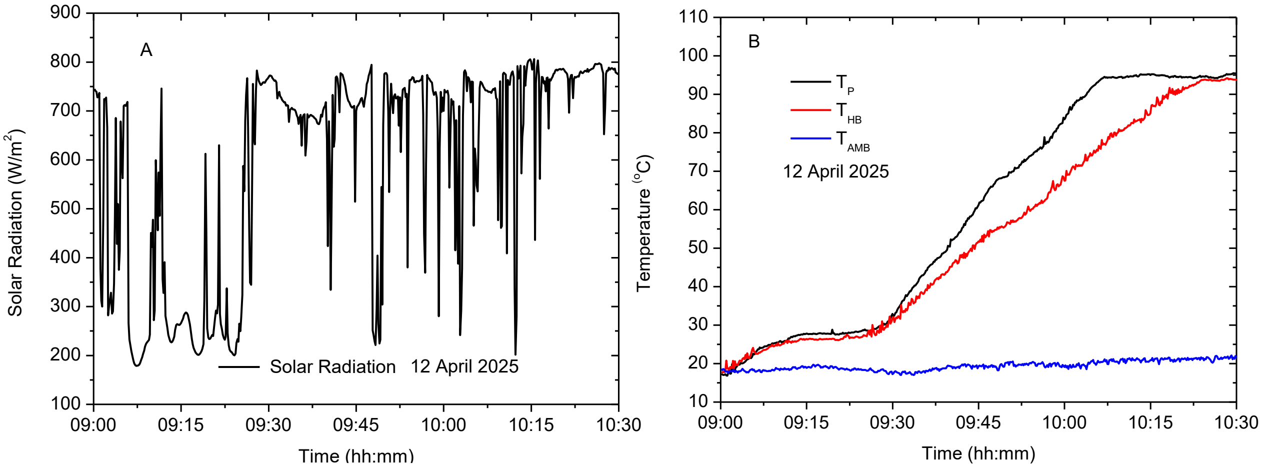

Fig. 3: (A) Solar radiation profiles, and (B) temperature profiles of the two pots during a partly cloudy period on 12 April 2025.

Fig. 4 shows the experimental test results on 13 April 2025 for two consecutive tests under partly conditions. Test 1 used 2.0 kg of water as the heating load, and test 2 used 4 kg. Although the solar radiation was not as variable as in Fig. 3, the two tests were conducted after noon from 14:15 to 17:00 hrs. Higher temperatures are seen with the pressure-cooking pot for both cooking tests. For test 1, during the first 15 minutes, the highest temperature achieved by the pressure-cooking pot is around 96 °C.

In contrast, the heavy base pot shows a maximum temperature of 89 °C during the same period. Water boils in 15 minutes for the pressure-cooking pot in test 1, whereas it only boils 30 minutes later for the heavy base cooking pot. The average water heating efficiencies for the first 15 minutes for test 1 are 51 and 49 % for the pressure and heavy base cooking pots, respectively, showing that the thermal performances are comparable during good solar radiation conditions. However, lower cooking temperatures are obtained with the heavy base pot. The temperatures of the two pots drop from 15:00 hrs because of the drop in the solar radiation. For test 2, the solar radiation is falling, and the average solar radiation from 15:35-16:30 hrs is around 356 W/m^2. Water boils in the pressure-pot in test 2, whereas it does not boil in the heavy base cooking pot, showing superior performance for the pressurised cooking pot for the heavy load of 4.0 kg. The thermal efficiencies from 15:35-16:30 hrs are comparable for test 2, with the pressure-cooking pot showing a slightly higher average water heating efficiency of 26 % compared to 23 % for the heavy base pot. As in test 1, when the solar radiation drops, the water temperatures drop in both pots. The results of the three tests under partly cloudy conditions show that the pressure-cooking pot is a more effective cooking pot, achieving higher temperatures and water heating efficiencies.

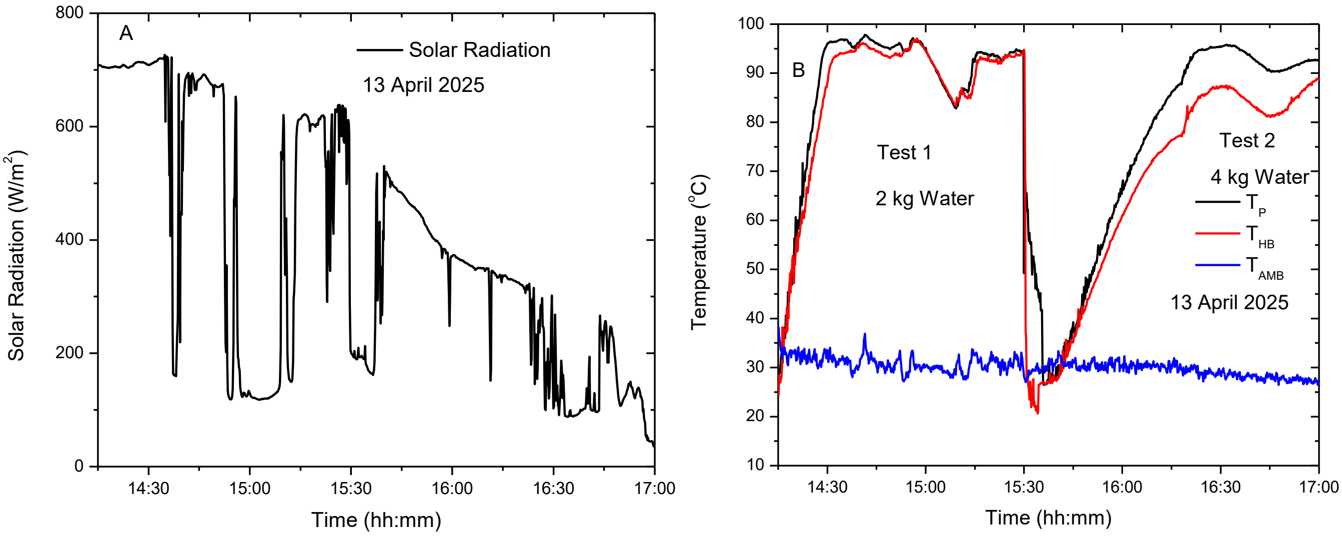

Fig. 4: (A) Solar radiation profiles, and (B) temperature profiles of the two pots during a partly cloudy period on 13 April 2025.

4. Conclusion

Experimental results were presented by comparing two specialised cooking pots using 1.5 m parabolic dish solar cookers to evaluate their performance during partly cloudy conditions. A 4-litre pressure-cooking pot was compared to a 4-litre heavy base cooking pot under partly cloudy conditions to investigate boiling water under variable high and low solar radiation conditions caused by cloud cover. With an average partly cloudy solar radiation value of 549 W/m^2 for the heating period up to boiling, the pressure-cooking pot could boil 4 litres of water in 1.1 hrs. This was faster than the 1.3 hrs the heavy base pot took at an average solar radiation of 570 W/m^2. The average thermal (water heating) efficiency was 33 % for pressure-cooking, greater than the heavy base pot of 26 %. Two additional experimental tests performed with 2.0 and 4.0 kg of water also show better performance for the pressure-cooking pot than the heavy base pot. During the two additional tests, the pressure-cooking pot achieved higher temperatures and slightly higher average water heating efficiencies (51 and 26 %) than the heavy base cooking pot (49 and 23 %). Water could not boil in the third test (Test 2 on 13 April 2025) for the heavy base cooking pot. The results obtained supported the use of the pressure-cooking pot during partly cloudy conditions.

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