Performance and revolving analysis of Solar box cooker using PCM with prediction Hybrid deep Algorithms

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Tables 1 to 5 are available in the Supplementary Files section.
Performance and revolving analysis of Solar box cooker using PCM with prediction

Hybrid deep Algorithms

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Abstract:

Human health is an important main part of the food to consideration in the performance analysis of PCM (Magnesium chloride hexahydrate - MgSO₄·7H₂O) covered plastic balls (PBs) were augmented in Solar box-type cooker (SBC). The Artificial Neural Network (ANN) prediction analysis of thermal behavior in SBC is simulated and integrated using a tree and seed metaheuristic algorithm (TSA) an accuracy level was achieved in predicting SBC's efficiency. Hence, the enhancements entailed by introducing a variant may depend on improving ANN's concert. Engineering design found the optimal weights of the neurons using the TSA and includes a copper bar plate (CBP) with 50% higher thermal performance comparable to a silver bar plate (SBP). The functioning of the ANN/TSA technique using SBC has been simulated in the direction of predicting hourly variation by CBP & SBP with ANN/ANN/TSA is verified from food cooking efficiency related to predicting improvements of the SBC is applied as R², RMSE, MRE, and MAE values like 0.99, 0.0475, 0.228, and 0.05 for the CBP design, while for the SBP design, they were 0.98, 0.086, 0.007, and 0.053, respectively. The R morals working out, testing, and whole statistics set of CBP design were 0.999, 0.995, and 0.997, respectively. For the SBP design, they were 1, 0.964, and 0.996, respectively. It is concluded that the SBC design with PCM-covered PBs and CBP improves cooking performance and increases the system's efficiency in preparing rice and eggs within 2 to 3 hrs.

Keywords: Solar box cooker; Copper bar plate; PCM-Plastic balls; ANN/TSA
Introduction:

A comprehensive food cooking request has rising payable populace density, and industrial
development for the recent research field of cooking food supplies using a solar thermal
application in Solar box-type cooker lacks natural food resources. Solar cooker technology makes
the cleaning process effective with many possible applications [1]. Since many scientists focus on
solar box cookers were developed with effective cooking organizations [2]. The exploitation of
technology was developed by [3]. It includes numerical simulation [4], which is approached
important that precedes an investigational effort to decrease determination [5] and money [6]. Then
solar cooking, a brief survey of previous studies gathered a lot of consideration of the units [7].

Tawfik et al. [8] studied tracking-type bottom parabolic reflectors (TBPR) with the
improving thermal performance of solar box-type cookers. They concluded the Opto-thermal ratio
with a total solar cooker efficiency in TBPR is 0.165 and 12.5%, respectively, while without TBPR
are only 0.123 and 10.7%, respectively; furthermore, the effective concentration ratio for the
cooker is 1.34. Palanikumar et al. [9] have designed the stepped solar cooker implemented for
SiO$_2$/TiO$_2$ nanoparticles with ratios of about 10% and 15%. The results of 37.69% for a 10%
absorption established the unit main part using SiO$_2$/TiO$_2$ nanoparticles influences of 49.21% is
focused on 15% absorption save energy of the system. Khallaf et al. [10] verified analytically and
experimentally the effect of heat energy by utilizing dome-shaped polymeric glaze for the solar
cooker by associating experimental, mathematical prototypical, and carrying out experiments for
the solar cooker using water. The efficiency increased from 6 to 35% while using glycerol, and
efficiency changed from 9 to 92%. Saxena and Agarwal [11] studied the effect of using hollow
copper balls and halogen lamps' SBC performance. It is confirmed that the result of the thermal
productivity is about 45.11%, with a gastronomic at 60.20W power production, which reduced the
thermal loss quantity has 6.01 W/m$^2$. Sunil et al. [12] investigated experimental analysis of optical
efficiencies performed by solar box cooker with a thermal concert and obtained characteristic
heating curves.

Sethi et al. [13] compared cooking act parameters as a motivation of SBC through a
horizontal mirror cooker. They also considered a parallelepiped solar cooker with a flat cooker
using a cylindrical pot in the same climatic conditions as Ludhiana, India (30° N 77° E). I-merit
number $F_1$ for the inclined solar cooker was 0.16, while it was 0.14 for the horizontal solar cooker.
The second merit number, $F_2$, for the inclined solar cooker and the horizontal solar cooker was
A parallelepiped-shaped solar cooker is used as time $\tau$ follows as hot water about 37% lower than for the traditional cylindrical vessel of a horizontal cooker. The standard cooking power $P_n$ was 40% higher when using the parallelepiped-shaped cooker than the conservative cylindrical pot as a flat oven.

Pia [14] investigated energy patterns and solar cooking profiles in Maputo, Sofala province at Mozambique, sub-Saharan Africa generally, and during sunset hours. They concluded that solar cookers were improved by combining them with heat-storing materials or providing them with a hybrid system. Mahavar et al. [15] made a solar cooker with several strong points, such as small size, hybrid insulation, and lightweight using polymeric glass. The thermal profiles (Solar cookers) of the different mechanisms are measured. The results indicated stagnation plate temperature is about 144°C and produced power of 103.5W with reached 1.474 W/°C for heat loss, which complied with the international standard. Saxena and Karakilcik [16] studied low-cost, sensible thermal energy save to mediums thermal act SBC in summer seasons; experimental results confirmed that the thermal efficiency of SBC is equal to 37.1%. Mahavar et al. [17] developed the parameters for the solar cum electric cooker. They found that the cooking time is about 80 minutes on the standby power of the cooker, about 170W. Soria-Verdugo [18] studied experimentally and numerically the performance of SBC.

The heat transfer model of SBC with convective coefficients, an interior air absorber, and interior wall surfaces equal 12 W/m$^2$K and 3 W/m$^2$K, respectively. It is equal to 4.5 W/m$^2$K for external convection. Singh et al. [19] empirically studied two liquids (water and oil) for heat transfer and the impact of the gate valve on the phase change material discharging process (commercial acetanilide) by a solar cooker. It is confirmed using thermal oil is better than using water as a liquid to transfer heat through the pipes, as the temperature difference between them was 3.1°C. The energy stored by the PCM increases by comparing a heat transfer fluid of about 18.88% with thermal oil. Nallusamy et al. [20] empirically investigated energy storage materials like constant/variable temperature with a solar cooker performance using PCM (paraffin) filling spherical capsules in an insulated cylindrical thermal energy storage. Mass flow rate affects the charge rate; fluid inlet temperature remains negligible at a constant temperature. Indeed, heat transfer amount raises liquid inlet temperature. The performance of the PCM (paraffin wax) compact solar collector is studied by Mettawee and Assassa [21], and research results verify that the usual amount of thermal transmission constant rises with a normal convective thickness of
molten layer during the charging process. However, during the airing development, the heat improvement and the flow rate of the mass process increased. Schwarzer and Silva [22] experimentally investigated the role of heat storage resources in improving the act of SBC. They concluded that combining SBC and heat-storing items increases food preparation hours and the possibility of night cooking. El-Sebaii et al. [23] carried out experiments considering a thermal storage material (MgCl₂ - 6H₂O) for its distinct thermophysical properties (the latent heat of melting point). The study was twofold: (i) to use the cooker during the night hours or the hours of the absence of the sun; (ii) to improve the cooking heat process. According to the principle auxiliary water, the thermophysical properties of MgCl₂ - 6H₂O were measured by making a thousand cycles in an airtight container. The results of [23] confirmed that MgCl₂ - 6H₂O was a good PCM using solar cookery. Buddhi et al. [24] considered a solar cooker by PCM (acetanilide). Thermal storage material has distinctive thermophysical properties (melt position 118.90° C, hidden temperature melting 222.00 kJ/kg). They also augmented the system with three reflectors' rise intensity the solar beam dropping onto PCM volume adopted material improved night hours or hours without sun energy for the effect solar cooker. The results confirm that PCM (commercial acetanilide) was gifted with solar technology cooking, especially in the evening. Nahar [25] tested the acting energy storage engine oil. They conducted other cookery prosecutions. The solar storage cooker was 23°C higher at 1700 to 2400 hours. The hot storage of the solar cooker efficiency is about 27.5%. Several authors have experimentally studied solar box cookers (e.g., El-Sebaii and Ibrahim, [26]; Harmin et al., [27]; Purohit [28]; Mahavar et al., [29]; Sethi et al., [30]). Other authors have been concerned with developing heat transfer models to increase and improve the temperatures of solar cookers (e.g., Binark and Türkmen [31]; Reedy and Rao [32]). We now survey previous studies focusing on numerical simulation.

The analysis of nonlinear autoregressive exogenous (NARX), Feed-forward ANN, and Elman NN have been measured in three types of ANN models with a prediction of a triple SS performance shown below climate conditions in Jordan by Hamdan et al. [33]. It concluded the feedforward ANN tool for achieving the desire performing. Mashaly and Alazba [34] established ANN perfect expects inclined SS's immediate productivity, aquatic yield, and operational recovery ratio. The results indicated ANN prototypical accuracy, effectively forecasting solar cooker SS model act by small blunders. The evaporative and condensing methods were not addressed for solar desalination owing condition on behalf of consistent, correct simulation yield in wick SS by using ANN
representations studied operative and climatological strictures by Hamdan et al. [33] and Santos et al. [35]. As the standards assigned ANN model parameters, numerous significant methods reported these parameters backpropagation by Chen [36], conjugate solution incline by Saini and Soni [37], and Quasi-Newton's method by Saini and Soni [38]. Therefore, Yu and Xu proposed metaheuristic optimization algorithms in heritable algorithms [39]. Armaghani et al. [40] have developed particle swarm optimization. Kiran [41] presented in tree seed algorithm (TSA) metaheuristic technique simulating an activity's leaves, which constrained optimization problems are illustrated in [42].

Contribution studies are progressing prediction methods for cookery performance systems, including copper bar plate or silver bar plate (CBP, SBP) and plastic balls (PBs) enclosing MgSO$_4$.7H$_2$O as PCM material. The new design has been associated with a conventional solar box cooker (CBC) operating under Andhra Pradesh, KLEF weather conditions. The new proposal approaches the ANN/TSA have estimated influences nerve cells an ANN prototypical in the preparation development. ANN qualification has considered expending an impartial purpose; an optimum prototypical has been performed results of TSA operators to be fulfilled, which is estimated to expending the challenging conventional. Solar cooker concert is analyzed by expanding change in the set of events. The novel ANN/TSA compared with ANN was established to calculate the hour based on solar cookers, and various input variable quantities ANN and ANN/TSA representations are considered. Also, planned ANN and ANN/TSA representations in predicting solar box cooker performance are estimated using different statistical conditions. The outline of the present research is as follows.

The newly developed box solar cooker is studied based on Koneru Lakshmaiah Education Foundation (KLEF) climatic conditions at Vijayawada, Andhra Pradesh, India.

- The plastic balls - PCM used in bar plate down increased internal heat energy for the system.
- The solar cooker established the ANN model using the algorithm TSA metaheuristic technique clarified for the hybrid algorithm (ANN/TSA).
- The different statistical criteria are discussed to estimate cookery organization.
2. Materials and Methodology

02.1 Design of Solar box Cooker:

Fig. 01 & Fig. 02 were designed and fabricated as illustrated. Solar box cookers (SBC) have been tested using a bar plate (BP) with copper sheets (CBP) and silver material (SBP) performance. The CBP has enhanced thermophysical properties compared with the SBP. The thermal conductivity of CBP has about 700% to develop SBP. The bar plate area was 0.95 m$^2$ for use with a one-meter dimension $\times$ 0.95 m breadth and selected the total large (each wall) was sideways with a length of 0.35 m. The glass cover thickness of 4mm had a high emissivity of about 0.94. The bottom inside is used in SBP (copper sheet), and Plastic balls (PBs) of height 0.10 m were arranged by spacing them by 0.10 m for a total number of 100 pieces. The balls' fix using a CBP for the thickness is 4mm. The inside walls and bar plate balls were painted dark to maximize solar energy's absorptivity. The outside wall is inaccessible to internal air at a 0.6mm profuse layer of insulating material (glass wool) with low thermal conductivity of about 0.033 W/mK to reduce heat losses by the SBC. Cooking pots with 0.20m height with a breadth of 0.18m were used to control the food cooking process of the active materials of the structure. The SBC is measured with appropriate tools to highest assessment data each half hour. The measurement instruments used in this research are specified in Table 1. Assessment statistics included heat air, i.e., SBC inside and outside the box), use of cooking materials, water, PCM, glass cover, solar radiation, wind velocity, and fresh cooking performance of the system.

A case study based on Guntur (D.T.) in KLEF climate conditions demonstrates the ability of developed representations to predict solar cooker performance. Meteorological and operational outcomes were recorded during period intervals for about one year; Vijayawada, Andrea Pradesh (longitudes 80.6480° E and Latitude 16.5062° N) utilizations an intercity solar cooker. Input statistics usually contain ambient temperature, sunbeams, bar plate temperature, saline water, plastic ball, PCM temperature, glass, and delivery values to control the efficiency of the SBC.

2.1 PCM-based performance of SBC

2.1.1 PCM analysis

In the solar cooker design, the used plastic balls (PBs) encapsulated the MgSO$_4$. $\cdot$ 7H$_2$O (PCM). The P.B.s were filled by liquid PCM as shown in Fig. 3a and Fig. 3b. The P.B.s were arranged into the SBC inner side, and the highest cross balls faced the bottom sideways absorber
bar plate. The height of a plastic ball is 0.10 m, and the breadth is 0.10 m. Balls are equally spaced for a total number of 100 pieces, the total quantity of MgSO\(_4\). 7H\(_2\)O put in all PBs was assessed as 12.4 kg. They (PCM) consider the energy condition to further ratio analysis of 20\%, 40\%, and 60\%. The SBCs energy storage material performs interior hotness transmission near a conceivable absorber (see Fig. 3c). The solar cooker system dynamics entails that MgSO\(_4\). 7H\(_2\)O filling P.B.s reaches its melting point. The outer surface surrounding the PBs was black painted to increase interest in sun rays. The ball top cover of the PCM is covered with a plastic cap. MgSO\(_4\). 7H\(_2\)O properties are filling all PBs are listed in Table 2.

The PCM is characterized, and improved chemical stability with high specific heat for a changeable check-liquify set the elevate compatibilities. It was tested for different loading levels of the cooking system. The absorber bar plate has been deposited with PCM (\(Q_{pcm}\)) and can be obtained as:

\[Q_B = \int m_{bp} C_{bp} dT = mC_{av}(T_i - T_f)\]  \hspace{1cm} (1)

The portion by a solar beam absorbed into the cooking system through the bar plate increases the PCM temperature. The equation for the whole quantity absorber plate has

\[Q_{f-bp} = a_f m \Delta h_c\]  \hspace{1cm} (2)

The PCM's enhanced system as a thickness continued heat about 52°C. PCM reached the saving energy range of about 144°C previously indicated by Oturanç et al. [43] and Buddhi et al. [44]. Melting point of the sunlight connected to the PCM (natural convection heat transfer) is 30-61°C. Energy storage is associated with the materials' phase changes since they compact toward fluid. The latent heat was melting or freezing at the smallest 1-2 orders of size develop than the vigor storage. It generates detailed hotness-ended characteristics of 11°C variations in the heating process. The stabilizing temperature process occurs during the short term, thus causing a large amount of thermal energy storage of the SBC. From an internal heat transfer of an SBC is solid and liquid phases by latent heat blend. The PCM properties were obtained according to the procedure reported by Jin and Zhang [45].

2.1.2 Energy analysis

The PCM used a solar cooker design has optimized the level of heat energy (see Fig. 3c). Internal energy of plastic balls was determined as:
The quantity of energy \( (Q_{q e + B}) \) absorbed by the plastic balls included in the solar cooker are:

\[
Q_{q e + B} = \frac{E_o \cdot \Delta T_{A - 95}}{\Delta t} \tag{4}
\]

The amount of heat energy process (evaporation power)\(- (\dot{Q}_{ep}) \) is

\[
\dot{Q}_{ep} = Q_{q e + B} \cdot h_L \tag{5}
\]

The SBC productivity can be estimated by way of the following:

\[
\eta_{q e + B} (\%) = \frac{\dot{Q}_{ep}}{H_s \cdot \lambda_{c-B}} \tag{6}
\]

### 2.3. SBC analysis of artificial neural network (ANN) process:

Artificial neural networks (ANNs) performance analysis of the SBC was improved and simulated in a machine-learning method. ANNs biological nervous arrangement obtained an optimum learning neuron influences. Maximum general supervision on NNs consists of layers containing a set of nodes or neurons using feedforward neural networks (FFNNs). Also, one by one layer was coupled as following another layer by a usual of influences. 1st coating of FFNN takes input statistics through passes next layers named the hidden layer (s). One by one, following the hidden layer, the previous layer's output is taken contribution pending the previous coating to consider a production coating (Basheer and Hajmeer [46]).

The multilayer perceptron (MLP) neural networks denoted in Fig. 4 showing in FFNNs. The neurons in each layer were solid 1D technique, an output \( l^{th} \) \((l = 0,1,2,3, \ldots, L) \) coating is expended \( l^{th} \) involvement \( (O^l_i) \) which is expressed equally \( 1 \leq l \leq L \) resulting calculation:

\[
O^l_i = \varphi_1 \left( u^l_i \right) = \varphi_1 \left( \sum_{j=1}^{n_l} O^{l-1}_j w^l_{j,i} + w^l_{0,i} \right) \tag{7}
\]

where \( L \) \& \( n \ell \), respectively, is the amount of quantity layering and quantity neurons of \( \ell^{th} \) coating. \( \varphi_1(.) \) represents the stimulation role of the layer; \( w^l_{j,i} \) is the weight concerning \( i^{th} \) neuron layer \( \ell \) with \( j^{th} \) neuron in the previous coating; \( w^l_{0,i} \) Biases \( i^{th} \) neuron of the layer \( l \).
2.3.1 SBC analysis of tree-seed algorithm (TSA):

Metaheuristic procedure mimics the tree behavior and has tree seed algorithm (TSA) as source [41,42,47] spreads the trees onto the ground surface seed grows, producing novel trees. A field characterizes ground superficial optimized from locations trees seed consent values given problematic. The search tendency \((ST)\) has controlled the variable for the search process result junction. AN optimum for the set of \(N\) solutions is developed in the TSA that locations of \(n\) trees \((X_{ij})\) in the interval \([L_1 \ U_1]\) (anywhere \(L_1 \ U_1\) has decreased & greater limits design variable) because:

\[
X_{ij} = L_1 + r_1 \times (U_1 - L_1) \quad (i = 0, 1, 2, ..., n ; j = 0, 1, 2, ..., Dim) \quad (8)
\]

where a random number has \(r_1 \in [0,1]\), but \(Dim\) was tested dimension problem. The produce of TSA new values are seed \((S_i)\) applying dual processes.

I\(^{\text{st}}\) process differs good quality mixture \((X^*)\) has said that

\[
S_{ij} = X_{ij} + \alpha_{ij} \times (X^*_{ij} - X_{ij}) \quad (9)
\]

where \(\alpha_{ij}\) is a random number in the \((0,1)\) interval

II \(^{\text{st}}\) process changes to a randomly selected mixture \(X_r\) as:

\[
S_{ij} = X_{ij} + \alpha_{ij} \times (X_{ij} - X_{ij}) \quad (10)
\]

\(ST \in [0,1]\) parameters have determined a suitable process of seed; additionally, total solutions of 25\% and 10\% were generated as the highest and lowest number for the seeds or trees, individually.

The pseudocode of the TSA algorithm proposed by Kiran [41] is given below.

<table>
<thead>
<tr>
<th><strong>TSA algorithm Kiran [41]</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input:</strong> Candidate numbers solution an optimum problem (N); determined quantity search repetitions (t_{max}); the number of optimization variables (i.e., problem dimension) (dim); the parameter (ST)</td>
</tr>
<tr>
<td><strong>Output:</strong> The best solution (X^*).</td>
</tr>
<tr>
<td>1. Build a set of (N) trees (X) (candidate solutions of the optimization problem) with dimension (dim).</td>
</tr>
<tr>
<td>2. While ((t &lt; t_{max}))</td>
</tr>
<tr>
<td>Evaluate the objective function for each tree location (X_i). ((i = 0, 1, 2..., N)).</td>
</tr>
</tbody>
</table>
All $X_i$

Determine the number of seeds used to generate the current tree.

For all seeds

For each $j$ ($j=1: \text{dim}$)

IF $r_j < \text{S.T.}$

Update component $X_{ij}$ using Eq. (8)

Else

Update component $X_{ij}$ using Eq. (9)

END IF

END For

Compare the tree with the best seed.

If the objective value of seeds has improved the objective value for a tree, then replace the seed with a tree.

END For

Find the greatest result populace $X$

Update best result $X_{\text{best}}$

$t = t+1$

END while

2.5 Application of the ANN/TSA algorithm to SBC evaluation

Fig. 5 shows the flowchart of the ANN/TSA algorithm developed for predicting the solar box cooker. The process outlined in the flowchart is general. The novel ANN method attempts to find optimum loads utilizing TSA. The dual periods involve ANN/TSA; the prior period weights are reduced of RMSE (root mean square error) amid slow SBC outputs corresponding to predicted standards.

If $^\text{st}$ is evaluated to condition qualify of ANN. Evaluate the correctness of ANN/TSA processes are

(i) Absolute Error (IAE),
(ii) Integral Square Error (ISE)

(iii) Maximal Deviation from the setpoint of \( (D^{\text{max}}) \),

The formal analysis of the SBC identified as follows:

\[
\begin{align*}
\text{IAE} &= \int_{t_0}^{t_1} |R(t) - Y(t)| \cdot dt \\
\text{ISE} &= \int_{t_0}^{t_1} (R(t) - Y(t))^2 \cdot dt \\
(D^{\text{max}}) &= \max |R(t) - Y(t)| \quad (11)
\end{align*}
\]

\( R(t) \) & \( Y(t) \) refer to SBC's involvement & production, while \( \text{IAE} \) denotes the passing reply. For the damping of \( \text{ISE} \) suitable for \( (D^{\text{max}}) \), we designate controller solar constancy oven start, Hong et al. [48], Guang et al. [49].

\[
\lim_{k \to \infty} \sigma_k \left[ \frac{e_{k+1}^2}{(1+\sigma_k\Phi_kP_{k-1}\Phi_k^T)^2} - \varepsilon^2 \right] \times Q_{\text{total energy + PCM}} = 0 \quad (12)
\]

\[
\lim_{k \to \infty} \text{sub} \left[ \frac{e_{k+1}^2}{(1+\sigma_k\Phi_kP_{k-1}\Phi_k^T)^2} \right] \leq \varepsilon^2 \times Q_{\text{total energy + PCM}} \quad (13)
\]

Remarkably, ANN/TSA obtained in the lowest Root Mean Square (RMSE) has been associated with different systems. Table 1 is calculated by the solar cooker analysis of temperature ANN/TSA operates quick techniques, particularly connected SVR (Support Vector Regression). Root mean square error (RMSE) has minimized just present study documents the first successful application of machine learning methods (here based on ANN/TSA) ever presented in the technical literature to predicting the cooker.

### 2.5.1 Primary Stage for SBC performance analysis

An input dataset has received the stage starts and is separated randomly, working out established with a testing set. After that, the \( N_{sl} \) results of a set \( X \) have formed with NN representative weights

For every one result is getting of \( X \), the qualification of work has been calculated as follows

\[
\text{RMSE} = \sqrt{\frac{1}{N_{sl}} \sum_{j=1}^{N_s} (y_j - \bar{y}_j)^2} \quad (14)
\]
where \( y_j \) and \( \bar{y}_j \) has predicted output rate as \( j^{th} \) model. The next stage has determined an optimum result as \( \mathbf{X}^* \) corresponding to a minimum value of RMSE. Then, more results are informed using TSA algorithm, which has repeated until stopping conditions are satisfied. NN trained a set of testing in the best solution of \( \mathbf{X}_{best} \) and computed the output quality of the result. An original target projected technique has been estimated compared to our model ANN prototypical.

In this study, internal parameters of TSA inhabitants' magnitude and quantity search iterations were determined via trials with errors approach for the system. Population sizes are equal to 25 to reach fitting correctness as a computation period, performance of the proposed ANN/TSA model degraded for population sizes including less than 25 individuals. In addition, the greatest quantity of search repetitions has been set at 100.00.

3. Results and discussion

A new model of SBC has been installed in a solar energy laboratory of KLEF, analyzing weather conditions utilizing the data measuring each day from 10:00 to 15:00 in hours of daylight. Fig. 6(a, b, c, d) shows an investigational response variable sample; it changes on solar radiation, mass cooking temperature, ambient heat, and moist air quickness indicated in the SBC prototype study. Fig. 6(a) demonstrates the model for the solar radiation numbers measured each period, with a mean radiation value of 894.37 W/m\(^2\). Fig. 6(b) expresses ambient temperature, while Fig. 6(c) shows the variation of air velocity: the corresponding mean value was 3.49 m/sec as per the system. Fig. 6(d) shows the daily variation in cooking liquid heat; ambient air and cooking liquid heat standards were 34.55\(^\circ\) C and 70.54\(^\circ\) C, respectively. Furthermore, Fig. 7 (a, b, c, d, e) demonstrates experiments have determined variable quantity using inputs to the training process of the proposed ANN/TSA prototype: Bar Plate (BP) temperature, Vessel temperature, average internal air temperature, plastic balls (including PCM) temperature, and glass temperature for the SBC have verified. Fig. 7(a) shows that maximum and minimum BP temperatures for the SBC, including the copper bar plate, were about 164 and 64\(^\circ\) C, respectively. A typical CBP heat about SBC have 123.77\(^\circ\) C (see Fig. 7(b)), and the vessel temperature was 102.24\(^\circ\) C, shown in Fig. 7(c). The standard internal air heat of SBC was 107.77\(^\circ\) C (see Fig. 7(d)), and the glass heat of SBC have 45.33\(^\circ\) C (see Fig. 7(e)).
In contrast, to compare the average BP temperature for the SBC design, including the silver bar plate, was only 96.54°C (see Fig. 8). Fig. 8 shows a scatter plot of the experimental data: the intermediate cooker bar plate, vessel, interior midair, PCM, glass temperatures of the system were about 130.88, 107.77, 122.24, 134.88, and 45.33°C, respectively, which increased by about 18.4%, 19.18%, 13.67, 15.24% and 6.94% concerning their counterparts referred to the SBC system with silver bar plate. CBP and plastic ball (PCM) materials improved overall cooking manufacture by around 49.00% in Table 1. As mentioned in the previous sections, the investigational information was separated hooked at two subgroups: an exercise information subgroup (90.00%) and a test drive statistics subgroup (10.00%) (see Fig. 8). Fig. 9 shows the cooking performance predictions made hourly by the ANN/TSA model. The neural networks model has developed decay schemes output to equally determine necessary (actual) results for the preparation and challenging stages. These schemes are shown a decent arrangement among NNs predicting outcomes. The high regression values of target outputs of regression values (R) are analyzed, and preparation processes by SBC with SBP and CBP were 0.999, then 0.995, individually. In contrast, the total rate for R values was 0.997. Furthermore, Figure 9 shows R standards in exercise, challenging phases of the SBC design are 1, then 0.964, individually, whereas the total amount for R has 0.996.

The SBC system for ANN/TSA prototypical has been implemented and associated with ANN prototypical same datasets operated in predicting cooking performance. ANN and ANN/TSA experimental data fitted by higher performance illustrates in Fig. 10. Moreover, Table 3 optimizes ten numerical constants for ANN and ANN/TSA shapes calculated information to achieve BP temperature by CBP materials in the system. Fig. 10 and Table 4 show that ANN/TSA is further successful than ANN in predicting the cooking performance of the SBP and CBP configurations of the SBC system. COV, RMSE, E.C., MRE, O.I., R², MAE, and CRM for seven statistical error values were evaluated in the two models. 0.98 (ANN) & 0.99 (ANN/TSA with R² values have referred to the classical solar cooker design (CSC) in Table 4. Corresponding values for the developed SBC system with PBs enclosing the PCM material were 0.975 (ANN) and 0.985 (ANN/TSA). Since the highest values of R² indicate a better association amid experimental data and NN predictions, we can accurately portray the behavior of all SBC designs compared in this study.

CBP solar box cooker design (PCM-SC) in the ANN/TSA prototypical (0.088), the RMSE value was lower than that obtained in ANN (0.110) prototypical. Furthermore, the RMSE value
applied in SBP designs ANN/TSA prototypical (0.086) has decreased than its counterpart for the
ANN model (0.108). MAE values also were smaller ANN/TSA model: only 0.038 vs. 0.065 was
computed for the ANN model (CBP design); only 0.053 vs. 0.103 for ANN (SBP design).
Additionally, applying the MAE value used in ANN/TSA shape (05%) has about 20% reduced
than its counterpart value evaluated by ANN for the CBP design. 20% is used in MAE rate,
ANN/TSA prototypical (8%), has reduced than one computed in an ANN prototypical (SBP).

Low values for RMSE and MAE achieved by ANN/TSA prove capability planned algorithm
expects SBC performance better than the ANN model. Furthermore, the ANN/TSA model
obtained O.I. values much closer to 1.0 than for ANN, thus almost reaching a perfect size among
investigational data calculated findings for OI=1 (see Mashaly and Alazba [50, 51, 52, 53]). Table
4 shows that the O.I. value obtained by ANN/TSA was about 0.96 for the classical design, about
7.86 higher than for ANN (0.89). Also, for the SBC design with PBs containing the PCM material
[52], ANN/TSA obtained OI=0.93, hence 4.49% higher than the ANN (OI=0.89).

CRM's last statistical parameter in this analysis must be close to zero to achieve better
model accuracy. It can be seen from Table 4 that in the case of the classical SBC design, the CRM
value is reduced for ANN/TSA (00.017) than for ANN (00.04). SBC design (i.e., with PCM
material and bar copper plate), the value of CRM further decreased to 0.008 for ANN/TSA,
considerably lower than the 0.054 value determined for ANN.

In summary, RMSE, CRM, and MAE should be near zero, while R² and O.I. should be
near one for the ideal data modeling. Current findings revealed an excellent ability ANN/TSA
prototypical expected cookery performance in various designs compared with the ANN model.

**F3.1 ANN/TSA algorithm using SBC performance:**

The SBC within the PBs-PCM and copper bar plate was established for cooking actual food.
Table 5 shows the ANN/TSA predictions of the SBC cooking performance data for water, rice,
eggs, and grilled vegetables. The ANN/TSA model was built based on the experimental data
gathered from 10.00 to 14.00 of each day (see Fig. 6 and Fig. 7). The model was verified via linear
regression (Fig. 9), and the relationship between cooking performance and temperature
modifications were analyzed. The experimental results of an SBC are predicted data by ANN and
ANN/TSA plotted in Figure 10. Temperature variations and their impact on cooking performance
are less pronounced in the case of the ANN/TSA model.
Conclusions

A novel SBC design augmented with PCM-covered PBs was examined and verified in terms of cooking performance using an ANN prototype established by an ANN/TSA. Main verdicts have been abridged by way of shadows:

a. SBC, including copper bar plate, improved by about 50% concerning the SBC design, including silver bar plate.

b. NN models input data has abandoned values (i.e., not recorded under controlled conditions) related to the atmospheric conditions for all parameters, and measured data are associated with the state of operation and temperatures for both bar plates.

c. The proposed ANN/TSA model is applied as $R^2$, RMSE, MRE, and MAE values like 0.99, 0.0475, 0.228, and 0.05 for the CBP design, while for the SBP design, they were 0.98, 0.086, 0.007, and 0.053, respectively.

d. The R morals working out, testing, and whole statistics set of CBP design were 0.999, 0.995, and 0.997, respectively. For the SBP design, they were 1, 0.964, and 0.996, respectively.

e. It is concluded that the SBC design with PCM-covered PBs and CBP improves cooking performance and increases the system's efficiency in preparing rice and eggs within 2 to 3 hrs.

Exhibit research showed using the ANN/TSA algorithm has a clear method to predict SBP and CBP designs more than the ANN deprived of essential aimed at more research, therefore convertible economic incidentals, determination with a period.

Nomenclature:

- $A_{c-B}$: Cooker Inside heat air conduct in bar plate area ($m^2$)
- $a_f$: Area of Solar cooker with heat fusion transfer ($m^2$)
- $C_{bp}$: The bar plate for the Specific heat ($kJ$ per $kg$ $K$)
- $C_{av}$: Average temperature for the design ($^oC$)
- $C_{pw}$: The design used water for the specific heat range ($kJ/kg$ $K$)
- $dT$: Total temperature of the system ($^oC$)
- $E_o$: Energy output in SBC ($^oC$)
- $E_{r-B}$: The measured internal energy of plastic balls ($^oC$)
\begin{align*}
H_s & \quad \text{Solar radiation (W/m}^2\text{)} \\
h_l & \quad \text{Design used the latent heat values (J/kg)} \\
m & \quad \text{Production mass rate (kg)} \\
m_{bp} & \quad \text{Bar plate range mass (kg)} \\
m_{bp} & \quad \text{Energy saving for the bar plate mass rate (kg)} \\
m_w & \quad \text{Range of mass water (kg)} \\
Q_{f-bp} & \quad \text{Amount of thermal energy arriving at the bar plate (kJ)} \\
Q_B & \quad \text{PCM used an SBC bar plate to save total energy quantity (kJ)} \\
Q_{q,e + B} & \quad \text{Quantity of energy absorbed by the plastic balls included in SBC (kJ)} \\
\dot{Q}_{ep} & \quad \text{Evaporative power cooking materials temperature (}^\circ\text{C)} \\
T & \quad \text{Temperature (}^\circ\text{C)} \\
T_i & \quad \text{Cooking initial temperature (}^\circ\text{C)} \\
T_f & \quad \text{SBC produced the final cookery temperature (}^\circ\text{C)} \\
T_{c-i} & \quad \text{SBC produced initial cookery water temperature (}^\circ\text{C)} \\
T_{c-o} & \quad \text{Cooking final water temperature (}^\circ\text{C)} \\
a_f & \quad \text{Bar plate absorbing a fraction} \\
t & \quad \text{Times (Sec.)} \\
T_g & \quad \text{SBC produced by glass cover temperature (}^\circ\text{C)} \\
T_a & \quad \text{SBC surrounding for ambient temperature (}^\circ\text{C)} \\
T_{sky} & \quad \text{Sky temperature (}^\circ\text{C)} \\
T_{bp} & \quad \text{Bar plate temperature (}^\circ\text{C)} \\
T_{swp} & \quad \text{SBC uses sidewall plate temperature (}^\circ\text{C)} \\
T_{fw} & \quad \text{SBC used fluid water temperature (}^\circ\text{C)} \\
T_m & \quad \text{Melting temperature (}^\circ\text{C)} \\
T_{ina} & \quad \text{Internal air temperature (}^\circ\text{C)} \\
T_G & \quad \text{Glass covers temperatures (}^\circ\text{C)} \\
w_s & \quad \text{Wind speed (m/s)} \\
\Delta h_c & \quad \text{SBC used heat reaction (kJ/kg)} \\
\eta_{q,e + B} & \quad \text{Overall thermal efficiency of SBC (\%)} \\
\end{align*}
Symbols

\( \alpha_{bp} \) Bar plate absorptivity energy level for SBC

\( \alpha_g \) SBC used absorptivity energy levels for glass cover

\( \alpha_v \) SBC used absorptivity vessel energy levels

\( \tau_{bp} \) SBC used in bar plate energy level of transmissivity

\( \tau_v \) Effective transmittance for vessel

Acronyms:

ANN Artificial neural network

CBP Copper bar plate

COV Variance coefficient values

CRM Residual mass coefficient values

SBP Silver bar plate

SBC Solar box cooker

MRE Mean relative blunder

MAE Mean absolute error

RMSE SBC is analyzed of root mean square error

R Regression

\( R^2 \) SBC determinates coefficient

OI Overall index model performance

PCM Phase Change Materials (Magnesium chloride hexahydrate - MgSO\(_4\). 7H\(_2\)O)

TSA Tree–seed metaheuristic optimization algorithm

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Conflict of Interest

There is no conflict of interest among the authors.
Author Contributions

Mr. Gothandaperumal Palanikumar
Synthesis of Experimental work design and characterization of Solar box cooker

Dr. Rajamanickam Muthucumaraswamy
Data validation, Editing of the manuscript.

Dr. Venkatesan Chithambaram
Analysis of results

Dr. Sengottaiyan Shanmugan
Analysis of results, writing the manuscript, reviewing, and editing the paper

Availability of Data and Material
The designed solar cooker and data of results of characterization are available.

Compliance with ethical standard
The research work is ethically complied.

Consent to participate
All the authors give their consent to having participated in the current work.

Consent for publication
All the authors give their consent for publication of this work.

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Armaghani DJ, Hajihassani M, Mohamad ET, Marto A, Noorani S. Blasting-induced fly rock and ground vibration prediction through an expert artificial neural network based on particle swarm


Schwarzer K, and Silva MEV. Solar cooking system with or without heat storage for families and institutions. Solar Energy 2003; 75: 35–41. DOI: 10.1016/S0038-092X(03)00197-X.


Figure 1

Schematic diagram of PCM - SBC.

- Glass cover thickness = 4 mm
- Inner each side walls length = 0.35 m
- Black paint
- Vessel
- Rice food
- GI sheet
- Copper sheet = 0.95 m²
- Plastic balls = 0.10 x 0.10 m
- Glass wool thickness = 0.6 mm
- 1.10 x 1.10 m
- 0.43 m
Figure 2

Photo of the experimental setup on PCM - SBC.
Figure 3

a shows a single plastic ball used in PCM

b shows testing on PCM (MgSO₄·7H₂O) performance with SBC.

c PCM (MgSO₄·7H₂O) analysis of SBC experimental performance.
Figure 4

details of MLP NN to arrangement on PCM-SBC.
Figure 5

details PCM - SBC performance based on ANN-TSA.
Figure 7

analysis of PCM - SBC extracted from the training data set in ANN and ANN-TSA:
7 (a) bar plate, 7 (b) vessel, 7 (c) Internal air, 7 (d) PCM and 7 (e) glass temperatures.
compare an PCM - SBC performance on training data set of ANN and ANN-TSA.
Figure 9

CBP Cooking performance (output) on training and testing for PCM - SBC using ANN-TSA.
Figure 10

analysis of CBP cooking performance on SBC experimental and the predicted data in ANN and ANN-TSA model.

Supplementary Files

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- Tables.docx