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Experimental evaluation of thermal performance of selected oils in Uganda for indirect solar domestic cooking applications.

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Short Abstract

This study experimentally evaluated the thermal performance of selected oils in Uganda for indirect solar domestic cooking applications. The oil samples used were refined sunflower oil, refined palm oil and thermia B; these oils are locally available in Uganda. Thermal stratification, energy and exergy analysis were performed for each oil to determine their suitability for TES using a thermosiphon principle. The results showed that thermal stratification of refined sunflower oil was higher as compared to refined palm oil and thermia B during the first one hour. The stored energy and exergy for refined sunflower oil was generally higher than that of refined palm oil and thermia B. The thermal performance of refined sunflower oil was comparative to refined palm oil which was better than that of thermia B.

Keywords: (Thermosiphon, thermal stratification, energy, exergy)

1. Introduction

Developing countries largely depend on firewood and charcoal for cooking (Prasanna and Umanand 2011). The dependence of firewood and charcoal for cooking has resulted into loss in biodiversity, health hazard risks, deforestation, extreme weather changes, and low agricultural productivity (Magala 2015). This calls for an alternative source of energy for cooking and solar energy seems to be the best option since it's abundantly received in the region throughout the year. Solar energy can be used for heat production and electricity generation. The heat produced can be used for cooking, and drying crops while electricity generated can operate most domestic electrical appliance and satellites (Okello et al. 2014). To improve the usefulness of solar cookers, they should be incorporated with Thermal Energy Storage (TES) system. The (TES) systems help to match energy demand to energy supply and cooking can be done at any time of the day (Okello et al. 2014). Numerous studies have been reported on thermal performance of TES medium for cooking purposes. Mawire et al. (2014) experimentally evaluated thermal performance of sunflower oil, thermia B, and thermia C during the charging process and found out that sunflower oil had better thermal performance as compared to thermia C and thermia B under high power charging. Nyeinga et al. (2016) presented a computational framework for a dynamic behavior of a solar concentrating system with rock bed for heat storage based on numerical integration of a set of conservation equations for mass, momentum and energy of heat carrier, rock pebbles, and the wall; the heat carrier was air. They found that initially large temperature gradient existed, but as charging progressed the temperature gradient between the top and the bottom disappeared. Mussard and Nydal (2013) designed a thermosiphon heat storage system which was coupled with a low-cost small-scale parabolic trough for cooking purposes. The results showed that at temperatures lower than 200◦C, the absorber without insulation was more effective while at temperatures higher than 200◦C, the absorber with glass tube was effective. In accordance to reviewed literature, limited information about the thermal performance of selected oils for TES medium for cooking purposes have been published especially during the charging using thermosiphon principle. Therefore the study investigated thermal performance of refined sunflower oil, refined palm oil, and thermia B during the charging process using thermosipon principles. Experiments were done on determination of thermal stratification, energy, and exergy during the charging process. The result showed that refined sunflower oil had generally a better thermal performance during the first one hour of the charging.

2. Methods

A storage tank of internal diameter 18 cm and height 40 cm made of mild steel was fabricated. A boiler of internal diameter 18 cm and height 20 cm made of mild steel was fabricated and oriented at 60◦ to the horizontal. A continuous copper pipe of internal diameter 0.9 cm and total length 151 cm ran from the top of the storage tank to the bottom through the boiler. The inlet point to the storage tank was 5 cm from top while the outlet point to the storage tank was 5 cm to the bottom. Both the outlet and the inlet pipes were oriented at 60◦ to the storage tank as shown Fig.1. The storage tank was supported by wooden plates screwed on the metal stand and a metallic stand made of mild steel angled bar.

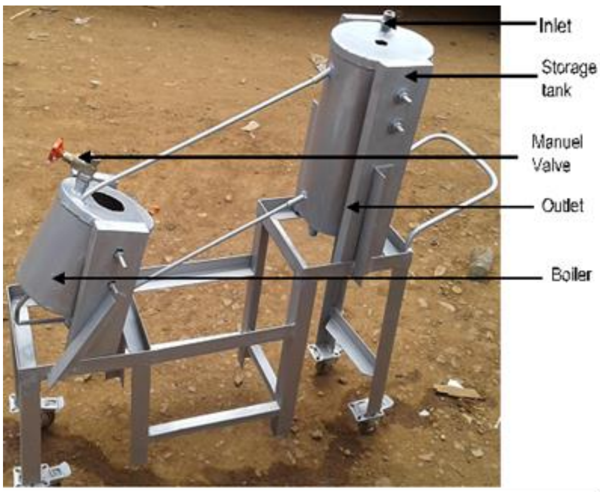

Fig.1. Constructed thermosiphon unit for charging the oils

The top covers of the stands for both storage tank and boiler were of size 25cm by 25cm. The height of the storage tank stand was 50cm while for the boiler was 25cm. The distance of separation between the two top covers of the stand was 78cm. For easy mobility, the stand was fitted with four rollers. Both tanks were fitted with manual valves from top and bottom using nipples made of mild steel. The thermocouples were tied together using a flexible insulated metallic thread. Another k-type thermocouple was inserted in the boiler to monitor the temperature of the oil. All the eight thermocouples were connected to a TC-08 Data Logger interfaced with a computer. 10 litres of each oil was poured in the storage tank while in the boiler 4 litres of refined sunflower oil was used. An electrical heater of 1.5kVA was used for heating the oil in the boiler. The temperature of the boiler was maintained in the range of 230-240◦C manually, by switching the electrical heater on and off. The switching on was at temperature of 234ºC and the temperature of the boiler continued decreasing to 230◦C as the result of thermal inertia; while the switching off was at the temperature of 238ºC and the temperature continued rising to 240ºC. The boiler was used for charging the storage tank for 6 hours and the experimental setup is as shown in Fig.2.

Fig.2: The experimental setup showing charging of the storage tank by thermosiphon principle in which eight thermocouples were connected to a TC-08 data logger to monitor the tanks' temperatures

3. Results and discussion

The thermal gradients for the three oils are presented in Fig.3. The thermal gradient for refined sunflower oil attained a maximum value of in 2 hours and 24 minutes while that of refined palm oil was attained within 4 hours and 6 minutes. Finally the thermal gradient of thermia B attained a maximum value of in 4 hours and 18 minutes. This rapid increase is attributed to increased temperature at the top of the storage tank and low temperature at the bottom as the hot oil entered the storage tank from top. As charging progresses, the hot oil from the top of the storage tank keeps flowing downwards, hence increasing the temperature of the oil at the bottom. This reduces the difference in temperature between the top and the bottom of the storage tank, hence reduction in thermal gradient. The thermal gradients for both refined sunflower oil and refined palm oil were comparatively the same in the first 30 minutes of the charging process because their densities are very close and hence the amount of heat transferred to the storage tank was almost the same. The thermal gradient of refined sunflower oil increased sharply within the first one hour due to its high density and specific heat capacity; it therefore absorbs large amount of heat faster. Thereafter, the thermal gradient for refined sunflower oil increased more than that of refined palm oil during the rest of the charging process. This result agreed with Mawire et al. (2014) in which they found that the thermal gradient of sunflower oil was higher than thermia B during the first two hours of the charging process when the oil flow rate was 2.2ml/s. They also reported the initial rapid increase in thermal gradient up to maximum and thereafter it decreases gradually. This result shows that the thermal gradient of refined sunflower oil was generally higher for more than 4 hours as compared to refined palm oil and thermia B. This means that refined sunflower oil has a better thermal stratification and for a longer period of time. Hence refined sunflower oil can be used for a longer hours before losing it thermal stratification.

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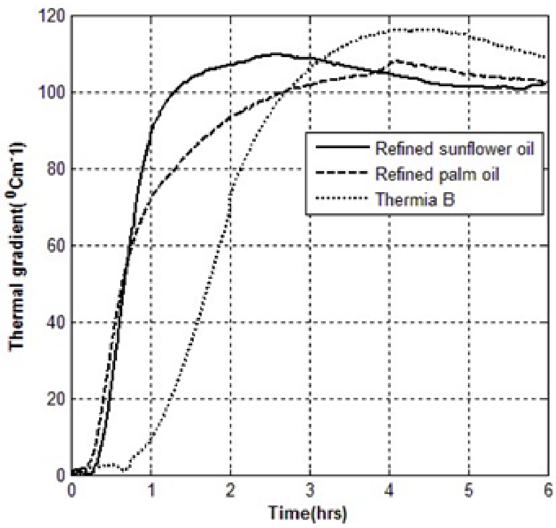

Fig.3. Thermal gradients of the oils during the six hours of the charging process

4. Conclusions

The thermal performance of refined sunflower oil, refined palm oil, and thermia B was evaluated experimentally. The results show that the thermal gradient for refined sunflower oil was higher than that of refined palm oil and thermia B in the first one hour. This means that refined sunflower oil has a better thermal stratification within the first one hour. The stored energy distribution during the charging process for refined sunflower oil was generally higher than that of refined palm oil and thermia B. In conclusion, both refined palm oil and refined sunflower oil can be used as TES medium for solar domestic cooking applications, however refined sunflower oil is preferred because it absorbs heat faster which is more suitable since the duration of solar insolation is short. Further studies to be carried out on the TES system size suitable for domestic cooking and heat retention with refined sunflower oil in an insulated TES system.

5. References

Esteban B., Riba J., Baquero G., Rius A., and Puig R. 2012. "Temperature dependence of density and viscosity of vegetables oils". *Biomass and bioenergy*, no.42:164—171. https://doi.org/10.1016/j.biombioe.2012.03.007

Magala R. 2015. Deforestation an environmental problems; a review of Uganda forestry policy and national. *Conference paper*. Makerere University. April, 2014. https://www.researchgate.net/publication/275401990_DEFORESTATION_AN_ENVIRONMENTAL_PROBLEM_A_REVIEW_OF_UGANDA_FORESTRY_POLICY_AND_NATIONAL_ENVIRONMENTAL_MANAGEMENT_POLICY

Mawire A., Phori A ., and Taole S. 2014." Performance comparison of thermal energy storage oils for solar cookers during charging". *Applied Thermal Engineering*, no.73: 1323—1331. https://doi.org/10.1016/j.applthermaleng.2014.08.032

Nyeinga K., Nydal J., Okello D., and Banda E. 2016. Dynamic model of a small scale concentrating solar cooker with rock bed heat storage. *Journal of Energy in Southern Africa*, no.27: 20—27. http://www.scielo.org.za/scielo.php?pid=S1021-447X2016000100004&script=sci_arttext&tlng=en

Okello D., Foong C., Nydal J., and Banda E. 2014. An experimental investigation on the combined use of phase change material and rock particles for high temperature (350◦C) heat storage. *Energy Conversion and Management*, no.79: 1—8. https://doi.org/10.1016/j.enconman.2013.11.039

Prasanna U., and Umanand L. 2011. Modeling and design of a solar thermal system for hybrid cooking application. *Applied Energy*, no.88: 1740—1755. https://doi.org/10.1016/j.enconman.2013.11.039