Experimental study on a north wall insulated passive greenhouse dryer: Effect of groundnuts sample mass

Shimpy[1], Mahesh Kumar[1*], Manoj Kumar Gaur[2]

(1. Department of Mechanical Engineering, Guru Jambheshwar University of Sciences & Technology, Hisar, India, 125001;
2. Department of Mechanical Engineering, Madhav Institute of Technology and Science, Gwalior, India, 474005)

Abstract: Ensuring food sovereignty for diverse communities could lead to a reduction in malnutrition and better health throughout the world. Investigating a locally developed, easy to fabricate and renewably powered food processing technology for better performance is a step towards strengthening food sovereignty. With this consideration, a north wall insulated passive greenhouse dryer (NWI-PGD) was fabricated and tested for groundnuts drying. Effect of varying sample mass (580, 880 and 1180 g) on thermal performance of the NWI-PGD was investigated. The enviro-economic indicators were also evaluated for the dryer along with the drying kinetics of groundnuts samples. The thermal performance indicators were observed to improve as the sample mass increased. The embodied energy and capital cost of the NWI-PGD were assessed as 111.68 kW h and INR 857.11, respectively. The dryer's enviro-economic performance improved as the sample mass increased. The Midilli-Kucuk model demonstrated a strong fit to the drying behavior of groundnut samples. This work would contribute towards improving food sovereignty at both the local and global levels.

Keywords: Insulated north wall, Passive mode, Greenhouse dryer, Groundnuts drying, Performance assessment

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1 Introduction

Food sovereignty has been considered as a keystone for active and healthy life. It is the 'right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems'(Alliance for Food Sovereignty in Africa, 2011; Wittman, 2023). Drying of agricultural or food items for safer and longer shelf-life has been practiced since ages under the light of the sun (Tiwari et al., 2016). It is a cost effective and eco-friendly method but has some limitations such as lower product quality due to climate dependence, external disturbances. Many industrial or large scale electricity powered dryers have been developed to overcome these limitations. But these dryers too have some challenging characteristics such as higher initial and operation costs, skilled labour requirements and polluting operation. Solar dryers have emerged as the advancement to both the open sun drying (OSD) and electric dryers. They are cost effective, environment friendly, results in good quality products and ensures sustainable food processing at local or household level (Kumar et al., 2016).

Greenhouse dryers (GD) have been studied for the drying of various commodities including, fruits (Ayyappan, 2018; Arun et al., 2014), vegetables

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***Corresponding author: Mahesh Kumar, Professor.** Department of Mechanical Engineering, Guru Jambheshwar University of Science & Technology, Hisar, 125001, Haryana, India. Email: mkshandilya1@gmail.com, maheshkumar@gjust.org, Telephone: +919416935137.

(Chauhan et al., 2018a, 2018b), grains (Huddar and Kamoji, 2019; Shimpy et al., 2022a), spices (ELkhadraoui et al., 2015; Morad et al., 2017), herbs (Malik and Kumar, 2025; Tham et al., 2017), etc. These dryers are easy to fabricate, needs lower capital investment and can be used for drying of any commodity in bulk (Sahdev et al., 2016). Patel et al. (2024), developed an active GD having embodied energy (EE) of 3154.71 kW h and tested it for tomato drying. Thermal efficiency (η_{th}) and payback period (PBP) were reported as 26.66% and 1.62 years, respectively. Panwar et al. (2014), tested a tunnel type GD for cotton drying and reported a variation of 1.051%–1.793% and 2.26-3.03 years in the energy efficiency and PBP, respectively. Peter et al. (2022), tested a portable GD for shrimp feed drying and reported a PBP of 1.4 years. Sansaniwal et al. (2022), tested a passive GD for date fruit drying and reported an average drying efficiency of 8.5%. The capital cost of the GD was reported as INR 2562. Kushwah et al. (2021), tested a hybrid GD for garlic drying and reported a maximum efficiency of 55.58%. Kishk et al. (2018), recommended Modified Henderson and Pabis model for mint leaves drying behaviour in an active parabolic GD. Shyam et al. (2015), developed a photovoltaic assisted GD with an EE of 11867.1 kW h and reported an energy payback time (EPBT) of 3.74 years. Kaewkiew et al. (2012), tested an active parabolic GD for chilli drying and reported a PBP of 2 years. Kumar et al. (2021, 2023b), reported a variation of 6.60%-11.90% and 8.87%-12.59% in drying efficiency under passive and active drying of vermicelli in a GD, respectively. Kant et al. (2023), dried mint leaves in an active hybrid GD and reported an average drying rate of 0.65 kg hour^{-1}. Kumar et al. (2019), dried groundnuts in a simple passive GD and reported an average η_{th} of 8.83%. Sahdev et al. (2018), reported that the efficiency varied from 26.95%-38-56% for groundnuts drying in an active GD. Nimnuan and Nabnean (2020), tested an active parabolic GD for ginger drying and reported an average η_{th} of 38.9% with 67% shorter drying time than OSD. Mishra et al. (2021), developed a GD and reported that the EPBT and PBP of the GD were 1.1 and 1.5 years; and 2.7 and 3.2 years, respectively. Shimpy et al. (2022b), reported a η_{th} of 17.46% and 18.62% for groundnuts drying in a passive GD under simple and modified conditions, respectively.

Recently, Shimpy et al. (2024b), reported that the η_{th} of a reflective north wall enabled passive greenhouse dryer increased with increasing sample mass and found to vary from 10.21% to 15.16%. Elwakeel et al. (2025), tested an automated indirect solar dryer and reported a payback period of 2.091 years for date fruits drying. Rejabov et al. (2024), reported that the indirect solar dryer reduced the drying time of apricot as compared to OSD. Khan et al. (2025), developed an infrared assisted GD with an embodied energy of 4499.37 kWh and capital cost of INR 95,071. The thermal efficiency and energy payback time of the dryer were estimated to be 30.8% and 2.6 years, respectively for the drying of pear slices. Borkakoti et al. (2025), developed a single slope GD having embodied energy of 215.95 kW h for the drying of bay and neem leaves. The energy payback time of the dryer was reported to be 0.37 years.

The literature shows that the greenhouse dryers (GD) have been tested for the drying of various commodities and with various design modifications. It has been observed that there is no study available in the literature to investigate the performance of a north wall insulated passive greenhouse dryer (NWI-PGD) for groundnuts drying. Groundnut has a significant presence in the market at both local and global levels. Its economic significance and post-harvest losses are crucial for both the end consumers and farmers (Sahdev et al., 2015). Therefore, this research is designed to study the effect of varying mass (580, 880 and 1180 g) of groundnuts samples on the thermal and enviro-economic performance of NWI-PGD along with the assessment of drying kinetics of groundnuts. This work is intended to give a sustainable groundnuts drying solution to farmers at local level to ensure their food security and sovereignty.

2 Materials and methods

A NWI-PGD was developed and tested for groundnuts drying. The details of the NWI-PGD, sample preparation and experimental procedure are presented as below.

2.1 Detail of the greenhouse dryer

An ultra violet (UV) glazing covered even-span greenhouse dryer was developed by using polyvinyl chloride (PVC) pipes structure. A 3 cm space was maintained at the base of greenhouse to act an air inlet vent. The greenhouse was oriented in east to west and its north wall was made as a composite insulation wall consisting a layer of glass wool sandwiched between thermocol sheets. The central top of the north inclined face was created with a rectangular air outlet vent for natural ventilation. A wooden framed wire mesh tray was used as drying tray. The dimensions of the greenhouse dryer are given in Table 1. The photographic view and schematics of the dryer with different dimensions and data measuring locations are shown in Figures 1 and 2, respectively.

Table 1 Dimensions of the NWI-PGD

Sr. No.	Parameter	Details
1	Diameter of PVC pipe	1.2 cm
2	UV film thickness	200 μm
3	Side height	40 cm
4	Central height	60 cm
5	Floor area	120 × 80 cm^2
6	Air outlet vent area	20 × 20 cm^2
7	Thermocol sheets thickness	Each of 1 cm
8	Glass wool layer thickness	1 cm
9	Drying tray area	60×40 cm^2

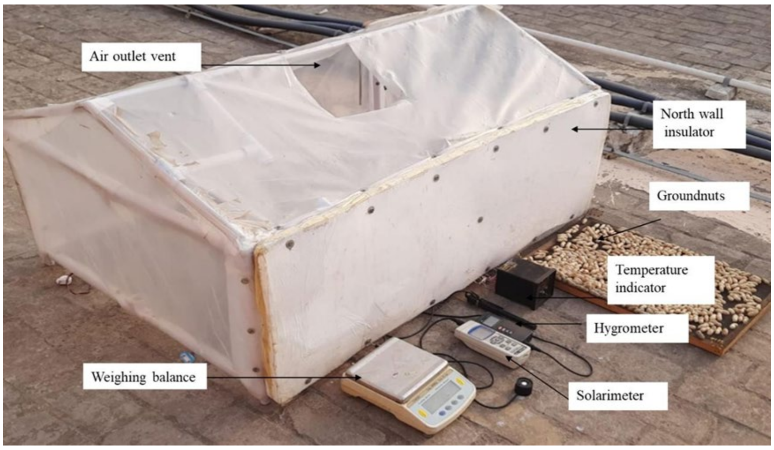

Figure 1 Photographic view of the NWI-PGD

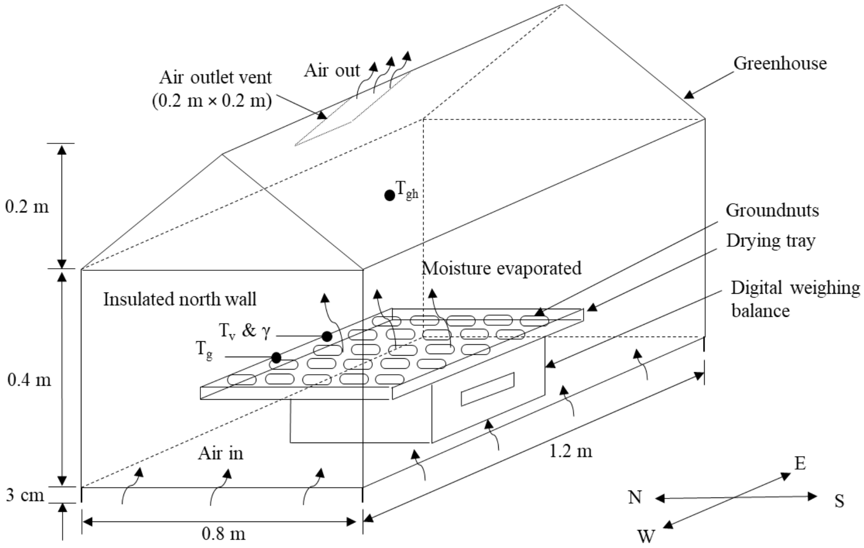

Figure 2 Schematics of the NWI-PGD

2.2 Sample preparation and experimental procedure

In the present work, locally purchased good quality double pod groundnuts were used for sample preparation. Groundnuts were soaked overnight for about 10 hours in normal tap water before experimentation. The soaked groundnuts were spread on a cotton cloth for about thirty minutes to wipe of the excess surface moisture before sample preparation. Three samples, namely, GS1, GS2 and GS3 with respective initial mass of 580, 880 and 1180 g were prepared for drying in NWI-PGD. The samples were placed on the drying tray which was kept on a digital weighing balance placed at the centre of the NWI-PGD.

Experimentation was performed in April, 2024 under the climate of Hisar, India (Latitude 29.17° N). Experiments were started at 7:30 am and hourly data was recorded till moisture evaporation was observed from the groundnuts sample. The data of temperatures at the groundnuts sample surface (T_g), 2 mm above the groundnuts sample surface (T_v), drying air in greenhouse (T_{gh}), ambient air (T_{amb}) as shown in Figure 2 was observed with PT-100 type digital indicator and thermocouples (least count; L_c: 0.1℃, range: 0-200℃). Relative humidity (γ) at 2 mm above the groundnuts sample surface as shown in Figure 1 was recorded with a HT-305 type digital hygrometer (L_c: 0.1%, range: 0-100%). The data of incoming solar radiation was recorded on each face of the greenhouse dryer with a MECO-936 type solarimeter (L_c: 0.1 W m^{-2}, range: 0-2000 W m^{-2}). The sample mass was recorded with a TJ-6000 type digital weighing balance (L_c: 0.1 g, range: 0-6000 g). The experimental data was analysed with the modelling given below.

2.3 Modelling

The convective (h_c) and evaporative (h_e) heat transfer coefficients were evaluated for groundnuts drying in NWI-PGD. The values of h_c were evaluated by using Equation 1 (Kumar and Tiwari, 2006).

$$h_c = \frac{K}{X}\, C(Gr \times Pr)^n = \frac{K}{X}\, C(Ra)^n \qquad (1)$$

Where, h_c is convective heat transfer coefficients (W m^{-2} °C^{-1}), K is thermal conductivity of drying air (W m^{-1} °C^{-1}), X is characteristic dimension (m), C and n are experimental constants, Gr is Grashof number, Pr is Prandtl number and Ra is Rayleigh number.

The rate of heat utilised for moisture evaporation from groundnuts samples (Q_e) was given as Equation 2 (Kumar et al., 2019; Shimpy et al., 2024b).

$$Q_e = 0.016\, h_c[P(T_g) - \gamma\, P(T_v)] \qquad (2)$$

Where, P(T) is partial vapour pressure at temperature (T).

The mass of moisture evaporated (m_{ev}) from groundnuts samples was evaluated by using Equation 3 (Sansaniwal et al., 2022; Shimpy et al., 2025).

$$m_{ev} = 0.016 \frac{K}{\lambda X} C(Ra)^n \left[P(T_g) - \gamma\, P(T_v)\right] t\, A_t \qquad (3)$$

Where, t is time (s), λ is latent heat of vaporisation (J kg^{-1}) and A_t is area of drying tray (m^2).

Equation 3 can be rewritten by considering as follows.

$$0.016 \frac{K}{\lambda X}\left[P(T_{ps}) - \gamma\, P(T_e)\right] t\, A_t = Z$$

$$\frac{m_{ev}}{Z} = C(Ra)^n \qquad (4)$$

Equations 4 can be written as $Y = mX + c$ by taking natural logarithm on both sides and can be solved with linear regression method to evaluate C and n values which were further used in Equation 1 to calculate h$_c$ values which were then used in Equation 5 to evaluate h_e values (Shimpy et al., 2024a).

$$h_e = 0.016\, h_c \left[\frac{P(T_g) - \gamma\, P(T_v)}{T_g - T_v}\right] \qquad (5)$$

The average of T_g and T_v was used for calculating thermo-physical properties of drying air required for various calculations using expressions given by Kumar et al. (2023a).

The values of thermal efficiency (η_{th}) and specific moisture extraction ratio (SMER) for groundnuts drying in NWI-PGD were calculated by using Equations 6 and 7, respectively (Ekka et al., 2021).

$$\eta_{th} = \frac{m_{ev} \times \lambda}{(IA_g) \times t} \qquad (6)$$

$$SMER = \frac{m_{ev}}{(IA_g) \times t} \qquad (7)$$

The values of various enviro-economic indicators were evaluated by calculating total embodied energy

(EE) and capital cost (C_c) of the NWI-PGD as given in Table 2.

Table 2 EE and C_c of NWI-PGD (Kumar et al., 2023b; Shimpy et al., 2022b)

S. No.	Material	Quantity (kg)	EE coefficient (kWh kg^{-1})	EE (kWh) NWI-PGD	Cost/ unit (INR)	C_c (INR) NWI-PGD
1	PVC pipes	3.9	19.39	75.62	55	214.5
2	Nuts and screws	0.31	8.89	2.76	1	0.31
3	Polyethylene sheet	1	10.19	10.19	240	240
4	Glass wool	0.45	4.06	1.83	24	10.8
5	Thermocol sheet	0.55	24.61	13.54	300	165
6	Polycarbonate sheet	0.6	10.5	6.30	360	216
7	Wire mesh (drying tray)	0.15	9.67	1.45	70	10.5
	Total			111.68	-	857.11

The values of EE, EPBT, annual CO_2 emission, CO_2 mitigation and carbon credit earned (CCE) were evaluated by using Equations 8-12, respectively (Shrivastava and Kumar, 2017).

$$EE = Quantity\ of\ material\ used\ \times EEC \quad (8)$$

$$EPBT = \frac{EE}{\frac{m_{ev}\times\lambda}{3.6\times10^6}\times \mathrm{D}} \quad (9)$$

$$Annual\ CO_2\ \text{emission} = \frac{EE\times 0.98}{j} \quad (10)$$

$$CO_2\ mitigation = \left(\frac{m_{ev}\times\lambda}{3.6\times10^6}\times 300\times j - EE\right)\times 2.042 \quad (11)$$

$$CCE = CO_2\ \text{mitigation} \times C_{cc} \quad (12)$$

Where, D is operating days (300/year), j is lifetime of the GD (30 years) and C_{cc} is cost of carbon credit (USD5-20).

The annualised cost (C_a) of the dryer was evaluated by using Equation 13 (Kumar et al., 2023a).

$$C_a = C_{ac} + C_m - S_a \quad (13)$$

The values of annual capital cost (C_{ac}), annual maintenance cost (C_m), annualised salvage value (S_a) were calculated by using Equations 14-16, respectively (Malik and Kumar, 2024).

$$C_{ac} = C_c \times capital\ recovery\ factor = C_c \times \frac{i(1+i)^j}{(1+i)^j-1} \quad (14)$$

$$C_m = 0.03\times C_{ac} \quad (15)$$

$$S_a = \text{salvage value} \times \text{salvage fund factor} = (0.1\times C_c)\times\frac{i}{(1+i)^j-1} \quad (16)$$

Where, C_c is capital cost and i is interest rate (5.5%).

The cost of drying one kg of groundnuts (C_{sd}) was calculated as the addition of the cost of fresh groundnuts/kg of dried groundnuts and drying cost/kg of dried groundnuts by using Equation 17 (Hadibi et al., 2022).

$$C_{sd} = C_f\frac{M_i}{M_d} + \frac{C_a}{\left(\frac{M_d D}{D_b}\right)} \quad (17)$$

Where, C_f is cost of fresh groundnuts (INR40), M_i is initial sample mass, M_d is mass of dried sample per batch and D_b is drying days/batch.

Savings/kg of dried groundnuts (S_{kg}) and lifetime savings (S_j) and payback period (PBP) were calculated by using Equations 18-20, respectively (Singh and Gaur, 2021).

$$S_{kg} = C_b - C_{sd} \quad (18)$$

$$S_j = \frac{S_{kg}\times M_d}{D_b}\times D(1+i)^{j-1} \quad (19)$$

$$PBP = \frac{\ln\left[1-\frac{C_c}{S_1}(i-d)\right]}{\ln\left(\frac{1+d}{1+i}\right)} \quad (20)$$

Where,

C_b is market price of dried groundnuts (INR130);

S_d is savings/day, d is inflation rate (5.69%);

S_1 is saving at the end of first year.

The drying kinetics of groundnuts samples was analysed by calculating experimental moisture ratio (MR_{exp}) using Equation 21 (Singh and Gaur, 2021).

$$MR_{exp} = \frac{\text{Moisture content at time,t}}{\text{Moisture content at time,zero}} = \frac{MC_t}{MC_{t,0}} \quad (21)$$

The moisture content (MC) was calculated by using Equation 22.

$$MC = \frac{initial\ mass - final\ mass}{initial\ mass}\times 100 \quad (22)$$

To analyse the drying behaviour of groundnuts samples in NWI-PGD, the predicted moisture ratio (MR_{pre}) was calculated by employing MR_{exp} in four drying models, namely, Lewis (Lewis, 1921), Page (Page, 1949), Handerson and Pabis (Pavis and Henderson, 1961) and Midilli-Kucuk (Midilli et al., 2002) model. The best fitted model was chosen by calculating the values of statistical parameters such as coefficient of correlation (*R*), root mean square error (*RMSE*), Chi square (χ^2) and mean absolute error (*MAE*) (Ambawat et al., 2022; Malik and Kumar, 2024; Sileshi et al., 2021).

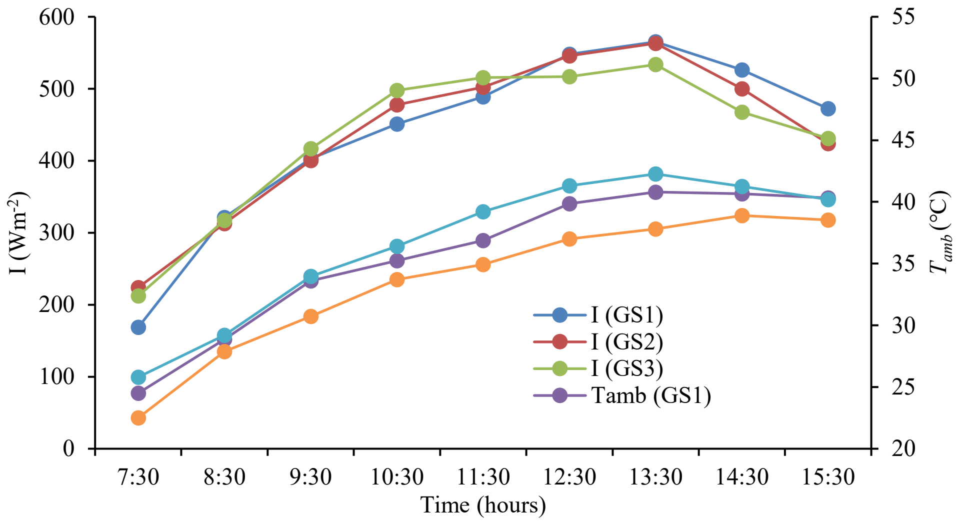

Figure 3 North wall insulated passive greenhouse dryer (NWI-PGD)

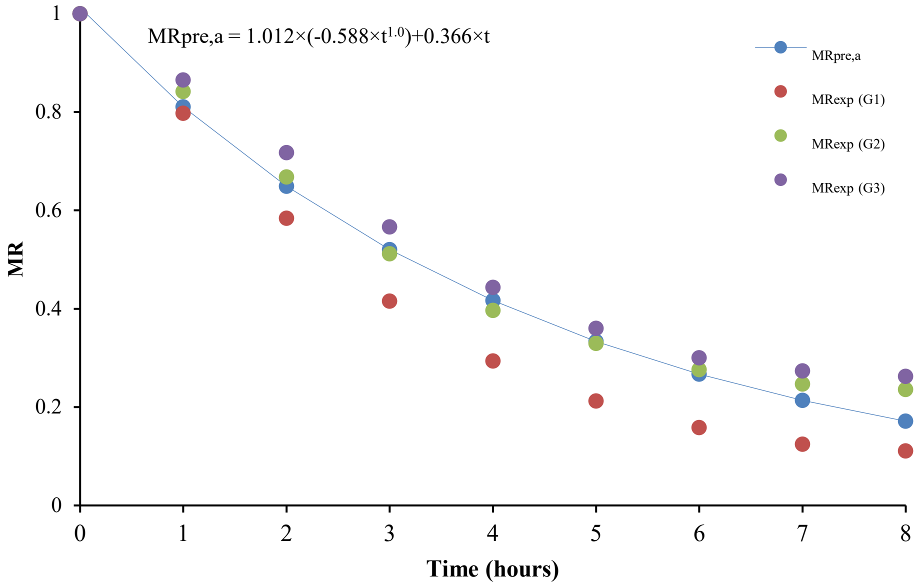

Figure 4 Fitting of $MR_{pre,a}$ with MR_{exp}

3 Results and discussion

The NWI-PGD was tested for groundnuts drying in the month of the April, 2024. Three groundnuts samples, namely, GS1, GS2 and GS3 having 580, 880 and 1180 g of mass were dried in NWI-PGD to analyze the effect of varying sample mass on its performance. The hourly experimental data of I and T_{amb} recorded during groundnuts samples drying in NWI-PGD is illustrated in Figure 3.

Figure 3 shows that the values of *I* and T_{amb} varied in the range of 168.6-565.2 W m^{-2} and 22.5°C-42.3°C, respectively. Figure 3 also shows that *I* and T_{amb} values were almost similar during different experiments. The hourly experimental data of T_g, T_v, γ and M_g recorded during groundnuts drying in NWI-PGD is given in Table 3.

Table 3 shows that the values of T_g, T_v and γ were in the range of 21.0°C - 71.2°C, 24.1°C -61.6°C and 8.1% - 48.8%, respectively. The sample mass was used to calculate moisture evaporation for given samples. The total moisture evaporated for GS1, GS2 and GS3 was evaluated to be 263, 343 and 444 g, respectively. The thermal and enviro-economic performance of the NWI-PGD along with the drying kinetics of groundnuts was evaluated by using the observed experimental data.

The evaluated thermal indicators (h_c, h_e, η_{th}, and *SMER*) with their respective averages ($h_{c,a}$, $h_{e,a}$, $\eta_{th,a}$, and $SMER_a$) are given in Table 4.

Table 4 shows that h_c, h_e, η_{th} and SMER varied from 0.35 to 0.68 W m^{-2} °C^{-1}, 6.55 to 89.38 W m^{-2} °C^{-1}, 1.07 to 33.68% and 0.02 to 0.50 kg kWh^{-1}, respectively. Highest average values of thermal indicators which are desirable for solar drying operation were observed for GS3 followed by GS2. The sample having higher mass has the higher exposed surface area to the drying air and higher total moisture evaporation, thus higher values of thermal indicators for groundnuts drying in NWI-PGD. The values of C and n varied from 0.81 to 1.06 and 0.145 to 0.180, respectively. The values of Ra for different experiments varied from 7.34×10^4 to 1.69×10^6 which shows that the experiments carried out for groundnuts drying in NWI-PGD falls under laminar region (i.e., $Ra\leq10^7$). The values of $\eta_{th,a}$ were also found to be higher than the corresponding values reported by Kumar et al. (2019), for passive simple greenhouse groundnuts drying.

The embodied energy (EE) and capital cost (C_c) of NWI-PGD were used for its enviro-economic performance assessment.

The calculated values of enviro-economic indicators (EPBT, CO_2 emissions, CO_2 mitigation, CCE, C_{sd}, S_{kg}, S_j and PBP) for groundnuts drying in NWI-PGD are given in Table 5.

Table 3 Hourly experimental data for groundnuts drying in NWI-PGD.

Time (hours)	T_g (℃)	T_v (℃)	γ (%)	M_g (g)	T_g (℃)	T_v (℃)	γ (%)	M_g (g)	T_g (℃)	T_v (℃)	γ (%)	M_g (g)
	GS1				GS2				GS3			
07:30	21.0	24.1	43.3	580.0	26.4	29.6	35.1	880.0	23.6	26.2	48.8	1180.0
08:30	32.6	34.2	27.1	520.0	34.2	36.0	28.3	809.0	35.6	36.4	32.3	1099.0
09:30	48.5	44.9	18.1	457.0	46.0	46.9	17.4	731.0	42.7	45.8	19.5	1010.0
10:30	56.1	52.0	14.0	407.0	54.3	51.3	14.7	661.0	55.3	50.5	15.7	919.0
11:30	62.4	55.1	12.5	371.0	67.2	56.3	11.7	609.0	62.0	52.8	12.7	845.0
12:30	70.0	59.1	11.1	347.0	70.2	58.1	10.4	579.0	69.4	54.8	10.5	795.0
13:30	68.9	61.6	9.3	331.0	71.2	60.6	9.6	555.0	67.7	55.4	10.1	759.0
14:30	66.0	59.9	9.7	321.0	65.9	56.4	9.6	542.0	59.1	51.0	10.4	743.0
15:30	59.6	55.9	10.0	317.0	68.2	59.5	8.1	537.0	54.7	48.4	10.9	736.0

Table 4 Thermal indicators for groundnuts drying in NWI-PGD.

Sample	GS1	GS2	GS3
h_c (W m^{-2} °C^{-1})	0.35-0.47	0.35-0.59	0.50-0.68
$h_{c,a}$ (W m^{-2} °C^{-1})	0.44	0.53	0.61
h_e (W m^{-2} °C^{-1})	6.55-42.26	9.75-54.53	13.43-89.38
$h_{e,a}$ (W m^{-2} °C^{-1})	22.23	27.56	29.01
η_{th} (%)	1.07-24.69	1.51-29.91	2.12-33.68
$\eta_{th,a}$ (%)	10.31	13.19	16.50
SMER (kg kWh^{-1})	0.02-0.37	0.02-0.45	0.03-0.50
$SMER_a$ (kg kWh^{-1})	0.15	0.20	0.25

Table 5 Enviro-economic indicators for groundnuts drying in NWI-PGD

Sample	GS1	GS2	GS3
EPBT (years)	2.10	1.61	1.24
CO_2 emissions (kg $year^{-1}$)	3.65	3.65	3.65
CO_2 mitigation (kg)	3034.50	4026.92	5279.84
CCE (INR)	2961.68	3930.27	5153.12
C_{sd}, (INR)	73.81	65.92	64.40
S_{kg}, (INR)	56.19	64.08	65.60
S_j, (INR)	25243.08	48769.22	68426.30
PBP (years)	0.17	0.09	0.06

Table 5 shows that the enviro-economic performance indicators of the NWI-PGD improved with increased groundnuts sample mass. The reason for this could be the higher amount of moisture loss and dried commodity obtained with sample having highest initial mass. The EPBT and PBP were recorded at 1.24 and 0.06 years, respectively, which are considerably lower than the estimated lifespan of a dryer (30 years). The reduced EBPT and PBP indicate a greater enviro-economic feasibility of the NWI-PGD for drying groundnuts. The evaluated values of EPBT for NWI-PGD were comparatively lower than the values reported for MGHD (Shimpy et al., 2022a), MMGGD, MMMGGD (Shimpy et al., 2022b), PMGGD and AMGGD (Shimpy et al., 2024b). The values of PBP for NWI-PGD were also found lower than the values reported for PMGGD (Shimpy et al., 2024b) and ETC assisted solar dryer (Malik and Kumar, 2025).

The drying kinetics of groundnuts in NWI-PGD was evaluated by fitting MR_{exp} to the given drying models. The values of R, RMSE, χ^2 and MAE for Midilli-Kucuk model were found to be highly desirable as compared to other drying models and varied from 0.995 to 0.999, 0.014 to 0.025, 0.00023 to 0.00071 and 0.012 to 0.022, respectively. The model constants of Midlli-Kucuk model (k', n', a' and b') varied from 0.226 to 1.234, 0.963 to 1.023, 1.007 to 1.014 and 3.82×10^{-5} to 0.979, respectively. To present a single model for groundnuts drying behaviour in NWI-PGD, an average Midilli-Kucuk model has been developed by taking average of model constants for the three samples. The fitting of average Midilli-Kucuk model ($MR_{pre,a}$) and MR_{exp} is shown in Figure 4.The model constants (k', n', a' and b') for average Midlli-Kucuk model were evaluated to be 0.588, 1.0, 1.012 and 0.366, respectively. The average values of R, RMSE, χ^2 and MAE for $MR_{pre,a}$ and MR_{exp} were found to be 0.996, 0.056, 0.004 and 0.049, respectively which show an excellent fit. Figure 4 shows that the GS1 shows fastest drying which could be due to lowest initial sample mass. The same amount of energy available to a lower mass could result in faster drying. The Midilli-Kucuk model also been recommended by Shimpy et al. (2024b, 2022a) for groundnuts drying in greenhouse dryers. Literature also shows that Page model (Shimpy et al., 2022b) and Henderson and Pabis model (Sahdev et al., 2017) can be used for the prediction of the drying behaviour of groundnuts in solar dryers.

4 Conclusion

This work presents a NWI-PGD developed and tested for groundnuts drying with varying sample mass (580, 880 and 1180 g). The thermal and enviro-economic performance indicators were also evaluated for the dryer which were found as improving with increased groundnuts sample mass. The values of EE and C_c of the NWI-PGD were found to be 111.68 kWh and INR 857.11, respectively. The lowest values of EPBT and PBP were observed for GS3 and were 1.24 and 0.06 years, respectively. The drying behaviour of groundnuts samples was in an excellent fit with the Midilli-Kucuk model. An average Midilli-Kucuk model was presented for further prediction of drying behaviour of groundnuts. This research provides a renewably powered sustainable solution to food wastage at local and farmer level ensuring food security and sovereignty. It would be highly beneficial to remote areas with no electricity. This work can be extended to evaluate the effect of higher initial sample mass and other modification such as latent and sensible heat storage materials, reflectors, floor coverings, desiccant materials and solar air collectors on the performance of NWI-PGD.

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