Performance Analysis of a Solar Dryer Integrated With Thermal Energy Storage Using PCM- Al2O3 Nanofluids

Babu Sasi Kumar Subrananiam (sbs.kumar1212@gmail.com)
Kings Engineering College
Arun Kumar Sugumaran
Sathyambama Institute of Science and Technology: Sathyabama Institute of Science and Technology
Muthu Manokar Athikesavan
BS Abdur Rahman University https://orcid.org/0000-0001-7523-6796

Research Article

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Performance analysis of a solar dryer integrated with thermal energy storage using PCM- Al_2O_3 nanofluids

Babu Sasi Kumar Subrananiam [a*], Arun Kumar Sugumaran[b], Muthu Manokar Athikesavan[c]

[a]Department of Mechanical Engineering, Kings Engineering College, Chennai.

[b]Department of Mechanical Engineering, Misrimal Navajee Munoth Jain Engineering College, Chennai, Tamil Nadu, India

[c]Department of Mechanical Engineering, B.S. Abdur Rahman Crescent Institute of Science and Technology, Chennai, Tamil Nadu, India

Corresponding author mail id : **sbs.kumar1212@gmail.com**

Abstract:

The use of solar energy will help to reduce the cost of fossil fuels .The present work is based on the study of a solar dryer with thermal storage using the working medium of water and waste engine oil at a flow rate of 0.035, 0.045 and 0.065 lit / sec. Heat was collected from a parabolic trough collector (PTC) and stored into thermal energy storage (TES) device. The TES consisted of rectangular boxes for stored heat containing Stearic acid phase change materials (PCM) with 0.3vol% of Al_2O_3 nanofluids. The parabolic trough reflected solar radiation focused on the receiver and the collected heat was stored in the storage medium after it was forced into circulation and transferred to the solar dryer. The dryer used the energy output in the storage tank at varying water and waste oil medium flow rates and discussed heat output of the drying crops of groundnut, ginger and turmeric were showed the flow rate of 0.035, 0.045 and 0.065 lit/ sec with water and waste engine oil medium. Finally, based on the findings of the tests, this research may be useful in agriculture, especially in the drying of vegetables.

Keywords: solar dryer, hybrid energy storage, nanofluids, waste engine oil, drying crops

1. Introduction

Energy needed for the purposes of cooking is increasing day by day. LPG, firewood, and other power sources are commonly used as fuel in India. The available fuel is currently expensive and known for low availability in the market. Solar cooking is the best option to cook food as it is free of environmental problems. (Noman et al. 2019) formulated a model mathematical of PTC cooker with a concentration ratio of 9 which, under stagnant conditions,

achieved a maximum efficiency range of 53-33 percent. (Asmelash et al. 2014) investigated parabolic trough cooker, installed indoor cooking sections while outdoor soya bean oil collector parts energy transfer from the absorber rendered 30 mm of copper pipe into the cooking stove. Its highest temperatures were 1910°C in the mid-absorber loop, 1190°C in the cooker and the system efficiency was found to be 6%. (Shukla and Khandal 2016) studied the value of collector exergy output, exergetic, thermal efficiencies and Stagnation temperature that depended on increased parabolic collector solar intensity. (Chaudhary et al. 2013) compared the presentation of a solar cooker to that of an ordinary cooker. Solar cooker with a black painted outer surface along with glazing was seen with storage of 32.3 % more heat than ordinary cooker phase change materials had stored 28 % more heat than PCM. (Wollele and Hassen 2019) deigned a solar cooker 45 minutes to cook 1 kg of rice and its corresponding temperature and power equivalent as 355 K, 421W was absorbed heat from sun energy. When the solar cooker was placed on an insulated tank and filled with water through the bowl. It attained the same water temperature within 40 minutes. (De et al. 2014) explained the "on-stove time" reduction procedure and energy-efficient cooking techniques. These experiments also pointed out to the sensitive heat and minimal amount of cooking energy required. The methods of stove time for cooking 1 lit of dry rice and preserving nutrient energy food and protecting the surroundings by diminishing CO2, the toxic emissions related all information have been explained. The resultant time and energy for stove without a pressure cooker were seen were 1.5 MJ and 2640 sec correspondingly. Methods for cooking 1 lit of dry rice and preserving food nutrient energy and protecting the environment by minimizing CO2, dealt with the toxic emissions associated with all information.

(Yahuza et al. 2016) tested the Box type SC at different water levels of 1.5, 1 and0.5 lit. The maximum cooking temperatures obtained were 81.6 °C, 81.7 °C, respectively with water levels of 1kg and 0.5kg and variations depending on the increase in solar radiation. (BalaKrishnan et al. 2012) experimented on the center of a black coated aluminum tray without a glass cover and tested the configuration of the parabolic solar oven with emphasis on sunlight. This system reached a maximum temperature of 104° C in sunshine. (Abu-Khadera et al. 2011) demonstrated the overall cooking for 3.0 kg of rice in 90-100 minutes with PTC depth measurements, height as1.8 m, 29.0 cm and focal length 69.8 cm. (Ronge et al. 2016) did experiments the cooking system static and tracking systems under the stationary position, at reached an output of 41.2 % in approximately 11-12 hours and its overall performance was 27.6 %.But in the tracking position, it was 53.1 % in 11-12 hours and its

overall performance was 40.6 %. This research article explains the different methods of solar cooking for improvement of the ecological aspects of CO_2 and an increase in effectiveness of the cooking pot. (Panwar et al. 2012) investigated the solar cooker's initial and exit energy at a variety of applications. They discovered that solar energy is the best source of cooking energy. (Wang et al. 2014) conducted perform experiments on a 10 connected solar collector connected to a parabolic cooker with circular concentrator shape. A U-shaped evacuated tube attached to the concentrator shape acted as the heat exchanger. Warm air introduced into the tube slowly heated up and moved into an exchange. The result showed the heat exchanger produced air outlet temperature as above 200°C. (AR et al. 2014) planned and constructed an oven with an evacuated tube soar collector for drying ginger under atmospheric conditions. The collector outlet and chamber temperature ranges were from 74-130°C and 50-87°C in that order, whilst the environment temperature range was 29.5-33.2°C.The maximum drying efficiency of musket grapes during the day was 29.92.They found a collector oven that reduced the drying time from 13 hours to 6 hours compared to natural sun drying. A new solar dryer with integrated solar collector pipeline was built by (Lamnato et.al. 2012). A hot air pipeline passage was incorporated in the solar dryer container without any preheating to dry vegetable products. The collector's sources of heat for convective, indirect solar drying process are discussed. (Kim et al. 2007) investigated solar collector heat output using both practical and numerical methods. These methods have been taking four different types of absorption media. These solar collectors show absorption medium having the best for the heat transfer. (Shah & Furbo 2007) worked on computational fluid dynamics model of the solar collector in the glass structure for operating under various conditions. The designed evacuated tube collector was in the horizontal or vertical directions are coupled to a manifold channel. The result showed only a slight the difference in energy under the various operating conditions. (Ma et al. 2010) analyzed the heat loss coefficient and efficiency factor of individual solar collectors, and intentional generating energy capacity of the copper tube and fin absorbing tube. The findings showed nonlinear heat loss coefficient of the absorber surface of the solar collector coating and ambient air temperature. (Hayek et al. 2011) tested the overall efficiency of the solar collector heat-pipe and the solar collector water-in-glass tube.The heated pipe showed efficiency 15-20% higher than the solar water-in-glass collector. (Medugu 2011) designed and produced an evacuated solar dryer tube for cardamome drying. The solar dryer produced a temperature of 55.7 %t higher than the ambient temperature, showing a net saving of 50% in drying compared to the open solar dryer. (Gumus and Ketebe 2013) conducted tests at different temperatures of

110°C,120°C and130 ° C on drying corn and ogbono. Drying at 110°C was considered as the best under all advantageous conditions producing soft, uniformly dried corn and ogbono. (Loha et al. 2012) tested sliced ginger using a forced convection type dryer. The experiment was performed at four different temperatures for drying air namely 45, 50, 55 and 60°C with a set air velocity of 1.3 m/s. The research also included ginger thermal conductivity at various humidity conditions.

1.2 Thermal energy storage system in Solar dryer: experimental approach

(Panchal et al. 2019) made a study of sensitive and latent heat storage materials used in the daytime and nighttime storage of heat. (Saini et al. 2016) used a solar cooker with a PTC and thermal storage device to conduct experiments using natural circulation of water and thermal oil media. Acetanilide was used as the material for the storage system. The temperature of the thermal oil was seen 10°C to 24°C higher than that of water and its heat contained by PCM was increased by 19.45 % to 30.38 % compared to water. (Mawire et al. 2008) investigated indirect solar cooking as an energy source using an oil / pebble-bed TES simulation model. Since it resulted in lower heat loss and the ability to withstand a high temperature, the variable flow rate was found to be suitable for cooking. (Mawire et al. 2010) used two variable flow methods to simulate the analysis of a solar cooker's initial and exit capability. In comparison to a constant flow rate, the variable flow rate was consistently maintained at a higher temperature. Very few experimental studies on solar dryer efficiency enhancement with TES are seen in literature, with experimental studies of different flow rates using stored medium of PCM- -Al_2O_3 nanofluids with medium working water and waste oil. This research examines the solar dryer study, heat output and productivity of various crops at flow rates of 0.035.0.045 and 0.065 lit /sec as a working fluid water and waste oil medium.

1.3 Nanofluids in Thermal energy storage: experimental approach

Solar energy has been reported as the best alternative to conventional energy by (Farhana et al. 2019) despite the existence of many other energy resources. Also, the use of nanofluids could improve the efficiency of solar collectors. Six different forms of solar collector output are examined in this paper. TiO2, CuO, ZnO, Al2O3, and MWCNTS in base fluids are among the nanoparticles used by the researchers. (Saxena & Gaur 2018) examined the effects of a variety of nanofluids in various solar collectors. They observed a big increase in the output by inclusion of nanofluids. (Hussein et al. 2008) investigated the ZnO/Ethylene Glycol-Pure Water (ZnO/EG-PW) in a parabolic trough collector with various volume concentrations of 1.0%, 2.0%, 3.0% and 4.0%). Experimentally, the efficiency of a ZnO/Etylene Glycol-PureWater (ZnO/EG-PW) working fluid was examined. For 0.3%vol

and a mass flow rate of 0.045kg/s, the maximum collector performance was found to be 62.87%. Literature shows the availability with PTC enhanced thermal storage using PCMs - nanofluids. Attempt at on the performance improvement of the PTC enhanced heat storage using nanofluids has been a driving force.

2.1 Design of the parabolic reflector

Fig. 1.Photo view of Parabolic trough collector

A designed and fabricated small scale model that consisted of a metal support frame, a reflecting sheet, a receiver tube of parabolic trough is presented in Fig. 1. In this design, width and length of the reflector are 1.5, 3 m respectively and its rim angle 84º. This research work aims at the use 4.5 m^2 of thermal energy from the entire space manufactured collector, the sheet absorbed heat by coated the aluminium foil reflected sheet with any smooth, non-porous surface can be coated with a rollable reflective film. This reflector design was concerned with providing a significant cost savings over glass mirrors.. Table. 1 shows the geometrical parameters of the PTC and receiver tube.

Table 1 Geometrical parameters of the parabolic trough collector and the receiver tube.

No	Properties	Dimensions	S.No	Properties	imensions
Collector			**Absorber tube**		
1	Collector aperture area	4.5 m^2	1	Vacuum tube outer diameter	0.051 m
2	Aperture width	1.5 m	2	Receiver tube outer diameter	0.047 m
3	Length-to-Aperture ratio	0.642	3	Receiver tube inner diameter	0.043 m
4	Rim angle	67.8º3	4	Thickness of the tube	0.04 m
5	Coating absorptance	0.944	5	Length (cover tube)	3 m
6	Coating emittance	0.9	**Reflector**		
7	Mirrors reflectivity	0.91	1	Specular reflectance	94%
8	Concentration ratio	131	2	hemispherical reflectance	94%
9	Slope error	rad ± 1 2	3	Nominal thickness	0.1mm
10	Specularity	rad ±13			

2.2. Preparation of PCM with nanofluids

For frying, roasting and baking food which occur at a temperature ranges from 50 to 90 ˚ C. Stearic acid as a phase change property has a melting point of 69.3 °C and a boiling point of 361°C. This facilitates the change of the phase for a large amount of energy to be relieved and low cost means, easy market availability and types of saturated fatty acids like many animals, vegetable fats and oil. The metal and oxides of the Al_2O_3 nanoparticles size distribution showed a higher concentration of between 10 and 40 nm as having a major effort undertaken to improve heat transfer efficiency. Recent advances in research relate to nanofluids stability improvement in thermal conductivity, viscosity, and heat transfer properties. Nanofluids evidently have a higher capacity for heat transfer enhancement and are more suitable for use in realistic heat transfer processes. The encapsulated PCM which in solid state with a stearic acid seal of 0.3 % Al_2O_3 nanofluids is shown in the Fig. 2. 75% of container was had Al_2O_3 nanofluids in Stearic acid-PCM and was 25 % free as a single container. The product saw change in the expansion cycle during charging and discharge. The storage system was completely isolated using making glass wool insulating materials. A

uniform dispersion of Al_2O_3 nanoparticles with SA-PCM was obtained by using a two-step method manufacturing Al_2O_3 nanofluids. Al_2O_3 purchased from SWASCO Laboratories, Mumbai. Al_2O_3 nano-powder averaged particle size was 40 nm. This nano-powder was mixed with a calculated proportion 0.3% in PCM. After coating and sealing, the mixture was melted and poured into rectangle boxes. The digital image of PCM with 0.3vol% of Al_2O_3 nanofluids as shown in Fig. 3. In nanoparticles of all concentrations, uniform dispersion and longer dispersion stability were observed. As a result, the prepared nanofluids can help to increase thermal conductivity. Tables 2 and 3 show the thermo physical properties of the PCM, Al2O3 nanoparticles as prepared.

Table: 2 Thermo physical properties of the Stearic Acid (Phase Change Materials)

S.No	Properties	Value/Type
1	Melting point °C	69.6
2	Density (g/cm^3)	0.847
3	Boiling point	376.1
4	Insoluble	Water
5	Insoluble	Ether
6	Freezing points°C	55 to 7°C

Table: 3 Thermo physical properties of the Al_2O_3 nanoparticles

S.N	Properties	0.3 vol % Al_2O_3	Uncertainty
1	Thermal conductivity (W/mK)	0.669	0.001
2	latent heat (kJ/kg)	1916	0.12
3	Specific heat capacity J/kg.K)	4.026	0.01
4.	Viscosity (mpa/S)	4.026	0.002
5	Density(kg/m^3)	1.034	0.001

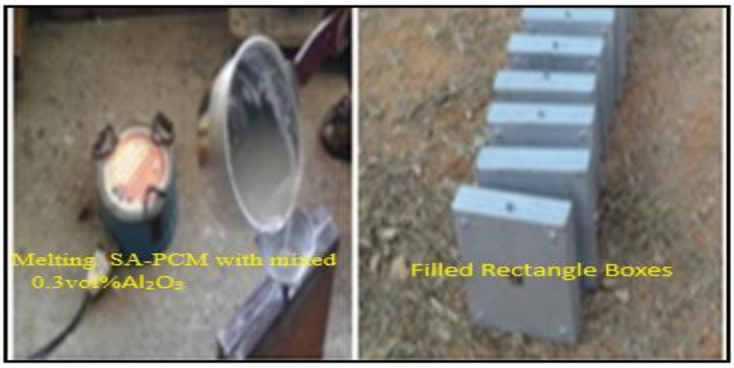

Fig. 2. Encapsulation of PCM - 0.3% vol Al_2O_3 nanoparticles

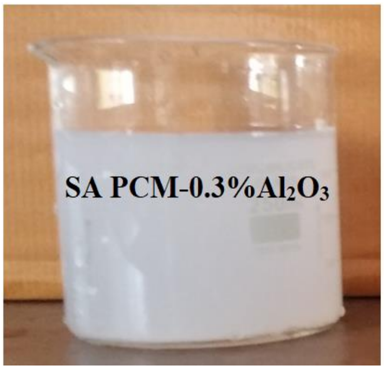

Fig. 3. Digital image of the PCMs - 0.3% vol Al_2O_3

2.3 Storage Tank

The tank used in the experiment had a capacity of 80 litres .It was made of mild steel material with thickness of 2.5 mm and its outer surface was fully insulated with the glass wool materials with the thickness of 0.05m used for the stored working fluid temperature in order to reduce heat losses in the storage tank (Fig. 4). A PCM-0.3%vol of Al_2O_3 nanofluids encapsulated rectangular box (size: 40 cm x 40 cm x 4 mm thickness) was arranged in a parallel manner from the left to the right side of the storage tank in the research work, as shown in Fig. 5.

Fig. 4. Photo view of Storage Tank

Fig. 5. Rectangular box in ST

During short time and cloudy conditions, the use of PCM-0.3% vol Al_2O_3 nanofluids helped increase the outlet fluid temperature of the heat transfer fluid flowing within the inner tube. A small PTC enhanced TES was designed and built at the Chennai, India (Latitude 13° 4' 2.78" North and Longitude 80° 14' 15.42'' East).

2.4. Crops used in dryer

The solar dried product meets export standards and provides livelihood for farmers. This type of solar dryers plays a significant role in fostering growth in agriculture. This form of solar dryer can be used for various applications such as dehydration and drying. It not only removes fossil fuels but also helps protection of the atmosphere from toxic emissions and pollution from the green air. Readings were taken from the different agricultural products which included groundnut, ginger, and turmeric. The maximum radiation intensity recorded was 590 W/m^2.Groundnut is an oilseed crop grown and consumed in most parts of the world. Its high protein content helps it has made accepted as an excellent source of nutrition for both

humans and animals. Ginger is an important crop grown commercially for its aromatic rhizomes and used as spice, condiment, and medicine. Turmeric is a member of the ginger family, native to Southwest India and the source of a bright yellow spice and dye is its rhizomes. Rhizomes are used as cosmetics both for the body and the face in Africa and Asia. The drying unit consisted of an insulated solar cooker for prevailing thermal loss. The crops to be dried were held in a semi-circular oven. It allowed the heated working fluid (water and waste oil) to circulate inside the solar cooker. The fluid passed through the crop when cooked, and the moisture therein was evaporated and dried. The weight gap provided information relating to how much moisture had evaporated.

2.5. Working medium

(George et al. 2010) tested the lubricating and cooling properties of various multi-grade SAE 20W-50 engine oil samples, with five samples taken. The result showed the higher mixing rate of multi-trade oil as the best for cooling and lubricating, and also the higher specific heat of oil with a lower internal energy and less viscous properties. The sample has been having high energy, less viscous lubricates was seen as better for the properties of heat transfer.The working medium of water ,waste engine oil thermodynamics properties as shown in the Table 4.

Table: 4 Thermodynamics properties of the Waste Engine oil, Water

S.No	Properties	Waste Engine Oil	Water
1	Specific heat (kJ/kg*K)	2.483	4.186
2	Density (g/m^3)	0.847	1
3	Kinematic viscosity (kg/ms)	5 x 10^6	0.01
4	Thermal conductivity (W/m k)	0.1314	0.6
5	Prandtl Number	84	7.56
6	Melting temperature °C	10 to 40	0
7	Boiling temperature °C	400	100

3 Mathematical Calculations:

Kalogirou et al. (2009) observed the intensity of solar radiation entering the PTC, which is dependent on the beam solar radiation (I) and the concentrator aperture area (A), as shown by the following relationship,

$Q_i = A \times I$ in W ---------------------- (1)

The heat absorbed by the working fluid was dependent on specific heat capacity Cp of the liquid, the flow rate of the working fluid and the temperature gain of the fluid from the collector's inlet to outlet as (T_0 - T_i). The useful heat gain in the receiver is calculated as follows,

$Q_u = m C_p (T_o - T_i)$ in W------------------------ (2)

The collector's TES is defined as the ratio of useful heat output to collected area of solar radiation intensity.

$\eta_{th} = Q_u/Q_i$ --------------------------------(3)

Utilized Energy Output for Solar Dryer:

Film temperature (T_F) = $(T_W + T\infty)/2$--------------------- (4)

$Re = m\, d / (A\, \mu)$

since $Re > 2300$ flow is turbulent

$10 < L/d < 400$

Nusselt number = $0.036(Re)^{0.8}(Pr)^{0.333}(L/d)^{0.055}$ ------------ (5)

Average heat transfer Coefficient $h = N_u\, k / d$ W/mK--------------------- (6)

Useful Heat Output $Q_u = hA\, (T_w - T_\infty)$ -------------------- (7)

4. Experimental work

The purpose of the observation was to detect solar dryer with thermal heat storage with an enhanced PTC as shown in Fig. 1 of the rapture. The system worked on the working principle of the injection of the fluid water and waste oil into the parabolic receiver at room temperature through the check value. Solar radiation absorbed by parabolic collector was reflected and concentrated in the receiver; working fluid passed through the parabolic receiver was transmitted to the thermal storage system through transmission of solar energy into thermal energy. The accumulated energy was used for purposes of cooking.

Fig. 6. Photoview of Experiment setup

The entire procedure was continuing from 8.00 am to 8.00 pm.The purpose of the observation was to detect the performance of the PTC enhanced ST through the use of PCM with 0.3% Al_2O_3 nanofluids at 0.035,0.045 and 0.065 lit/sec flow rate of working medium setup as shown in Fig. 6. There were two tracks in the system. Initially, the transfer liquid was made in storage system at room temperature. This transfer fluid was pumped into the PTC receiver through a check valve to absorb heat from the receiver and store it in the storage tank. The heat transfer fluid in the ST is pumped into the SD through a check valve in the other route. The experiment was carried out continuously. 0.5 HP motor attached pump was fixed at the suction inlet of storage tank. It worked at a constant speed and was used for pumping water and engine waste oil working medium. Instantaneous temperature was measured using K-type Thermocouple's sensor at required locations and connected to a data acquisition unit (MAX6675) for monitoring PTC and ST temperatures at the inlet and outlet were precisely measured of ± 0.05%.

Volatility of the calculated values was identified in the following ways:

(maximum value – minimum value)/number of readings = volatility

The calculated data's volatility was found to be 0.12 based on the above relationship.

5. Results and discussion:

The aim of the device was to track the mean heat output value and efficiency of the determined and measured parameters in SD at groundnut, ginger, and turmeric crops at flow rates of 0.0350.045 and 0.065 kg / sec under working medium of water and waste oil. The study was conducted in the 4th week of April 2018, known for typical Indian summer. The measurements were taken for 4 weeks, with atmospheric temperature variations from 28° C to 40 ° C during the period.

5.2 Comparison of Heat output of Solar dryer

The aim of this study is to extract heat from the storage tank (ST) that was allowed to pass through the solar dryer for cooking purposes. The comparative output of SD in water, waste engine oil were around 4.68 and 5.85 times higher than that of the PTC receiver and 1.33 times lower than ST at flow levels. During the from 8:00 a.m. to 8:00 p.m. solar dryer's charging and discharge processes recorded energy output values at flow rates of 0.035, 0.045 and 0.065 lit/s respectively for a water and waste engine oil working medium. Solar dryer losses in water, waste engine oil average were approximately 0.9 times lower than the ST at volume levels of 0.035, 0.045 and 0,065 lit / sec respectively due to atmospheric energy loss. Fig. 7 shows at 1.00 pm the solar dryer output was 8939 W, 11923 W for water, waste engine oil medium at the flow rate of 0.035 lit/sec , at 0.045 lit / sec the heat output was 7107 W, 9851 W for water , waste engine oil medium respectively. The result showed the flow rate of waste engine oil medium as 1.33 times advanced than the water output. Fig. 7 shows energy outputs of 7080,4808 and 2893 W in the waste engine oil medium at a flow rate of 0.035 lit / sec in the SD during 6.00, 7.00 and 8.00 p.m. and output of 0.045 lit /sec was 5686,3629 and 1777 W, respectively. The generated outputs were 4514, 2675 and 911 W for a rate of 0.065 lit /sec, respectively. In addition, the energy used by SD in between 6 and 8 p.m., the waste oil medium was 1.39 times more than the water.

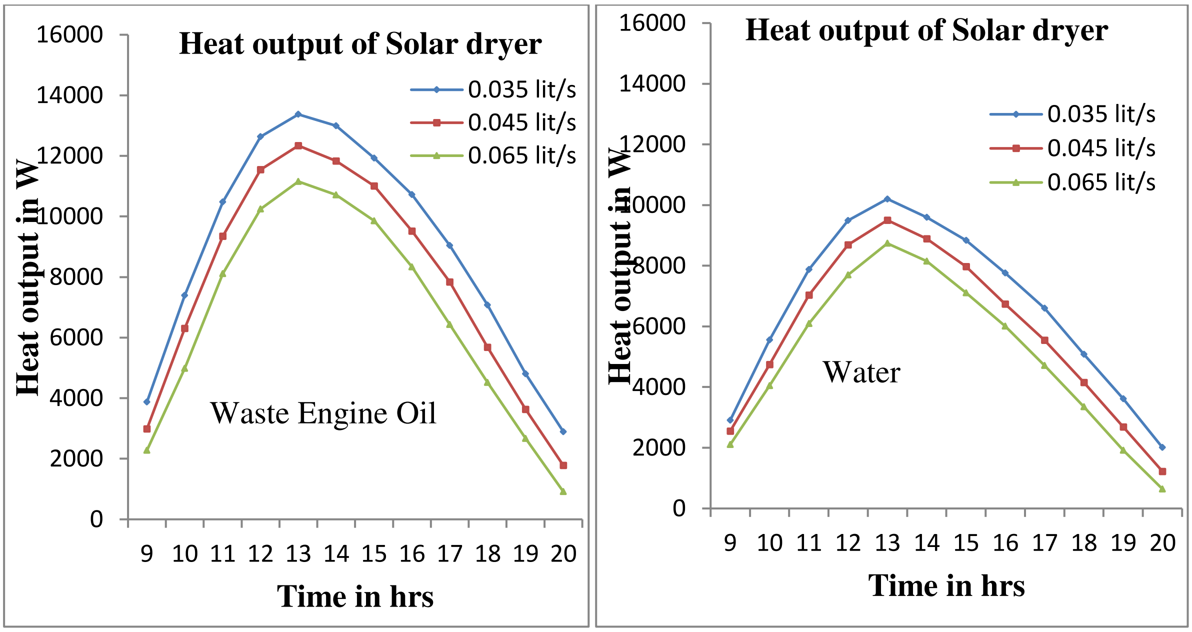

Fig. 7 Comparison of Heat output with respect to Time

The flow rate for waste oil medium under larger radiation absorption was 0.035 lit /sec due to the smaller flow rate. It also reduced losses to the environment and increased the temperature at storage tank. The experiment showed the PCM-0.3 Al_2O_3vol% nanofluids helping increase in 25 to 35 % heat efficiency during charging and discharge . Thus, the time taken to melt the PCM material was approximately 40% to 50%.The energy storage rate was lower compared to the 0.045 and 0.065 lit / sec flow rates. When heat was drawn out of the flow path, the higher flow rate was absorbed, and the increased heat loss was due to environment.

5.2 Comparing Heat output for Crops (0.035 lit/sec)

The performance of solar dryer under Meteorological condition for drying crops was investigated. The thermal efficiency of the designed dryer showed a reduction in the moisture content for the crops found at variant hours. The recital and quality showed rapid drying rate with helping to store heat due to its solar dryer and as more efficient than other drying modes. Numerous agricultural products, such as groundnut, ginger, and turmeric, and their heat output and efficiency performance were calculated by measuring crop temperature.

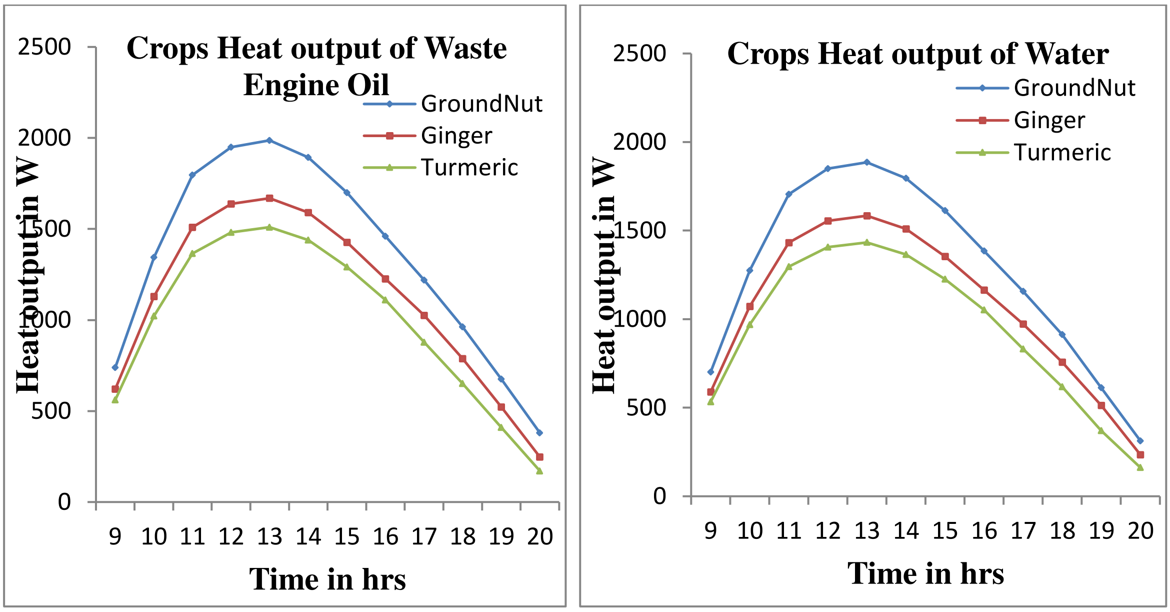

Fig. 8 Heat output of crops with respect to Time (0.035 lit/sec)

The heat output performance for SD crops at a rate of flow 0.035 lit / sec using water and waste oil as well as the heat removal rate and humidity loss were higher in the SD system as shown in Fig. 8. At 9.00 am, groundnut, ginger, and turmeric crops in the SD reached output energy of 738 W, 620 W, and 561 W, respectively, in the WEO medium and the water medium of 701W, 589W, and 532 W. At 1 pm groundnut, ginger and turmeric crops in the SD reach output power of 1987 W, 1669 W and 1510 W in the waste oil medium in the water medium they were respectively 1886 W, 1584 W and 1433 W. The average output of water

was about 0.94 less than the waste engine oil average. Groundnut, ginger, and turmeric crops in the SD achieved output capacity of 1220W, 1025W and 877 W in the waste oil medium at 5.00 pm.These were 1158 W, 973 W and 832 W respectively in the water medium. Crop energy absorbed in groundnut was 6 times less than WEO and 4.6 times less than the energy absorbed in SD. This was due to the transfer of heat losses by various heat transfer mechanisms that exist in the ambient environment.

5.3 Comparing Heat output for Crops (0.045 lit/sec)

Fig. 9 shows the working media of water and waste oil compared to the heat output of crops at a rate of 0.045 lit / sec. At the initial stage at 9.00 a.m., groundnut, ginger and turmeric crops in the SD achieved output energy of 714 W, 600 W and 543 W in the waste oil medium.

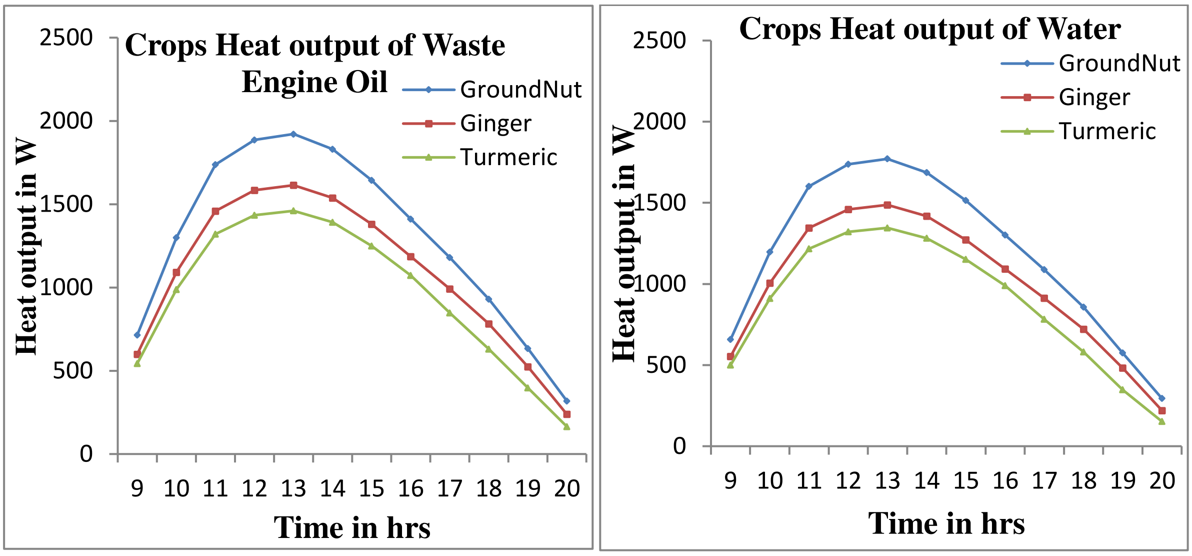

Fig. 9 Heat output of Crops with respect to Time (0.045 lit/sec)

The water around was 658 W, 553 W and 500 W respectively. The energy outputs of groundnut, ginger and turmeric crops in the SD at 1 p.m. were 1886 W, 1584 W and 1433 W in the water medium and 1921 W, 1614 W and 1460W in the waste oil medium respectively, and the water medium output was around 1 % lower than that in the WEO medium. The SD's around energy output at 1 pm was 7977 W for water and 11008 W for waste oil at a flow rate of 0.045 lit/sec. Compared to groundnut, ginger and turmeric the absorbed energy by solar dryer was found to be approximately 6, 4.2 times lower than waste oil and water due to increased losses of radiation, conductivity and convection in the surroundings.

5.4 Comparing Heat output of Crops (0.065 lit/sec)

Fig. 10 shows a comparison energy output of crops at a rate of 0.065 lit / sec on water and waste oil medium. Groundnut, ginger, and turmeric crops showed output energy of 699,597 and 531 W in the waste oil medium and 701,589 and 532 W in the water medium respectively at the initial stage at 9.00 am. Groundnut, ginger and turmeric crops achieved output energy of 1155, 970 and 831 at 5p.m. in the waste oil medium and 1015,873 and 730 W respectively in the water medium. For the drying crop charging rate was lower than the flow rates of 0.035 and 0.045 lit / sec because of the high volume flow rate, same time as the absorbed heat was drawn through the flow Path. Groundnut, ginger, and turmeric outputs at

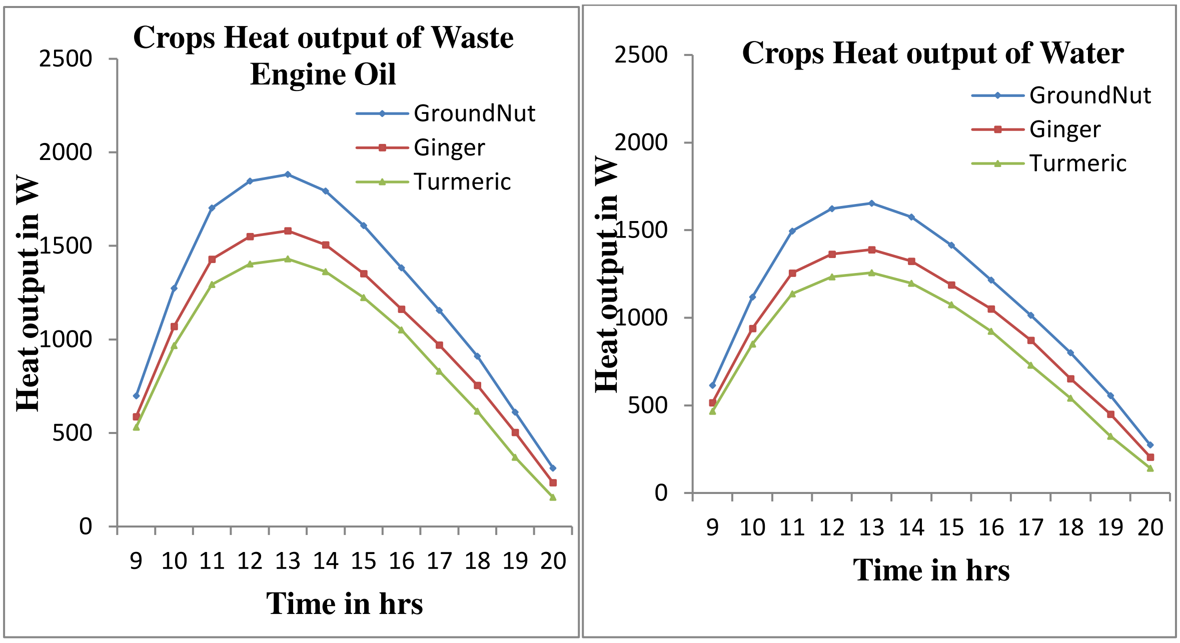

Fig. 10 Heat output of Crops with respect to Time (0.065 lit/sec)

1 pm were approximately 1882, 1581 and 1430 W in the waste oil medium and 1654, 1389 in the water medium and as for 1257 W. It was about 1.14 times less in the water mean output than the waste oil medium. When SD absorbed energy output was found to be approximately 5.2, 6.2 and 8.2 times lower compared to waste oil for groundnut, ginger and turmeric and for water 5.3, 5.9 and 5.6 times lower than the waste oil medium due to radiation, occurrence of conductivity and convection losses was seen in the surrounding environment showing higher heat flow rates occur at a high heat loss rate.

5.5 Comparing the Efficiency of Crops (0.035 lit/sec)

Fig. 11 shows a comparison of crop efficiency at a rate of 0.035 lit / sec in the water medium and waste engine oil. At the initial stage of 9.00 am, groundnut, ginger and turmeric crops had an efficiency of 38, 32 and 29 % in the waste oil medium and 36, 31 and 28 % respectively in the water medium. Efficiency of groundnut, ginger and turmeric at 1 p.m. was

73.4, 61.6 and 55.7% in the water medium and 77, 65 and 59 % in the waste oil medium, respectively, after 1 p.m. the efficiency values decreased due to decrease a solar radiation and heat loss in the surrounding area. For groundnut, ginger and turmeric crops, crop efficiency for 6.00 pm at a rate of 0.035 lit / sec was 54, 45 and 41 % for waste oil, 51, 43 and 39 % for water medium after its output at 7.00 pm, 8.pm decreased 4 % to 9 % respectively. The output of waste oil for all crops was 4 % approximately higher than the water medium.

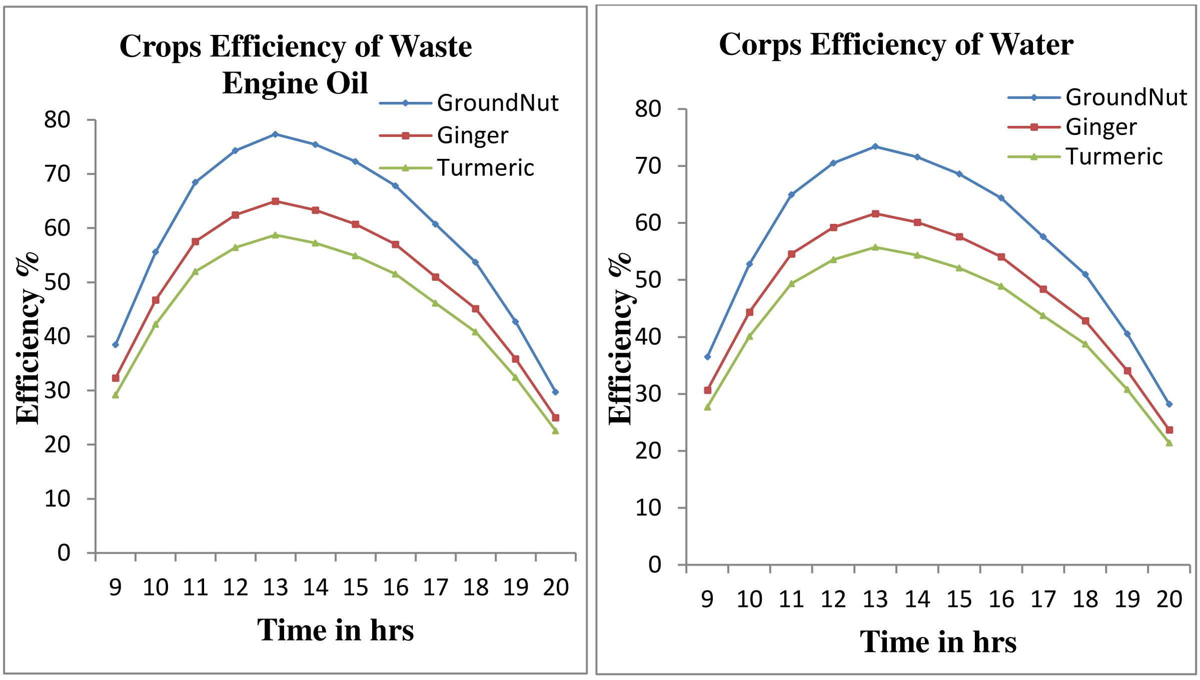

Fig. 11 Efficiency of the Crops with respect to Time (0.035 lit/sec)

5.6 Comparing the Efficiency of the Crops (0.045 lit/sec)

Fig. 12 demonstrates the efficacy of the crops with a flow rate of 0.045 lit / sec in the water and waste oil medium. The groundnut, ginger, and turmeric crops had an efficiency of 35, 30 and 27 % in the waste oil medium and 34, 29 and 26 % in water respectively at the initial stage of 9.00 am. At 1 pm, there were 69%, 58% and 52% in the water and 71, 59 and 54%

respectively in the waste oil. At 5.00 pm the crops had an efficiency of 56, 47 and 42 % on

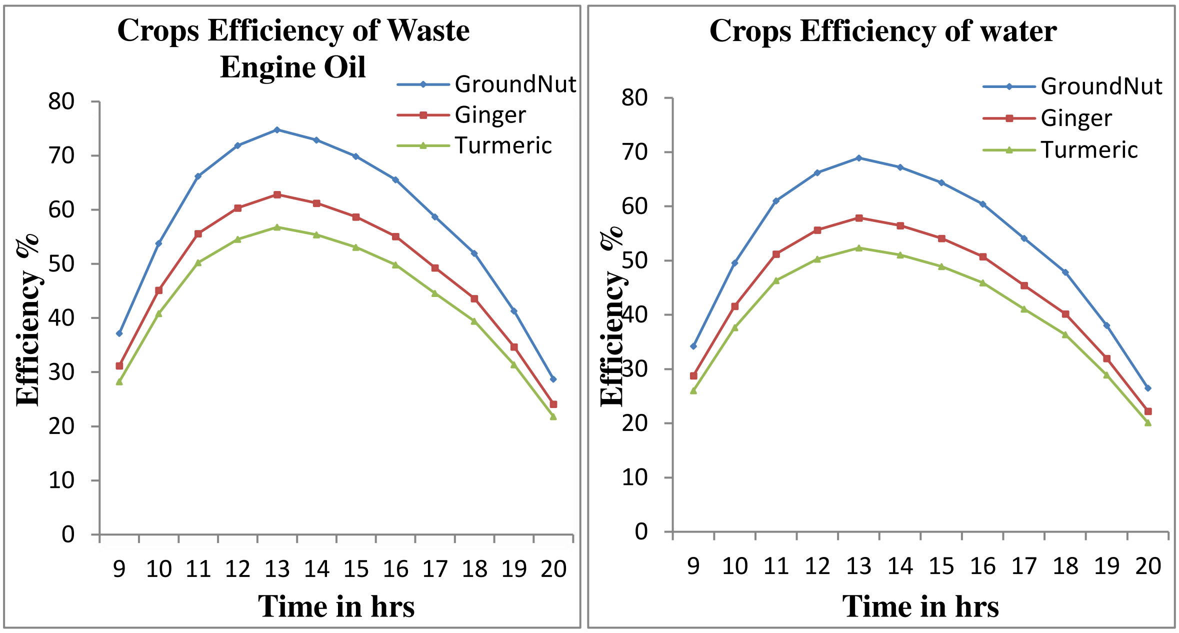

Fig. 12 Efficiency of the Crops with respect to Time (0.045 lit/sec)

the WEO medium and 54, 45 and 41% on the water medium respectively. Efficiency values decreased after 1 pm due to a reduction in SR and heat loss that occurring due to the surroundings. The efficiency of crops for groundnut, ginger and turmeric crops during 6.00 pm at 0.035 lit/sec flow rates was 49, 41 and 37 % for waste oil, 48.40 and 36 % for water medium after its efficiency at 7.00 pm, 8.pm decreased 8% respectively. The output waste oil for all crops was just 3 % higher than in the water medium.

5.7 Comparing the Efficiency of the Crops (0.065 lit/sec)

Fig. 13 shows a flow rate of 0.065 lit/sec in the crop efficiency on the water and WEO medium. Groundnut, ginger and turmeric crops had an efficiency of 35, 30 and 27% for the waste oil medium and 32, 27 and 24 % for the water medium respectively at the initial stage of 9.00 am. The crops at 1 p.m. showed 64, 54 and 49% efficiency in water and 71, 59 and 54% in waste oil, respectively. Values decreased after 1 p.m. due to reduced solar radiation and ambient temperature loss.

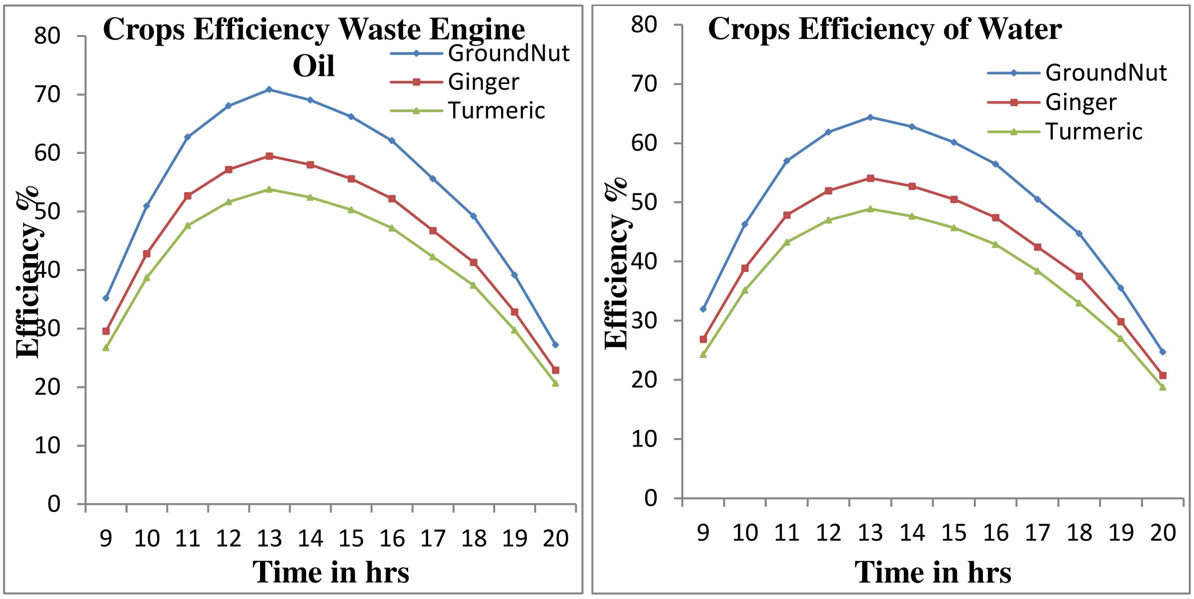

Fig. 13 Efficiency of the Crops with respect to Time (0.065 lit/sec)

The crops at 5.00 pm had an efficiency of 56, 47 and 42 % in the WEO medium and 51, 42 and 38 % in the water medium, respectively. The efficiency of crops at 6.00 pm at 0.065 lit/sec flow rates for groundnut, ginger and turmeric crops was 49,41 and 37 % for waste engine oil, 45,38 and 33 %for water medium after their efficiency at 7.00 pm, 8.00 pm decreased by 4 to 8 %, respectively. The output of waste oil for all crops was 7% higher than in the water medium. The crop flow rate efficiency of 0.065 was lower compared to 0.035 and 0.045 lit / sec because of the high volume flow rate. At the same time, the radiated heat was drawn out over the flow path, and due to the environment, a greater amount of heat was lost.

5.8 Comparison of results of experiments

(Tesfay et al. 2014) have reported the stored heat output of 1227.4 kJ per unit as suitable for drying at 180 ºC temperature. The analysis showed the PCM melting time as about 100 min, while the heat stored was about 730 kJ. The tested output was successful in fringing potatoes. The experiment was carried out 12 hrs during the PCM-nanofluids storage for charging and discharging process at higher beam radiation time obtained PTC at higher temperature of 78.7 ºC and its corresponding heat output 2.285 kW and storage temperature was 125º C, heat output of 13.455 kW, while the crops obtained the highest temperature and heat output as 77.35C, 1987 W respectively. From the experiment work, useful heat output and efficiency were higher when compared too much researcher work (Table. 5).

Table 5. Summary of the previous studies and present study based on nanofluids.

S.No	Authors	Nanofluids	Thermal Efficiency
1	Kasaeian et al., (2017)	0.2 % of carbon dispersed in ethylene glycol	75 %
2	Mwesigye et al., (2017)	Silver Nanoparticles, Copper Nanoparticles, Alumina Nanoparticles.	Improved by 13.9 percent, 12.5 percent, and 7.2 percent for silver, copper, and Alumina, respectively,
3	Coccia et al., (2016)	TiO_2, SiO_2, Fe_2O_3, ZnO, Al_2O_3, and Au Nanofluid	63.14, 63.14, 63.12, 63.14, 63.14, and 63.15 %
4	Mwesigye et al., (2016)	Copper Nanoparticles	Improved by 12.5%
5	Bellos and Tzivanidis, (2017)	Al_2O_3,CuO,TiO_2, and Cu nanoparticles dispersed in base thermal oil Syltherm 800	Improved 1.75 % in nanofluids compare to pure thermal oil.
6	Bellos et al., (2016)	Thermal oil, Thermal oil with nanoparticles, and Pressurized water.	Improved 4.25 % by using the nanoparticles
7	Potenza et al., (2017)	Air-disperse Copper dioxide nanopowder	65%.
8	Present work	PCM -0.3 vol % of Al_2O_3 nanofluids, PCM -0.3 vol % of Al_2O_3	Improved by 30 % by using 0.3 vol % Improved by 40 % by using 0.4 vol %

6. Conclusion

The practicability of the performance of solar dryers for drying groundnut, ginger and turmeric crops for water and waste engine oil medium at rate of flow 0.035, 0.045 and 0.065 lit / sec has been successfully demonstrated.

Specifically,

- During the experiment, the energy output of the solar dyer at a rate of flow 0.035 lit /sec, the waste engine oil medium as 0.33 times greater than the water medium. In the process, storage medium of the PCM -0.3 vol % of Al_2O_3 nanofluids helped a 25 % to 35% efficiency increase for the charging and the discharging processes. Not only that, but it also consequently increased the solar radiation used for melting the PCM - 0.3 vol % of Al_2O_3 nanofluids was approximately up to 40% to 50 %.
- The energy output at the rate of 0.035 lit/sec was higher than the flow of 0.045 and 0.065 lit/ sec for water as well as waste engine oil medium.
- At the rate of flow 0.035 lit/sec ,the energy output of the waste engine oil medium of solar dryer was found to be approximately 12.4, 14 and 15.1 times lower than the crops output of groundnut, ginger and turmeric and for water medium of solar dryer was found to be approximately 9.8, 10.5, 11.5 times lower than crops output due to radiation, conductivity and convection losses occur in the surrounding environment and also showed the occurrence of higher heat flow rates at a high heat loss rate.
- The output for the waste oil medium of groundnut, ginger, and turmeric crops was 4, 5.9 and 5.9% higher than that in the water medium at flow rates of 0.035, 0.045 and 0.065 lit / sec respectively. The rate of flow output of 0.035 of the crops was higher contrasted to the rate of 0.045 and 0.065 lit/ sec due to the high rate of heat was drawn out along the flow path and environmental heat losses. At the rate of 0.035 lit /sec was very full flexible for drying the food at varying different condition of time.
- There was a decrease in crop efficiency decreased over time after sunshine at flow rates for water and waste oil medium at 5.00, 6.00 and 7.00 pm as 11 to 13 % respectively.

Nomenclature

PCM	phase change material
PTC	parabolic trough collector
TES	thermal energy storage

I	solar radiation
A	concentrator aperture area
Cp	specific heat capacity
T_i	collector's inlet temperature
T_0	collector's outlet temperature
T_F	film temperature
Q_u	useful heat gain
Q_i	heat in
Re	Reynolds Number
Pr	Prandtl Number
L	length
d	diameter
h	average heat transfer Coefficient
N_u	Nusselt number

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The authors would like to thank the Principal and management of Kings Engineering College for their assistance in completing this research project, as well as the University Malaysia Pahang for providing financial support through research grant RDU190386.

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Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Authors Contribution

Babu Sasi Kumar Subrananiam - Investigation, Project administration, Writing original draft

Arun Kumar Sugumaran- Data curation, Software-, review & editing

Muthu Manokar Athikesavan - review & editing

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Declaration of competing Interest

The authors declare that there is no competing interest.

Availability of data and materials

All data are given in the manuscript

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Figures

Figure 1

Photo view of Parabolic trough collector

Figure 2

Encapsulation of PCM - 0.3% vol Al2O3 nanoparticles

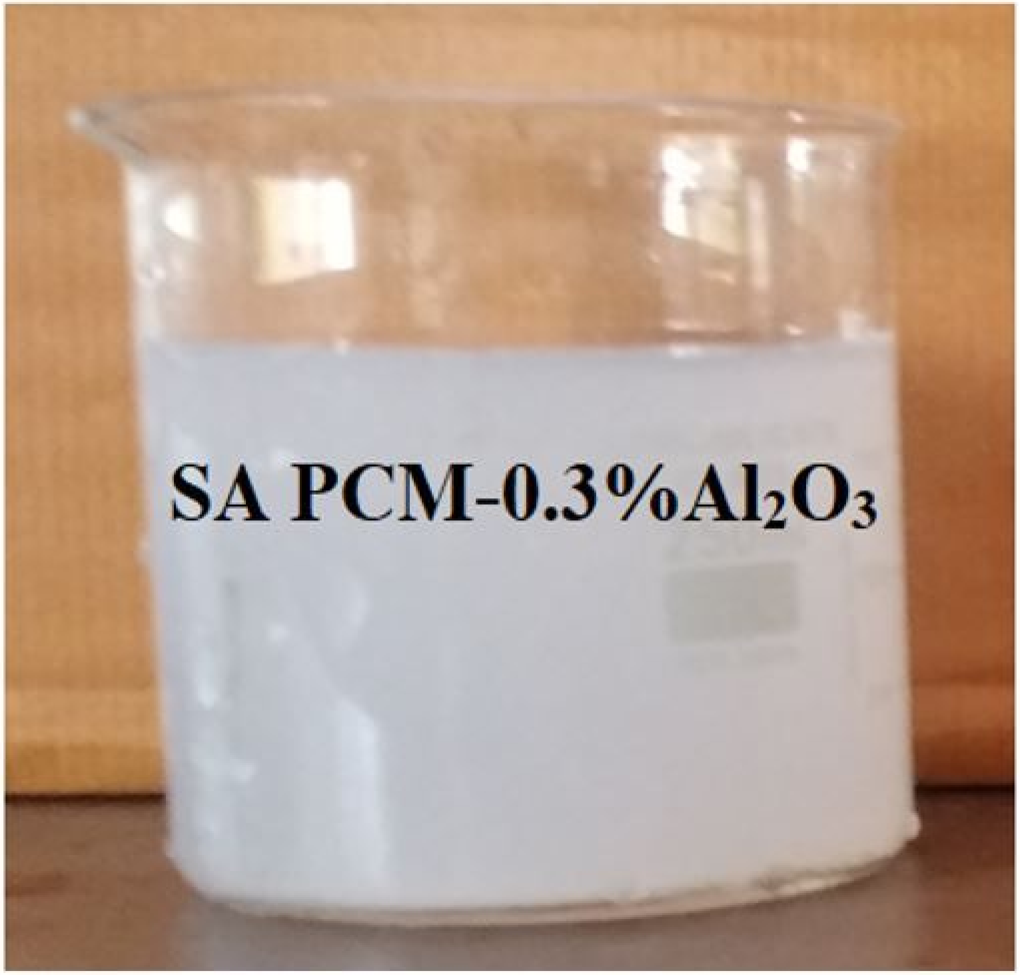

Figure 3

Digital image of the PCMs - 0.3% vol Al2O3

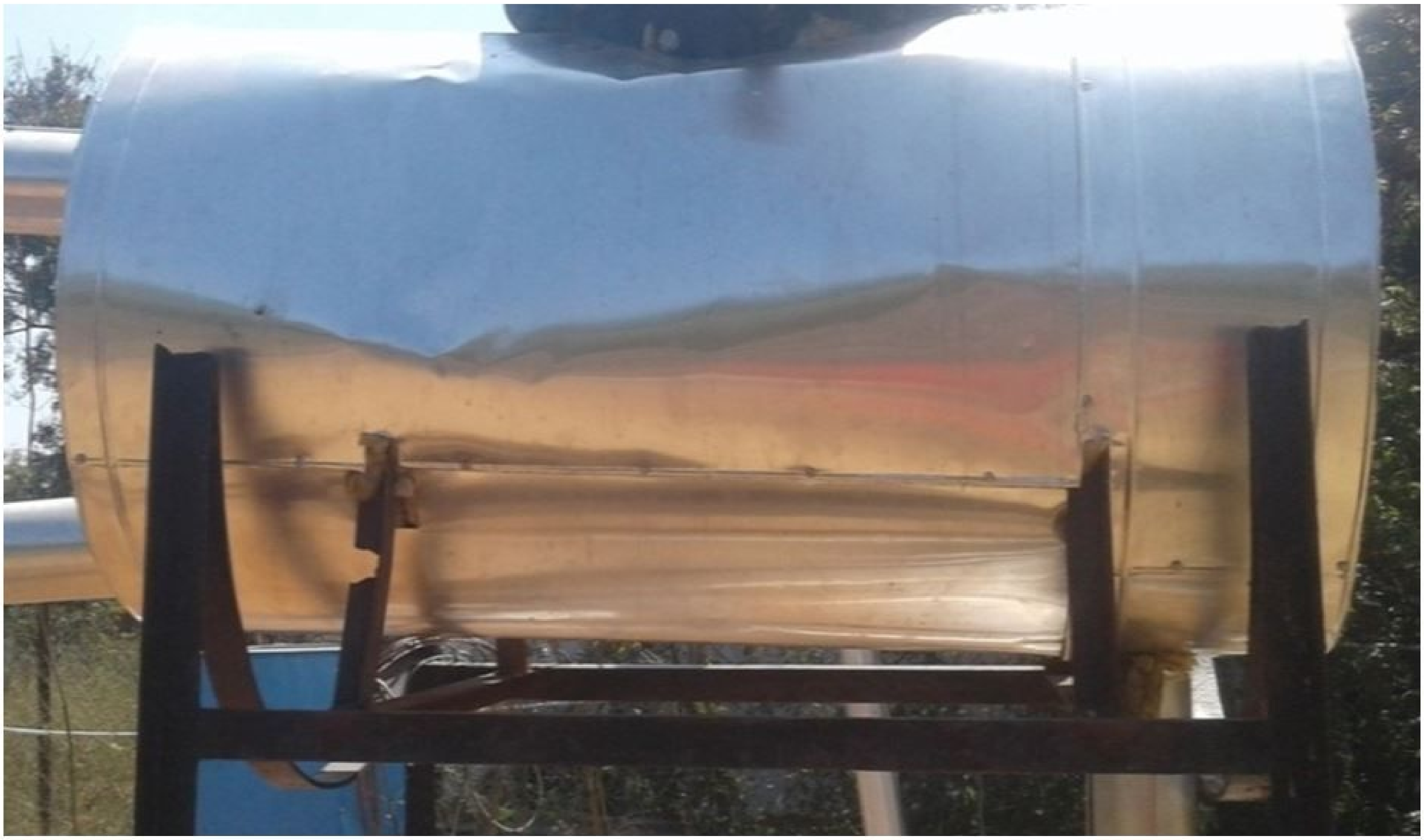

Figure 4

Photo view of Storage Tank

Figure 5

Rectangular box in ST

Figure 6

Photoview of Experiment setup

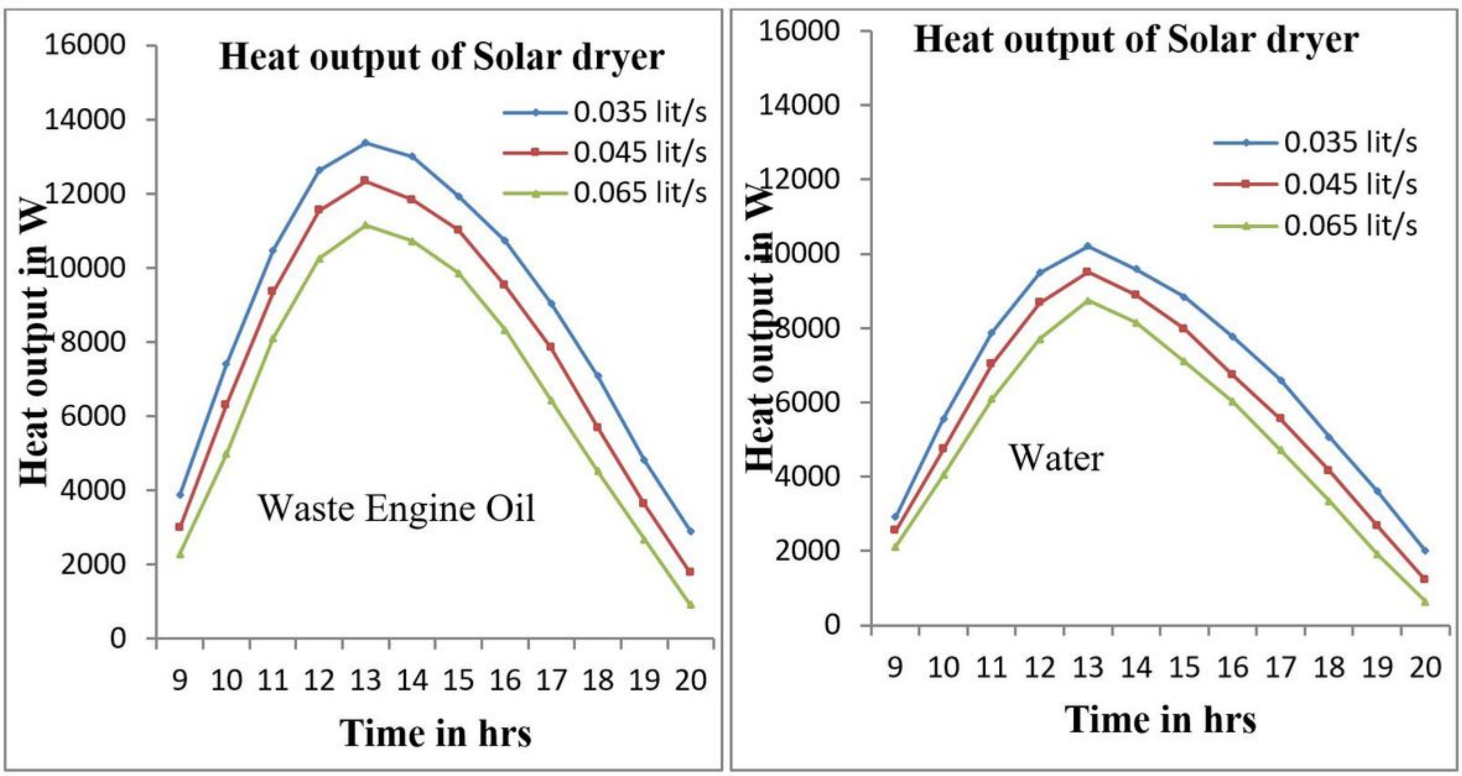

Figure 7

Comparison of Heat output with respect to Time

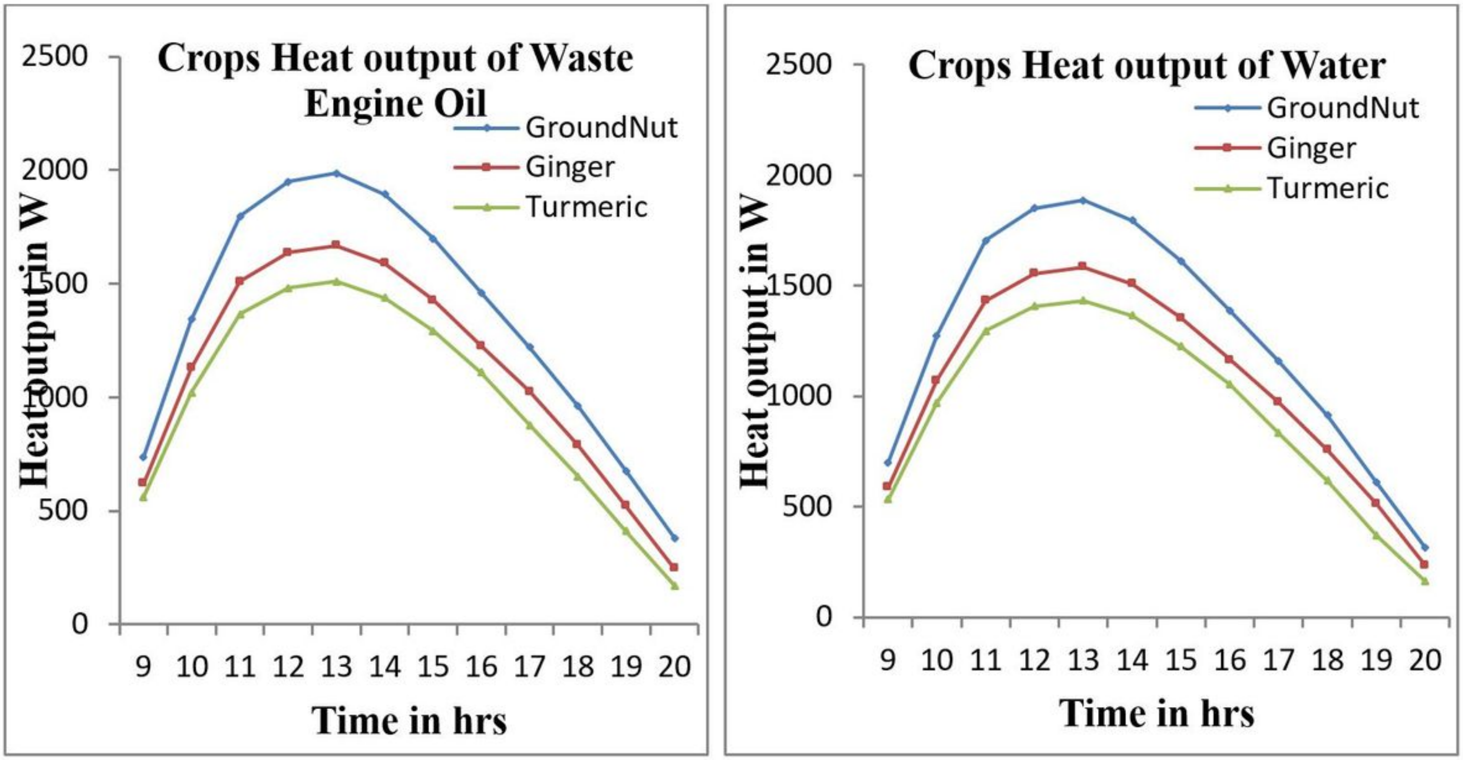

Figure 8

Heat output of crops with respect to Time (0.035 lit/sec)

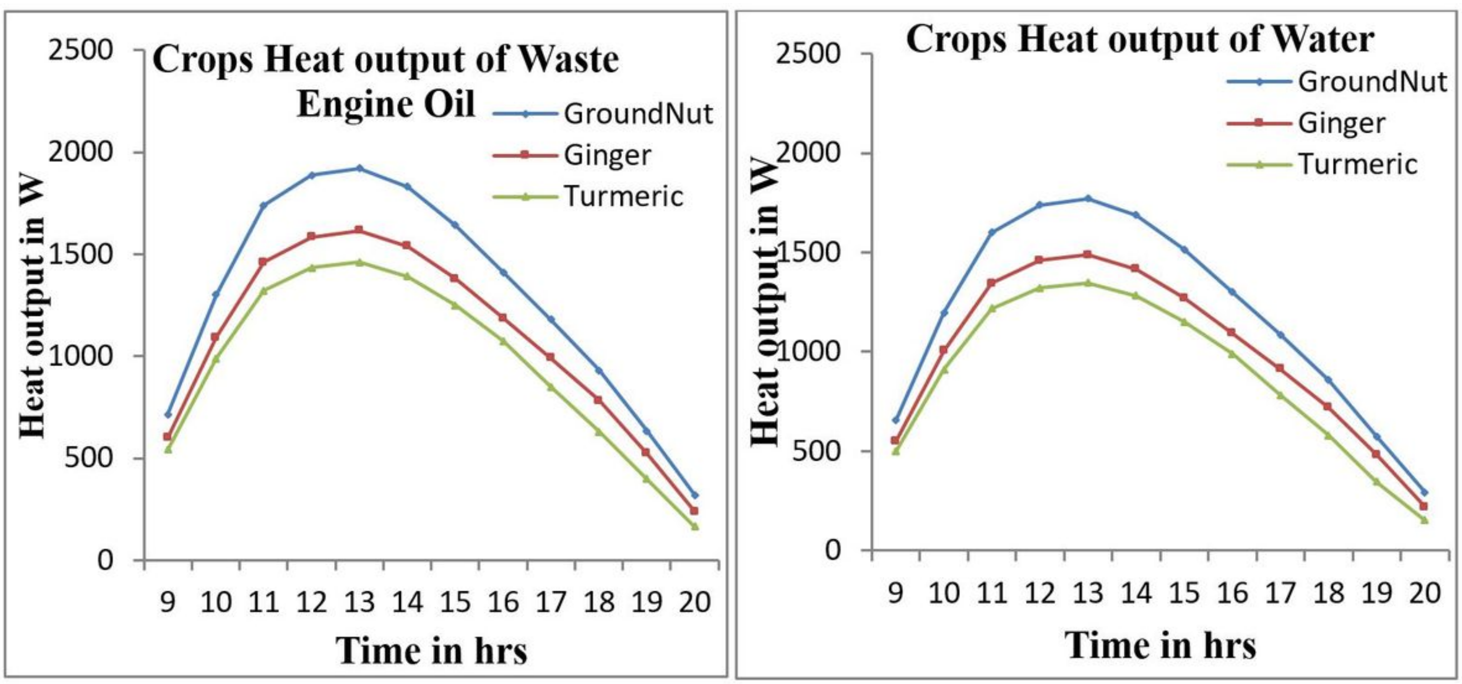

Figure 9

Heat output of Crops with respect to Time (0.045 lit/sec)

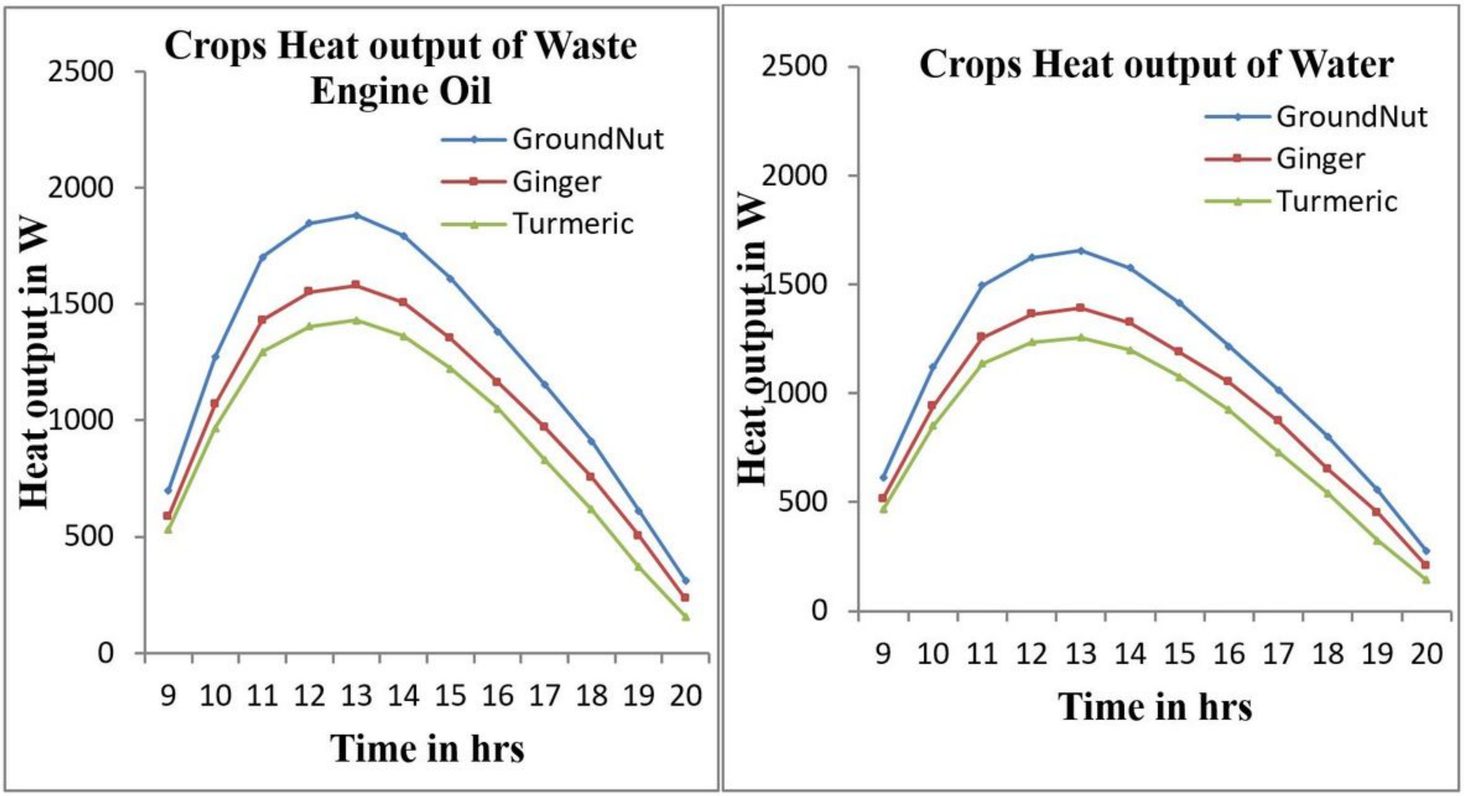

Figure 10

Heat output of Crops with respect to Time (0.065 lit/sec)

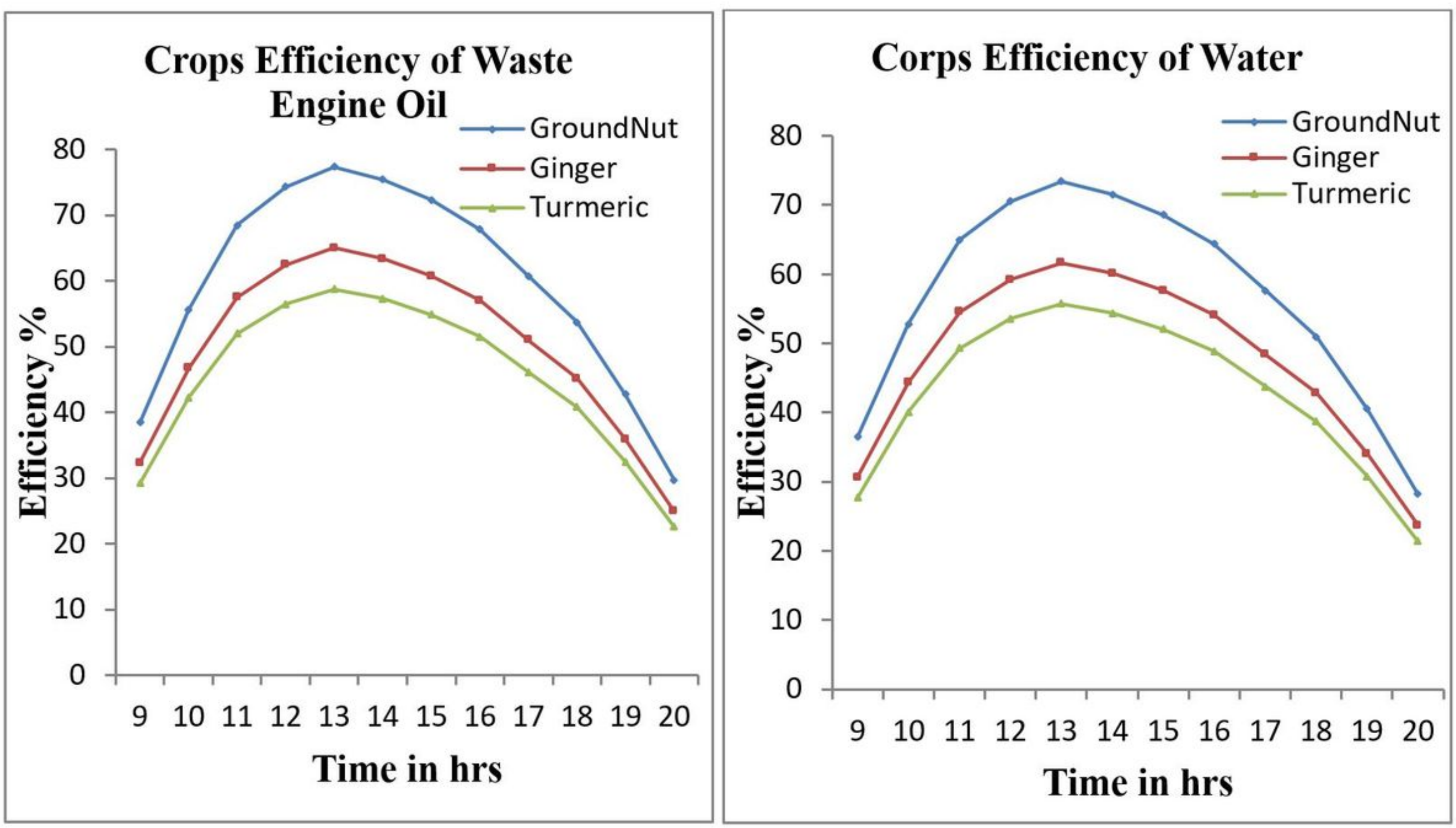

Figure 11

Efficiency of the Crops with respect to Time (0.035 lit/sec)

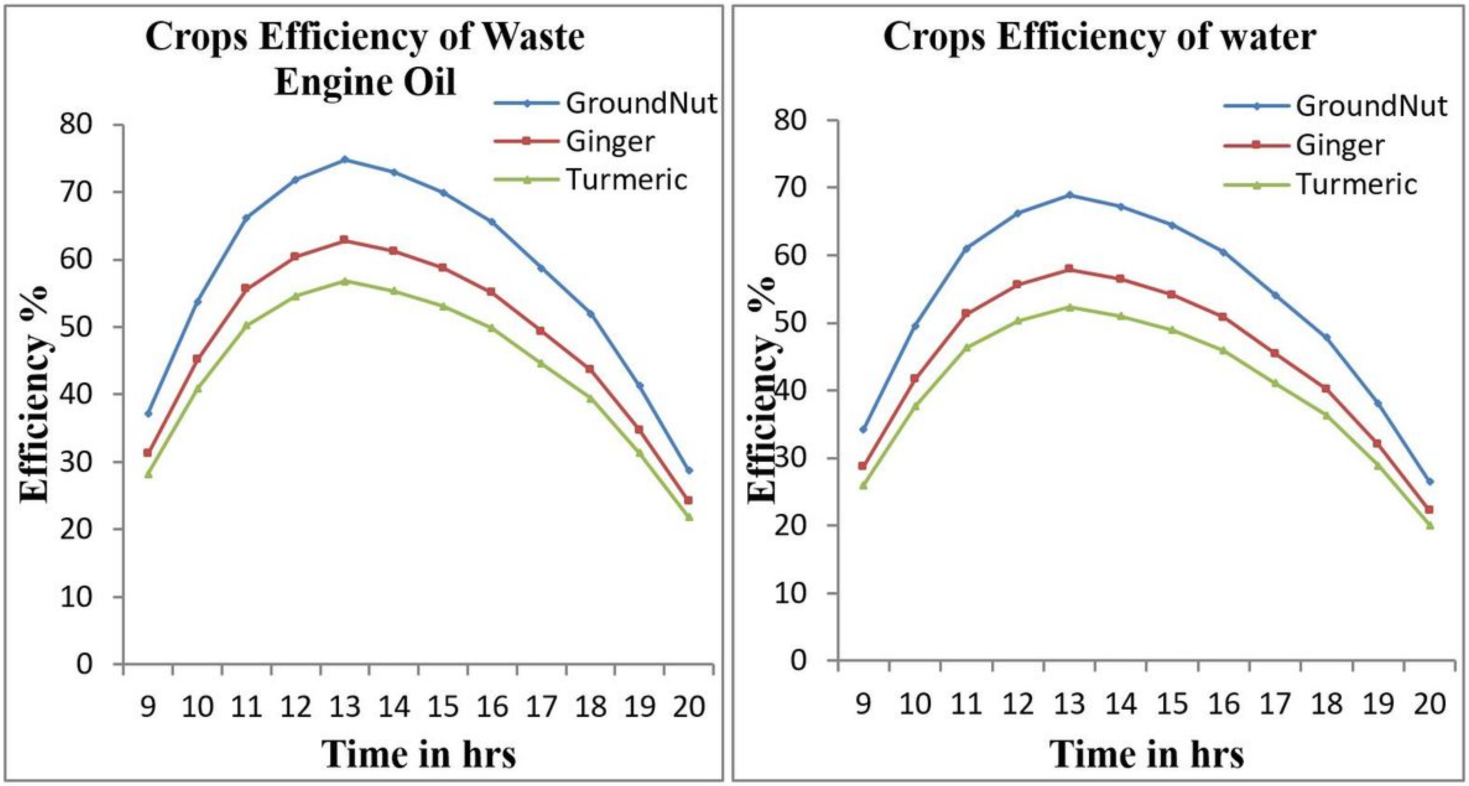

Figure 12

Efficiency of the Crops with respect to Time (0.045 lit/sec)

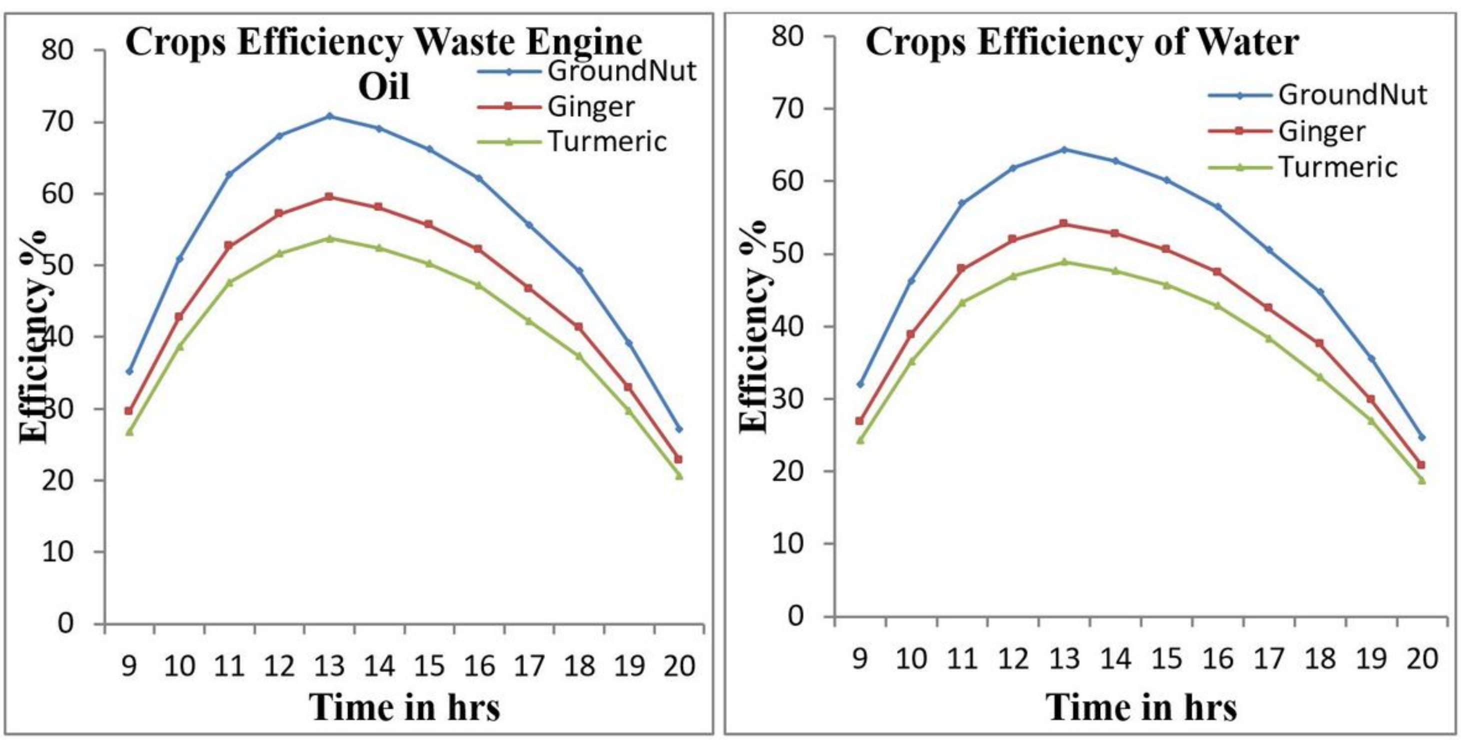

Figure 13

Efficiency of the Crops with respect to Time (0.065 lit/sec)