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Operational trends of a mini parabolic solar collector for agricultural purposes in a non-active solar environment

M. E. Emetere[a,b,*], S. E. Sanni[c], A. O. Dauda[a], A. A. Akinsiku[d], O. I. Osunlola[a] and A. D. Adejumo[a]

[a]*Physics Department, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria*
[b]*Mechanical Engineering Science Department, University of Johannesburg, Auckland Park, Johannesburg, South Africa*
[c]*Chemical Engineering Department, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria*
[d]*Chemistry Department, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria*

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Abstract

The mode of operation of mini parabolic solar panels made of germanium, mild steel, and aluminum are investigated experimentally, as a means of providing heated water on farmland; the process is also modeled. Angular adjustments of the solar collectors from 70-90° are adopted in order to determine the best material of construction for the parabolic solar collector and the angular orientation with the highest heat collection tendency and absorption rate. The highest quantity of adsorbed heat/best heating effect of the solar collector is obtained at an angular orientation of 80° for mild steel and aluminum. It is also observed that the parabolic solar collectors have optimum exposure time, after which the heating rate drops, or there is loss of heat from its surface. The experimental and model estimates, in terms of heat absorption for the mild steel solar collector at 70 and 90° angular tilts, shows that the optimum heating time is 40 min while at 80°, it is found to be 50 min.

1. Introduction

The use of heated water in a farm serves sterilization of equipment, cleaning animal hutches, and washing fruits and vegetables alongside processing milk products as well as administering drugs in the poultry [1]. In most site locations in developing countries, the application of electrical heating for farming is very minimal. Most farmers use liquefied propane (LP) or natural gas to heat water for agricultural applications. However, the disadvantage of the former is the likely increase in the release of carbon dioxide (CO_2) into the atmosphere. The continuous burning of this fossil fuel has caused a drastic rise in the earth's atmospheric CO_2 level by more than 25% over the past 150 years. The second disadvantage of the use of LP or natural gas for water heating is that they are non-renewable sources of energy, meaning that, they are limited in availability and could cease to exist after a period of time.

In recent times, farmers use heat recovery units, waste oil burners, solar, and/or geothermal energy to heat water and provide supplementary water heating. However, the prospects of waste oil burners and geothermal energy are limited by

*Corresponding author
email address: emetere@yahoo.com

geographical location. The viable option in tropical regions is the use of solar energy. Solar water heating mainly depends on geographical location, due to the fact that it is more effective in places of abundant sunlight [2, 3]. Nevertheless, solar water heating systems also have the potential to function effectively in countries with less sunlight.

The main aim of this study is to model an efficient heating water source for agricultural use via the design and construction of a prototype parabolic solar collector. Hence, the focus of the study is to:

1. Construct a parabolic solar collector using an aluminum sheet, reflective coating/mirrors, and a central heat pipe.
2. Analyze the performance of parabolic solar collector using MATLAB software.
3. Advance the functionality of the parabolic solar collector in a convectional environment.

This research serves as an eye-opener to people on the use of a renewable source of energy that is more environmentally friendly alongside other derivable benefits.

In the past, few scientists worked on design construction and the use of solar devices in rural areas of developing countries. Musa et al. [4] did the design, construction, and performance test of a parabolic fresnel concentrator cooker which used locally accessible materials. The success of the device is hinged on the precise adoption of concentric illustrative rings and glass mirrors. Sulaiman et al. [5] showed the importance of parabolic concentrators for cooking. Ever since further research on improving solar parabolic collectors has advanced [6-10]. Concentrated solar power is a cost-effective renewable emerging technology. The challenge of continuous heat generation after sun hours often faced this technology can be overcome by heat storage in oil or molten salt; which is cheaper when compared to energy storage in batteries [11]. From the four optical types of concentrating technologies: parabolic trough, dish concentrating, linear Fresnel reflector, and solar power tower, this study focuses on parabolic-trough concentration as it gives 1/3 of the theoretical maximum for the design of acceptance angle [12, 13]. There is a promising future in this study in rural areas as it is simple and clean. Mason and Reitze [14] developed a low cost high-performance parabolic trough solar collectors.

The application of photovoltaic cells in agriculture has been discussed by Liu et al. [15]. They, however, mentioned that shortage of land and desertification are limitations besetting their use. Their novel technology which tends to harness these combined problems uses the diffractive and interference principles of photovoltaics which helps to split sun rays over transmitted and reflective wavelengths for optimal plant growth and solar power generation respectively. The maximum efficiencies recorded from the implementation of this technology against conventional solar panels are 6-8 %. According to Choo [16], the increased demands for clean energy lead to the increased development of solar energy research ranging from the use of solar thermoelectricity (STE) to dye-Sensitized solar cells (DSSC), concentrated photovoltaic cell (CPC), photovoltaic solar panels (PV), and concentrated solar power (CSP). According to them, CPC, DSSC and STE are emerging technologies under intensive investigation and may occupy a significant share of the solar market if significant breakthroughs are achieved in terms of their relative pricing with respect to conventional solar panels. Based on the work of Torshizi and Mighani [17], greenhouse solar houses can be built in order to help to meet the demands of agriculture in far-reaching rural areas. In their paper, the benefits of solar energy in agriculture were also discussed and this includes irrigation, drying, plant growth, etc. Kawira et al. [18] investigated the performance of three different designs (i.e. aluminum sheet, car solar, and aluminum foil reflectors) of thermal parabolic trough solar concentrators for steam production. The same dimensions of aperture width, collector length, and areas were adopted in the designs. The absorber pipe was made of copper that carrying water in it as the heat transfer fluid. Their design considerations include considerations for minimal heat losses. A concentration ratio of 128 was adopted for the solar concentrators. The maximum steam temperature obtained was 248.3^{o}C, while the average steam temperature produced was 150^{o}C. The efficiencies of the different solar configurations were determined when they were closed and when open. The closed solar concentrator efficiencies in descending order of magnitude are aluminum sheet, car solar, and aluminum foil while for the open solar concentrators, the performances are in the order of car solar, aluminum sheet, and aluminum foil in increasing order of efficiencies. Umair et al. [19] designed a parabolic concentrator with wings angled in the east and west directions (surface Azimuth angle) and modeled its performance considering different angular orientations in space of 70-90^o. The aim was to determine at several tilt and bend angles, the optimum temperature absorbed by the solar concentrator which is an improvement on the conventional straight types whose wings are angled facing southwards. Based on their findings, the proposed CPC improves the efficiency of energy-driven solar panels at increased exposure times of 2-3 h. Borah et al. [20] succeeded in designing and constructing a compound parabolic solar concentrator for efficient drying via an indirect method. A total of six semi-parabolic concentrators were integrated on a receiver plate for direct conversion of solar to thermal energy by absorbing the incident rays upon metallic tubes placed on the principal focus of the parabolas. Their results showed that, the new design gives better performance when compared with fixed CPC, and the absorption time was found to increase by 1.5 h for the tilted parabolic concentrators over their fixed counterparts. According to Norton [21], the following are useful design considerations when designing a parabolic solar concentrator for energy storage applications: collector types, aperture cover materials, plate absorbers, line-axis collectors, and the need for non-convecting solar panels. Lee [22] constructed a solar drying system (compound parabolic concentrator) with an evacuated solar collector, having a storage tank, a water-to-air heat exchanger, an auxiliary heater, and a drying chamber whose performance was compared with indoor and outdoor drying methods. However, the results from the investigation showed that, solar drying is the most effective one for all drying samples considered, although outdoor drying gives comparable results for the drying process of oyster mushroom. Hernandez et al. [23] carried out a review on the beneficial and adverse environmental effects of utility-scale solar energy development alongside their impacts on biodiversity, land use, land-cover change, soils, water resources, and human health. They highlighted the intention of being motivated by the need to reduce carbon-intensive sources of energy and emission of greenhouse gases. However, they underscored the numerous benefits of the use of solar energy against the very few/negligible disadvantages that they claimed have not been carefully investigated. Despite the underlying economic benefits and potentials in the use of solar energy sources as replacements for fossil fuels, their use still remains relatively low, thus, in order to achieve higher market penetration, there is need to create more awareness on the benefits therein, provide financial aids/control mechanisms that will cover for overhead costs with special advocacy towards the use of solar thermal energy as an alternative heating source of energy for fossil fuels for industrial applications [24].

In this research, the acquired knowledge from literature is scaled by 50% to serve a mini-farm size. The efficiency of the parabolic solar concentrator is hinged on its concave, reflecting surfaces that capture and focus the solar beam radiation onto a smaller receiving area with relatively high energy density, which can withstand temperatures between 100-1000°C. Also, another advantage is its flexibility to adapt to electronic structures like trackers.

The advanced application of the parabolic solar concentrator can be found in large power stations, where steam is produced to drive turbine engines [25]. The application of this technology is far-reaching in rural communities of developing nations, hence the originality of the study is in the adoption of common local materials to build solar structures for rural farmers. The prototype of the solar concentrator is schematically shown in Fig. 1. Its basic components include the receiver tubes, curved mirror assemblies, and the heat transfer fluid [26]. In this design, the heat transfer fluid is water, and the curved mirrors are shaped-sliced-glass pieces aligned in a curved wooden frame.

2. Design and construction of the mini parabolic solar collector

The physics of the latent heat of the fluid (water) that circulates through a pipe is hinged on the absorbing properties of the pipe. Hence, the improvised curved surface reflects sunlight and focuses it onto the absorber tube. To conserve the heat-gain by the tube, a degree of vacuum is created to ensure maximum transfer of absorbed heat energy to the moving fluid. Sahoo et al. [28] estimated the heat gained by the running fluid within the absorber tubes. The saturated steam parameters reached up to 55 bar/270°C. The initial assessment of the device is done using the authors' previous studies [2, 3]. Different gradients of water storage tanks are adopted to create an open or closed loop. This idea helps to avoid the cost of purchasing a pump for circulating the heated fluid. Based on the design considerations, a parabolic solar concentrator is constructed as shown in Fig. 2.

The materials used for the construction of the parabolic solar collector are purchased in accordance with the material specification on the design analysis. The equipment for the construction include a wooden stand, square sized mirrors of sides 10 mm (3 mm thick), bearing seal, ball bearing, receiver pipe, tilting adjuster, cover/top frame, end bar, joint angle piece, metallic stand brazes, edge redressing bar, aluminum steel, germanium steel and mild steel.

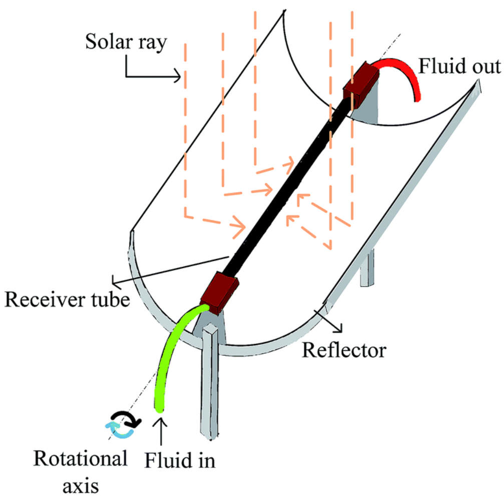

Fig. 1. Schematic of solar collectors based on parabolic trough system [27].

Fig. 2. Mini-parabolic solar concentrator with water storage tanks.

2.1. Experimentation

A digital thermometer is used to obtain the temperature of the circulating fluid. The readings are daily taken at 10 min interval for 4 h. The angle of orientation of the concentrator is gradually adjusted from east to west. The information from the experimentation procedure is inputted in the Microsoft Excel sheet, and the corresponding plots are done using MATLAB. The information entered in the Microsoft Excel sheet are the day, time, angle of the trough, the initial heat of the water, the heat of water after passing through the central heat-pipe, and the number of runs. The experimental parameters are optimized using the following mathematical representations:

$$Q = mc(\Delta T) \tag{1}$$

where M is the mass (kg), C is the specific heat capacity (J Kg^{-1} $^oC^{-1}$), Q is the heat energy, and ΔT is the temperature change ($T_2 - T_1$) (^{o}C).

$$\Delta T = \frac{M_{AL} C_{AL} (T_x - 33.3)}{M_W C_W + M_{AL} C_{AL}} \tag{2}$$

where M_{AL} is the mass of aluminum (kg), C_{Al} is the specific heat capacity of aluminum (J Kg^{-1} $^oC^{-1}$), T_x is the temperature of the central heat pipe (^{o}C), the initial temperature of water is 33.3 (^{o}C), M_w is the mass of water (kg), ΔT is the temperature difference, and C_w is the specific heat capacity of water (J Kg^{-1} $^oC^{-1}$).

3. Results and discussion

Fig. 3 shows the thermal analysis for germanium steel at angles of 90^o, 80^o, and 70^o tilt. The number of runs is theoretically calculated since it is very difficult to find it physically. It is observed that the water reaches its highest temperature at the angle of 80^o. At higher fluid circulation (number of runs) it is observed that the temperature of fluids at the angles of 90 and 70^o is almost close, as seen in Fig. 4, which depicts the range for a good model. It is observed that the same trend occurs when steel is replaced with aluminum (Fig. 5). The difference between Figs. 3 and 5 is that, aluminum pipes generate more heat than germanium pipes. The adoption of mild steel is theoretically not far from the trends in aluminum and germanium (Figs. 7 and 8).

Based on the 3D plots in Figs. 4, 6, and 8, it is clear that the parabolic solar collector made of aluminum is the most sensitive one to solar radiation while mild steel is next, and the solar collector made of germanium being the least temperature sensitive, hence the difference between the three pipes is in direct relation to the predicted properties of the materials (Fig. 9). The raw temperature modulation of the circulating fluid is shown in Fig. 10. The graph shows the thermal variation at 80^o tilt. The initial temperature of the water is higher in germanium steel than aluminum. An excerpt from the raw data obtained for mild steel is displayed in Tables 1-3.

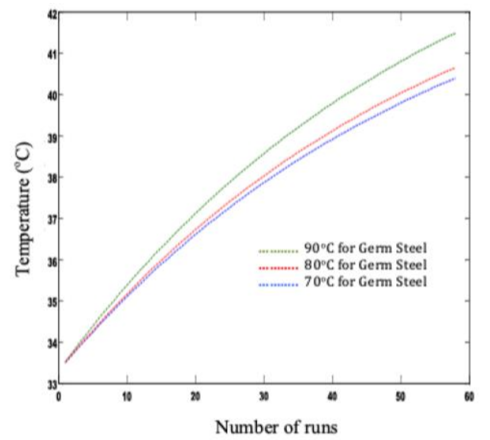

Fig. 3. Graph of temperature against number of runs at 90^o, 80^o and 70^o tilt for germanium steel.

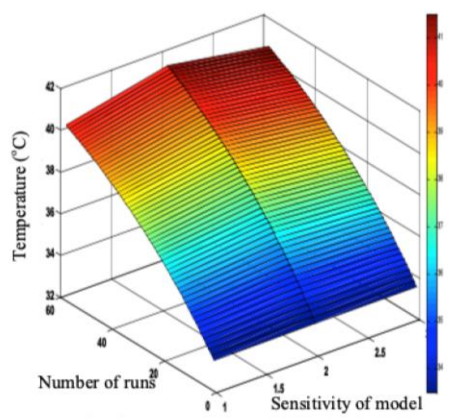

Fig. 4. 3D analysis for the sensitivity of germanium steel pipe at 90^o, 80^o, and 70^o.

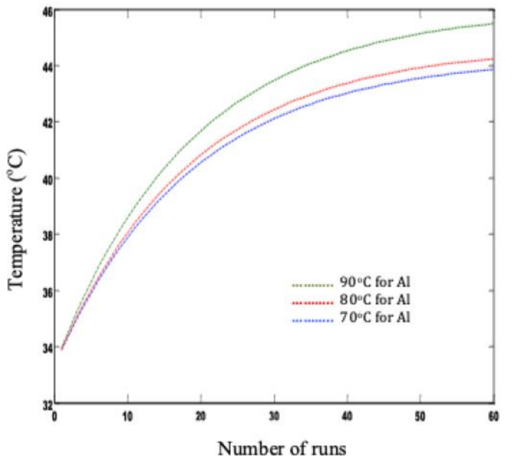

Fig. 5. Graph of temperature against number of runs at 90°, 80°, and 70° tilt for aluminum.

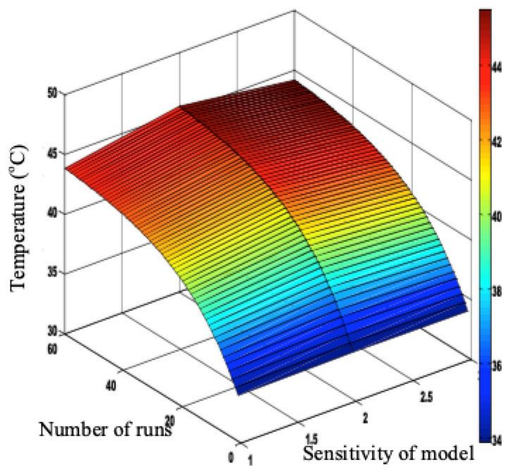

Fig. 6. 3D analysis for the sensitivity of aluminum steel pipe at 90°, 80°, and 70°.

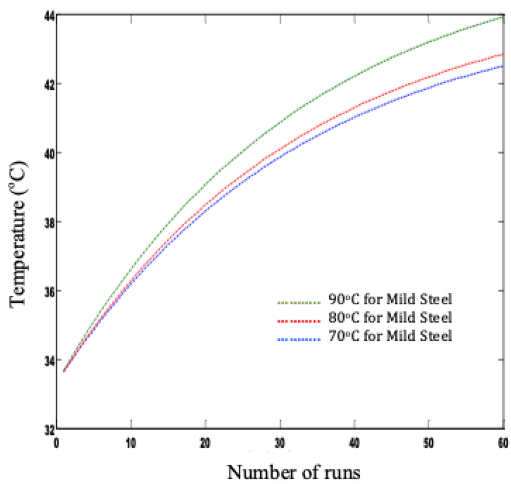

Fig. 7. Graph of temperature against number of runs at 90°, 80°, and 70° tilt for mild steel.

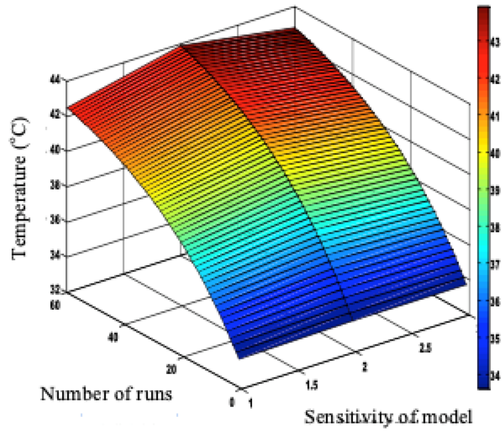

Fig. 8. 3D analysis of the sensitivity of mild steel pipe at 90°, 80°, and 70°.

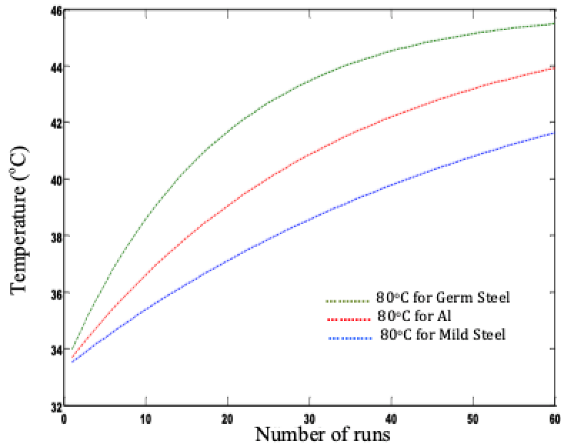

Fig. 9. Graph of temperature against number of runs at 80° tilt for germanium steel, aluminum steel, and mild steel.

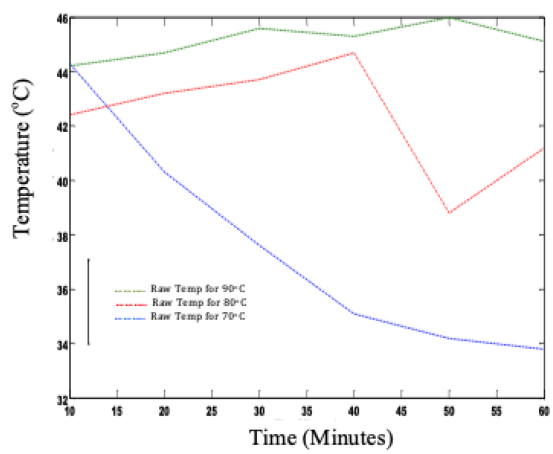

Fig. 10. Graph of temperature against time for the raw temperature analysis for germanium, aluminum, and mild steel at 80° solar tilt.

In Fig. 9, for the different runs, aluminum gives the highest heating rate followed by mild steel, then germanium. This is evident in their relative conductivities i.e. aluminum, mild steel, and germanium in the order of increasing conductivities. However, it is expected that aluminum absorb radiation more than mild steel and germanium do, hence it is the best material for the construction of the parabolic solar panel for achieving the maximum results and efficient heat utilization. Again, at different times, it is observed that, aluminum still gives the highest heat sensitivity by absorbing the highest quantity of heat. Next to it is mild steel while germanium gives the least heat absorption tendency (Fig. 10).

In Table 1, the external surface temperature of mild steel varied between 44.3 and 33.3ºC, while its internal temperature varied between 38.6 and 33.3ºC in 10-70 min. The temperature increases with the rise of the number of runs from 10 to 40 min along the rows but it decreases along the columns for each run (this agrees with the model results in Figs. 3-5). From 50 to 60 min, the recorded temperatures seem to show only little differences for the 58th run while the 59th and 60th runs give similar outlet temperatures. Comparing the results with those of the internal and external temperatures, when the solar mirror angle is 90ºC, the maximum heat, that can be reflected from the surface of the material, is 33.3ºC at 70 min, although it is higher at other times.

From Table 2, it is evident that, when the angle of the tilt of mild steel solar collector is 80ºC, the external temperature increases from 44.2 to 45.6ºC within the first 30 min, but it drops slightly by 0.3ºC at the 40th min. The external surface temperature rises to 46ºC at 50 min, and it drops by 0.9 and 3.8 at 60 and 70 min, respectively. It can be implied that maximum heating of the external surface of the solar mirrors at the tilt angle of 80ºC, is 50 min, after which the temperature at the surface of mild steel begins to drop. Considering the internal surface temperature of mild steel, a maximum heating rate can only be achieved when the parabolic solar mirror is exposed to the sun for 30-60 min. This is because the maximum attainable temperature at such a time range is 42.3ºC since it drops to 40.7ºC in the 70th min. Based on the temperature readings taken for the 58th and 59th runs, the lowest attainable solar temperatures are 39.04 and 39.09ºC, respectively. The temperature profile for these two runs is quite similar based on the trend established by the temperature changes recorded for every 10 min of exposure time of the solar panel to the sun. This is also validated by the model results in Figs 3-5. This then implies that the maximum temperature reflection of the mirror is obtained after 50 min giving temperatures of 41.49 and 41.57ºC, respectively, while for the 60th run, the maximum attainable temperature is also obtained after 50 min to be 41.65ºC. At further exposure times, the temperature profile shows reductions for all runs. Generally, at all times for 80º tilt angle of the solar mirror, the temperature of the material increases for all the runs across the rows at all times. When the tilt angle of the mild steel solar collector is 70º, the temperature of the mild steel increases to 44.7ºC and is lower than this value for the next 30 min.

Table 1. The values for first day at 90o tilt and number of runs.

Time (min)	Exterior temp. of pipe (°C)	Interior temp. (°C)	Temp. at 58th run (°C)	Temp. at 59th Run (°C)	Temp. at 60th run (°C)
10	44.3	38.6	40.39	40.46	40.5
20	40.3	37	37.81	37.86	37.89
30	37.6	35.8	36.07	36.09	36.13
40	35.1	34.3	34.461	34.47	34.48
50	34.2	33.7	33.88	33.89	33.89
60	33.8	32.6	33.62	33.63	33.63
70	33.3	33.3	33.3	33.3	33.3

Table 2. The values for first day at 80° tilt and number of runs.

Time (min)	Exterior temp. of pipe (°C)	Interior temp. (°C)	Temp. at 58th run (°C)	Temp. at 59th Run (°C)	Temp. at 60th run (°C)
10	44.2	41.6	40.33	40.39	40.46
20	44.7	41.6	40.65	40.72	40.79
30	45.6	42.3	41.23	41.31	41.38
40	45.3	41.9	41.04	41.11	41.19
50	46	42.3	41.49	41.57	41.651
60	45.1	42.3	40.91	40.98	41.05
70	42.2	40.7	39.04	39.09	39.15

Table 3. The values for first day at 70° tilt and number of runs.

Time (min)	Exterior temp. of pipe (°C)	Interior temp. (°C)	Temp. at 58th run (°C)	Temp. at 59th Run (°C)	Temp. at 60th run (°C)
10	42.4	39.7	39.17	39.22	39.28
20	43.2	40.3	39.68	39.75	39.81
30	43.7	40.5	40.01	40.07	40.13
40	44.7	41.2	40.65	40.72	40.79
50	38.8	35.4	36.78	36.81	36.85
60	41.2	36.3	38.29	38.34	38.39
70	41.7	36.6	38.61	39.36	38.72

A similar trend is also observed in the values recorded for the internal temperature of mild steel. For all the different runs, it is clear that, the maximum attainable temperature is 40.79ºC, and this is at 40 min since lower temperatures are recorded at further times. However, the 58th run seems to give the least temperature after 70 min of exposure time of the panel to solar radiation. Considering the results for all angle orientations, this then implies that the material cannot receive/retain/reflect much heat at 70° like other solar angle orientations (i.e. 80 and 90° solar tilt angles) in space. This agrees with the model results shown in Fig. 7). The highest heating rate is obtained at 80° angular tilt of the solar panel, which agrees with the results in Figs. 9 and 10.

4. Conclusions

In the study, few challenges are encountered that are suggested for further work, i.e., solar tracking errors and low transmissivity of the glass cover. The thermal analysis trends of the metallic pipes show that they are good candidates for the specified purpose. However, the low temperatures recorded are as a result of the low surface temperature associated with the convectional environment, where the research is done. However, at higher runs, a farmer within such a location can get the desired heated water for the day's work. This research is prescribed for rural communities in developing nations. Based on the findings, it is also evident that the farmer needs to maintain an angular tilt of 80° for maximum heating rates. This event occurs because the highest temperature is obtained at 80° tilt of the panel relative to other angular orientations. The results obtained are also indicative of the optimum exposure times for the solar panels; it is 40 min for the 70 and 90° angles of tilt, while it is 50 min for the 80° angular tilt. Hence it is recommended to adopt these heating times for these angular orientations to achieve the maximum heating rates.

References

[1] VetRX VetRx Poultry Remedy. https://www.drugs.com/vet/vetrx-

poultry-remedy.html (Retrieved 4th November, 2017).

[2] E. Moses Emetere, L. Marvel Akinyemi and B. Edeghe Etimbuk, “A Simple Technique for Sustaining Solar Energy Production in Active Convective Coastal Regions”, *International Journal of Photoenergy,* Vol. 3567502, pp. 1-11, (2016).

[3] M. E. Emetere and M. L. Akinyemi, “Weather Effect on Photovoltaic Module Adaptation in Coastal Areas”, *International Journal of Renewable Energy Research*, Vol. 5, No. 3, pp. 821-825, (2015).

[4] U. Musa, A. S. Sambo and E. J. Bala, Design, “Construction and performance test of a parabolic concentrator cooker”. *National Solar Energy Forum, Sokoto,* Vol. 4, pp. 102-118, (1992).

[5] A. K. Sulaiman, S. C. Bajpai and A. T. Sulaiman, “Design, fabrication and testing of a low-cost collector for steam generation”, *Directory of Renewable Energy Research and Development Activities in Nigeria*, Vol. 1, pp. 45-68, (1989).

[6] E. O. M. Akoy and A. I. A. Ahmed, Design, “Construction and performance evaluation of solar cookers”, *Journal of Agricultural Science and Engineering* Vol. 1, No. 2, pp. 75-82, (2015).

[7] S. S. Mathur, J. K. Sharma, Dang Aman and H. P. Garg, “Design and Development of a Solar Conical Concentrator”. *International Journal of Energy Research*, Vil. 6, No. 1, pp. 73-81, (1982).

[8] A. T. Abdulrahim, I. S. Diso and A. S. Abdulraheem, “Design analysis of solar bi-focal collectors”. *Journal of Mechanical Engineering Research*, Vol. 4, No. 4, pp. 136-141, (2008).

[9] S. E. Baker and J. D. Parker, “Use of alternative energy”. In Doty, S. and Turner, W.C. (Eds.) Energy Management Handbook. Seventh Edition. Publisher Fairmont Press. ISBN10: 142008870X, (2009).

[10] Muhammad Jamilu Ya'u A “Review on Solar Tracking Systems and Their Classifications”, *Journal of Energy, Environmental & Chemical Engineering*, Vol. 2, No. 3, pp. 46-50, (2012).

[11] Y. P. Chandra, “Numerical optimization and convective thermal loss analysis of improved solar parabolic trough collector receiver system with one sided thermal insulation”. *Solar Energy*, Vol. 148, pp. 36–48, (2017).

[12] B. Norton, “Industrial and Agricultural Applications of Solar Heat. In: Sayig”, A, (ed.). *Comprehensive Renewable Energy*, Vol. 3, pp. 567-594, (2012).

[13] J. Chaves, “Introduction to Non-Imaging Optics, Second Edition”. CRC Press. ISBN 978-1482206739, (2015).

[14] A. Mason and E. Reitze, “Establishing bankability for high performance cost reducing sky trough parabolic trough solar collector”, *Energy Procedia*, Vol. 49, pp. 155-162, (2014).

[15] L. Liu, C. Guan, F. Zhang, M. Li, H. Lv, Y. Liu, P. Yao, J. Ingenhoff and W. Liu, “A Novel Application of Concentrator Photovoltaic in the Field of Agriculture Photovoltaics”. AIP Conference Proceedings, *American Institute of Physics*, pp. 1-10, (2017).

[16] Y. Chu, Review and Comparison of Different Solar Energy Technologies. Global Energy Network Institute (GENI), pp. 1-56, (2011).

[17] M. V. Torshizi and A. H. Mighani, “The Application of Solar Energy in Agricultural Systems”, *Journal of Renewable Energy and Sustainable Development*, Vol. 3, No. 2, pp. 234-240, (2017).

[18] M. Kawira, R. Kinyua and J. N. Kamau, “A Prototype Parabolic Trough Solar Concentrators for Steam Production”, *Jomo Kenyatta University of Agriculture and Technology*, Vol. 14, No. 2, pp. 90-103, (2012).

[19] M. Umair, A. Akisawa and Y. Ueda, “Optimum Settings for a Compound Parabolic Concentrator with Wings Providing Increased Duration of Effective Temperature for Solar-Driven Systems: A

Case Study for Tokyo”, *Energies*, Vol. 7, pp. 28-42, (2014).

[20] A. Borah, S. M. Khayer and L. N. Sethi, “Development of a Compound Parabolic Solar Concentrator to Increase Solar Intensity and Duration of Effective Temperature”, *International Journal of Agriculture and Food Science Technology*, Vol. 4, No. 3, pp. 161-168, (2013).

[21] B. Norton, (2013). Harnessing solar heat. Springer. ISBN 978-94-007-7275-5

[22] G. H. Lee, “A Study on the Use of Solar Energy for Agricultural Industry- Solar Drying System Using Evacuated Tubular Solar Collector and Auxiliary Heater”, *Journal of Biosystems Engineering*, Vol. 38, No. 1, pp. 41-47, (2013).

[23] R. R. Hernandez, S. B. Easter, M. L. Murphy-Mariscal, F. T. Maestre, Tarvassoli, MAllen, C. W. Barrows, J. Belnap, R. Ochoa-Hueso, S. Ravi and m. F. Allen, “Environmental Impacts of Utility-Scale Solar Energy”, *Renewable and Sustainable Energy Reviews*, Vol. 29, pp. 766-779, (2013).

[24] International Renewable Energy Agency (IREA). Solar Heat for Industrial Processes: Energy Technology Systems Analysis Programme. pp. 1-40, (2015).

[25] S. Chu and A. Majumdar, “Opportunities and challenges for a sustainable energy future”, *Nature,* Vol. 488, pp, 294-303, (2012).

[26] Natalia Kulichenko and Jens Wirth, (2012). Concentrating Solar Power in Developing Countries: Regulatory and Financial Incentives for Scaling Up. World Bank Studies. Washington, DC: World Bank https://openknowledge.worldbank.org/handle/10986/9382 (Retrieved 4th November, 2017).

[27] M. K. Islam, M. Hasanuzzamana and N. A. Rahim, “Modelling and analysis of the effect of different parameters on a parabolic-trough concentrating solar system”, *RSC Advances*, Vol. 5, pp. 36540-36546, (2015).

[28] S. S. Sahoo, S. Singh and R. Banerjee, “Analysis of heat losses from a trapezoidal cavity used for linear Fresnel reflector system”, *Solar Energy*, Vol. 86 No. 5, pp. 1313-1322, (2012).

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