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Thermal analyses on solar cooker with Nano-structured trays

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Abstract
Solar cooker with improved figures of merit is necessitated for relatively faster cooking in domestic sectors. In this connection, investigation, the solar cooker with double glazed toughened glass cover, nano -sized graphite and manganese oxide coated cooking tray and PUF insulator was designed. It was developed and thermally analyzed. Its figures of merit were estimated to adhering BIS specifications. In the case of testing of components of solar cookers the double glazed toughened glass cover was tested and its transmittance was found to be 72%. The XRD analysis on the coating of the cooking tray was carried out and crystallite size was found to be 57 nm. The PUF insulation was also tested and its resistance was found to be 0.92w/m². As far as testing of solar cooker was concerned, the figure of merit in no load condition was found to be 0.11 and the figure of merit in load condition was found to be 0.71. As the developed cooker had enhanced figures of merit, it could be concluded that solar cooker with double glazed cover, nano-structured tray and PUF insulation would be utilized for domestic applications.

Keywords: Solar cooker-Nano-structured cooking tray- Estimation of figures of merit

1. Introduction
Solar box type cooker is a compact cooking device and its thermal characteristics are to be improved for relatively fastest cooking in domestic sectors (Ref). In this connection, the present research work was carried out not only to incorporate the nano-structured cooking tray along with standard component in cooker but also to experimentally evaluate the figures of merit of the solar cooker. The research outcomes related to preparation, deposition and characterization of solar trays have been documented in this research paper. The research outcomes pertaining to the thermal characteristics of the developed solar cookers have also been documented in this research paper. The documented research outcomes would be beneficial to the researchers, manufacturers and end users of solar thermal gadgets worldwide.

2. Material and Methods
In the present research, the double glazed toughened glass cover and PUF insulation were commercially procured. They were tested in outdoor conditions so as to find out their transmittance and thermal resistance respectively as per BIS specifications. In addition, Nano-graphite and metal oxide were commercially procured. They were mixed at different proportions in solar emulsion. The prepared emulsion was coated on metal tray by spray coating method. The developed sample was characterized through XRD and the diffractogram was obtained. The crystallite size was calculated by using the Scherer formula

$$D = x\lambda\beta\cos\theta$$

Where D is particle size, x is the correction factor, λ is wavelength of x-ray used and β is the FWHM of the observed peaks.
The double glazed glass cover, nano-structured cooking tray and PUF insulation were integrated with suitable auxiliaries and the solar cooker was developed. It was tested as per BIS specifications and figures of merit were estimated. In the case of first figure of merit (F_1), the box type solar cooker was kept in outdoors and the experiments were carried out on clear sunny days.

The quasi steady state was maintained and the cooker tray temperature (T_p), the atmospheric temperature (T_a) and the incident solar radiation (G_T) were recorded. Subsequently the figure of merit (F_1) was calculated by using the equation $F_1 = T_p - T_a / G_T$ where T_p=Tray temperature in ^{0}**c**, $T_{a=}$ ambient temperature in ^{0}**c** and G_T= Incident solar radiation in **w**/m^2. The calculated figure of merit was used further computations.

As far as the second figure of merit (F_2) was concerned, the box type solar cooker was kept in the field conditions and the tests were conducted on clear sunny days. The cooking pots were filled with 8 liters of water per square meter of aperture area of solar cooker and the filled in cooking pots were kept in the cooker. The recording of data started at working fluid temperature of 60ºC and it was finished at the final temperature of 90ºC.

The second figure of merit (F_2) was calculated by using the formula,

$$F_2 = \frac{T_1 (mc)_w}{A(t_2 - t_1)} In \frac{1 - \left(\frac{T_{w1} - T_2}{F_1 G}\right)}{1 - \left(\frac{T_{w2} - T_2}{F_1 G}\right)}$$

Where F_1= First figure of merit from stagnation tests, (MC) = Product of the mass of water and specific heat in J/c, A= aperture area of the cooker of cover plate in m^2, (t_2-t_1) = time taken for heating from T_{w1} and T_{w2} in seconds, T_1= Average air temperature over time period (t_2-t_1) in C and G = Average radiation over time period (t_2-t_1) in W/m^2. The procured double glazed cover was tested and its transmittance was found to be 72%. The procured PUF was also tested and its resistance was found to be 0.92 W/m^2 ^{0}c.

3. Result and discussion

The present research work was devoted to apply the nano-structured component along with conditional temperature in solar thermal gadget. While the technical specifications of solar cooker have been presented in Table 1, the estimated figures of merit of solar cooker with nano-structured cooking tray have been presented in Table 2 and Table 3. The diffract gram of the developed nano-structured sample has been presented in figure I.

Table 1: Technical specifications.

Components	Materials
Glass cover	Toughened glass
Cooking tray	Aluminium
Cooker box	Fiber Reinforced Plastic (FRP)
Insulation	Poly Urethane Foam (PUF)
Gaskets and sealants	Silicon rubber
Reflecting mirror	Plain mirror
Cooking pots	Stainless steel

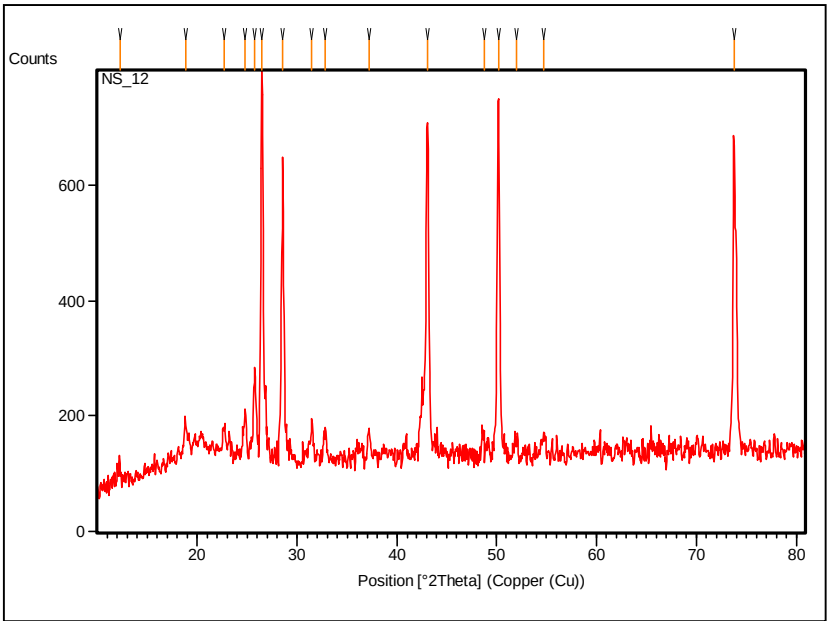

Fig 1: Diffractogram of graphite and Mno_2 coated samples.

Table 2: Technical specifications

Time	Solar radiation W/m^2	Box temperature (ºC)	Ambient temperature (ºC)	Wind speed (m/s)
10.00	785.3	89.6	33.4	0.5
10.15	811.2	101.7	33.5	0.2
10.30	836.1	110.8	33.8	0.4
10.45	877.8	117.5	34.1	0.4
11.00	903.2	121.2	34.3	0.5
11.15	904.5	125.1	34.7	0.2
11.30	903.7	128.9	34.0	0.2
11.45	914.8	131.4	35.3	0.0
12.00	926.3	133.9	35.4	0.0
Figure of merit F1				0.11

Table 3: Technical specifications.

Time	Solar radiation (W/m^2)	Water temp (^Oc)	Ambient temp (^Oc)	Wind speed (m/s)
10:00	770.8	27.8	33.9	0.6
10:15	808.7	34.2	34.1	0.5
10:30	838.9	57.2	34.4	0.2
10:45	865.4	68.0	34.6	0.4
11:00	884.6	78.5	34.9	0.4
11:15	903.7	87.0	35.2	0.5
11:30	917.2	94.5	35.5	0.2
11:45	912.3	96.3	35.7	0.1
Figure of Merit F_2				0.71

In the present research work, the single piece toughened glass cover was used and it was selected due to its elevated transmittance, reduced reflectance and improved durability (Ref). The aluminium was selected for the fabrication of cooking tray and it was selected due to its satisfactory thermal conductivity (Ref). The fiber reinforced plastics (FRP) and silicon rubber were preferred due to their durability at different metrological conditions (Ref). The plain glass rock wool and stainless steel were selected for other components so as to have desirable optical and thermal efficacies (Ref). On the whole the selection of materials of components of the cooker was satisfactory.

In the case of no load condition, for the estimation of first figure of merit, the expected value was 0.11 as per BIS specification. The calculated value of the developed cooker crossed the desirable limit and so the developed cooker could be used for heating purposes. As far as the load conditions were concerned, the estimated figure of merit was found to be higher than those of other conventional cookers (Ref). The relatively higher figure of merit could be correlated with the presence of more number of absorption particles in the nano-structured absorber. This could also be correlated with the selection of opt materials, selection of opt dimension of materials and the selection of optimized fabrication techniques (Ref).

5. Conclusion

It could be concluded that aluminium cooking trays with nano-structured coatings could be utilized in solar cookers so as to reap the benefits of enhanced absorption of solar radiation, enhanced heat transfer to the cooking material and enhanced thermal characteristics of solar cookers.

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