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Research Article

Response surface optimization and social impact evaluation of *Houttuynia cordata* Thunb solar drying technology for community enterprise in Chiangrai, Thailand

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Abstract. Drying has emerged as one of the most important ways of preserving high-quality and quantity food goods. A force convection solar drying is considered an ecologically and environmentally friendly alternative. This research presents parameter optimization of greenhouse tunnel dryer of *Houttuynia cordata* Thunb (*H. cordata*) using response surface methodology with the assessment of economic feasibility and social return on invesment. The influence parameters of the drying process were evaluated to obtain maximum efficiency. The individual parameters were temperature (40 – 60 °C), material length (10 – 30 cm), and relative humidity (30 – 50%). The individual parameters of drying temperature showed an extreme effect on the response of moisture content and color value change, while the relative humidity had only an influence on moisture content. On the other hand, the parameter of material length was not significance in both responses. When compared to open-air drying, solar drying reduced the drying time of *H. cordata* by 57.14%. The payback period of the dryer was found to be 2.5 years. Furthermore, the results reveal that the social return on investment ratio in 2021 was 2.18, then increasing to 2.52 in 2022 and 2.91 in 2023. According to the findings, solar drying technology has the potential to be an adequate product quality improvement technology for *H. cordata*. It is a feasible drying technology in terms of economic evaluation.

Keywords: Solar drying, *Houttuynia cordata* Thunb, Response Surface Methodology, Social Return on Investment analysis, Community enterprise

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1. Introduction

One of the most well-known methods of food storage is drying. Drying is an essential post-handling activity in the food production industry that may decrease postharvest losses, increase product quality, and prolong the shelf life of harvested items (Kamarulzaman *et al.* 2021). By removing water from food goods, this technique inhibits the emergence of undesirable changes such as microbial degradation and enzymatic reactivity. This technique not only helps to maintain the integrity of the materials that are being dried, but it also greatly cuts down on product weight and volume, which results in reduced expenses associated with packing, warehousing, and shipping (Poblete *et al.* 2018).

Houttuynia cordata Thunb is a fragrant medicinal herb with a spreading root stock. Raw *H. cordata* is prepared as a medicinal salad and consumed to reduce the amount of sager in the blood. In addition, the juice extracted from the leaves is used to cure cholera, dysentery, and other gastrointestinal disorders and purify the blood. Internal usage of a decoction made from this plant is effective in treating various conditions, including cancer, coughs, dysentery, enteritis, and fever (Kumar *et al.* 2014; Rafiq *et al.* 2022). *H. cordata* has become a medical value in medical products and the food industry in Thailand. Based on the harvesting in a rural area, hand harvesting is the usual, followed by a period of time spent allowing the product to open air-dry until it reaches the level of dryness necessary for commercialization. Thus, drying is required for post-handling activity in the food production industry, which may decrease postharvest losses and increase product quality. For the target area, the thermal applications of solar energy especially for drying process of small community enterprises are attractive (Jangde *et al.* 2021).

Typically, the conventional drying approach has several drawbacks, some of which include the unfavorable impacts of variables such as wind, dust, precipitation, and insects. Open solar drying calls for substantial land areas and extended drying durations. In addition to being susceptible to variations in solar radiation, weather conditions, wind speed and direction, relative humidity, beginning moisture content product mass per unit of the exposed area, and equipment design. Because of the inherent limits of managing sun drying, the result is

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inappropriate product drying and has poor consistency (Majdi *et al.* 2019; Getahun *et al.* 2021). Compared to conventional open-air drying, solar dryers may minimize food waste and increase the quality of the product (Azaizia *et al.* 2020; Colorado *et al.* 2022). Solar dryers have shown technological promise for drying agricultural and marine goods more effectively and reliably (VijayaVenkataRaman *et al.* 2012). Solar dryers require less time to achieve optimal drying and occupy less space than would be needed by traditional open-air procedures, which means that the overall process of solar drying is economically favorable and more efficient than the traditional alternative (Ekka *et al.* 2021). In addition to being more energy efficient, solar dryers require less time to achieve optimal drying and are smaller in size (Mustayen *et al.* 2014). According to recent research, Poblete *et al.* (2018) determined the ideal settings of various elements influencing the performance of a closed solar dryer in drying *Gracilaria chilensis*. The solar dryer achieved a greater degree of moisture evaporation than open-air drying (86.1% versus 67.6%, respectively). The specific energy consumption needed for the optimum solar dryer process was 1.64 kWh/kg. Joseph Etim *et al.* (2021) optimized the drying process parameters of cooking bananas dried on an active indirect mode solar drier using response surface methodology. The air intake area of an active indirect mode solar drier and the product slice thickness were considered independent parameters. For best drying of cooked bananas using an active indirect mode solar drier, a square air inlet area of 100 cm^2 and slice thickness of 20 mm were suggested. Wang *et al.* (2022) conducted the possible use of a mixed-mode solar dryer for Qula dehydration in the Qinghai-Tibet Plateau of China. The influences of drying process variables were evaluated by using a central composite rotatable design of the response surface methodology. The optimal operating temperature was found to be 43.0 °C, material thickness of 11.0 mm, and wind velocity of 1.0 m/s based on the value of target chemical compounds. These findings indicate that optimizing influence factors is required for solar drying to maximize the value of starting materials. Zhang *et al.* (2019) optimized the parameters of hot air-drying characteristics of jujube. The primary effect order of the test influence elements on the comprehensive quality level of jujube drying was drying temperature, humidity, and wind speed, respectively. Among solar drying technology, the solar greenhouse drier may function in both forced and natural convection modes. It is possible to dry materials on a massive scale (Hempattarasuwan *et al.* 2019). Compared to the standard open-air sun drying process, it is faster, more efficient, and needs less surface area for product drying (Elkhadraoui *et al.* 2015). Kaewkiew *et al.* (2012) presented a large-scale greenhouse type solar dryer for drying chilli. It was observed that 500 kg of of chilli with the initial moisture content of 74% (wb) were dried within 3 days. Morad *et al.* (2017) analyzed the thermal behavior of a solar tunnel greenhouse for peppermint plants based on thermal balance equation and evaluated the drying process of the solar dryer from the economic point of view. Krungkaew *et al.* (2020) reported cost and benefits of using parabolic greenhouse solar dryer for dried herb production. The results of net present value, internal rate of return, payback period and CO$_2$ mitigation indicating that the investments were attractive. According to process optimization, the combined of drying technology with material characteristic resulted in different operating condition, quality and quantity of product and socio-economic evaluation. In this research, the process optimization of GTD technology for production of dried *H. cordata* is needed to clarify the optimal condition based on the response of product properties.

Technical research would particularly acquire the information in the point view of process optimization. However, evaluation in terms of energy-economic-environmental is required to determine its benefit and effectiveness. The knowledge obtained via energy and economic evaluation is useful for determining and enhancing plant and operating costs, energy conservations, fuel flexibility, and pollution levels. Further, knowledge in the social, technological, and economic level involves taking into account the requirements of the user and the ultimate use of products. Desa *et al.* (2020) determined thermoeconomic analysis and environmental evaluation on various solar drying systems. Philip *et al.* (2022) also determined the benefit of greenhouse solar dryer with a short payback period of 1.5–2.1 years for the considered agricultural products. Utilizing solar dryers to dry agricultural goods, as well as poultry and marine items, improves product quality via enhanced drying system integration. Solar dryers also help with environmental preservation by reducing the energy demand in the food processing industry. Additionally, solar dryer involves the benefit of financial savings and environmental impact.

This research aimed to improve the drying process of the *H. cordata*. The novelty of this research is the evaluation of influence factors for drying *H. cordata*. Various drying process parameters were examined under different conditions to determine the influence of each parameter on drying efficiency based on the estimation of center composite design (CCD) and response surface methodology (RSM). The productivity of the improved solar dryer system was then compared to that of an open-air system. The methods evaluation involved the assessment of product quality, economic analysis, and social return on investment (SROI).

2. Materials and methods

2.1 Description of the solar dryer

This research requires using a Greenhouse Tunnel Dryer (GTD), as illustrated in Fig. 1. The dryer was operated on the principles of convective force. The device's components include a concrete floor, parabola dome, insulator, centrifugal ventilator, dryer shelf, and thermoregulatory. Briefly, the dryer dimension is 8 m wide, 12 m long, and 3 m high. A polycarbonate sheet of 6 mm thickness was used as transparent cover material, while steel was used for the construction of the frame and housing. A centrifugal ventilator (axial fan, 220 V, 1.2 A) gives room to a theoretical air velocity of 1.5 m/s. The wind velocity was detected by a digital anemometer. A temperature sensor measured the temperature with a temperature range of 0-100 °C and of a 0.1 °C precision. Five shelves with equal spacing were arranged in the drying zone.

2.2 Experimental Design

In this study, the RSM was used to investigate the impact of drying factors, e.g., temperature (X_1), material length (X_2), and relative humidity (X_3) based on the moisture content in the derived products. Various parameters of temperature (40-60 °C), material length (10-30 cm), and relative humidity (40-60%) ranges were chosen based on our preliminary research. The Center Composite Design (CCD) was used to design the experiment with 3 factors 3 levels. Center points were repeated three times to establish the method's repeatability. The effect of experimental variables was studied based on the response of moisture content and color value.

2.3 Sample preparation

Fresh samples of *H. cordata* were obtained from a local area in the Chiagrai province of Thailand. After being cleaned, peeled, and cutted to length ranging from 10.0 to 30.0 mm. An electronic weighing scale was used to determine the weight of the prepared samples. To minimize overlapping, the samples were carefully put into the dryer tray. The products were

Fig. 1 Solar drying system

Table 1
Experimental design parameters and corresponding values.

Coded parameter levels	Actual value		
	Temperature (°C)	**Length (mm)**	**Relative humidity (%)**
-α (-1.68)	33	5	23
-1	40	6	30
0	50	8	40
+1	60	10	50
+α (+1.68)	67	11	57

removed and weighed at an appropriate time. The drying experiment was conducted between 7:00 am and 5:00 pm each day until the experimental runs were completed. The weather was generally sunny, and no rain appeared.

2.4 Color measurements

Surface color measurement was conducted using the L* a* b* system (Universal HunterLab, Model 45/0 S/N CX- 0413), calibrated to a standard white tile (L*=91.7, a*=-1.16, b*=1.06). L*corresponds to lightness, a* represents red(+)/green (-) and b* refers to yellow (+)/blue(-). A total of five measurements were carried out for each treatment, with each measurement using five *H. cordata*. Color measurements such as chroma and hue angle have been proposed as more practical (McGuire 1992).

The overall color change or difference (ΔE) from fresh to dried sample was also calculated using the equation below (Seerangurayar *et al.* 2019):

$$\Delta E = \sqrt{(L_{0*} - L^*)^2 +} (a_{0*} - a^*)^2 + (b_{0*} - b^*)^2 \qquad (1)$$

where, $L0*$, $a0*$ and $b0*$, are the $L*$, $a*$, and $b*$ values of the freshdates and $L*$, $a*$, and $b*$ are corresponding values of the drieddates, respectively. A larger ΔE denotes greater color change from the fresh dates.

2.5 Determination of moisture content

The moisture content of the product was calculated according to the equation 2:

$$Moisture\ content\ (M.C.) = \frac{(W_i - W_f)}{W_i} \text{ x } 100\% \qquad (2)$$

where M.C. (wb) = Moisture content of the sample on wet basis (%); W_i = Initial weight of sample (g); W_f = Final weight of sample (g)

2.6 Economic analysis

The payback period for the solar dryer is calculated as follows (Prakash and Kumar 2014):

$$N = \frac{In\,[1 - \frac{Ccc}{S1}(d-i)]}{In(\frac{1+i}{1+d})} \qquad (3)$$

2.7 SROI evaluation

SROI is determined as the ratio of earnings and social performance (the net amount for a set period) to the organization's resources (primarily the net assets that remain) according to the following equation.

$$SROI = \frac{Total\ Present\ Value\ (PV) of\ Impact}{Total\ Present\ Value\ (PV)\ investment} \qquad (4)$$

3. Results and discussion

3.1 Fitting response surface models

Influencing of drying paarameters on moisture content, temperature show a significant impact on the drying performance of materials, particularly when it comes to the rate of moisture removal. The relationship between temperature and drying performance can be explained by the concept of vapor pressure. When the temperature is higher, the vapor pressure of the surrounding air increases, which causes more moisture to be drawn out of the material being dried (Premi *et al.* 2012; Babu *et al.* 2018). Many medicinal plants could well be dried at

Table 2
Experimental matrix for response surface quadratic model based on the response

Run	Actual value			Responses (%)	
	Temp. (°C)	Length (cm)	Relative humidity (%)	Moisture content (%)[a]	Color value change (ΔE)[a]
1	40	6	30	15.39	9.59
2	40	6	50	17.08	8.63
3	40	10	30	16.25	10.77
4	40	10	50	19.23	12.28
5	60	6	30	7.06	24.81
6	60	6	50	8.15	23.95
7	60	10	30	9.02	20.21
8	60	10	50	10.06	21.08
9	33	8	40	28.23	5.77
10	67	8	40	6.65	26.33
11	50	5	40	7.33	15.41
12	50	11	40	11.25	16.42
13	50	8	23	7.73	16.38
14	50	8	57	23.01	13.98
15	50	8	40	8.67	16.33
16	50	8	40	7.99	15.24

[a] *Based on the relative contents of in raw material*

temperatures between 50 and 60 °C (Rocha *et al.* 2011). It has been shown that a drying temperature of 50 °C causes negligible quality loss in drying herbs and spices (Babu *et al.* 2018). Temperature plays a critical role in the drying process, and it's important to carefully consider the optimal temperature range for each specific application to achieve the best possible results. Material size is also an influence parameter of drying process. A small material size result in a high evaporation area that the water content can contact with the ambient. In addition, relative humidity is the ratio of the quantity of moisture in the air to the maximum amount that air at that temperature can contain. Temperature and relative humidity of heated entering and outgoing waste air are connected to air humidity pickup and product moisture content. Lower relative humidity in the ambient air causes a faster drying rate if the heated air temperature is maintained because the moisture gradient between the materials and the ambient air is more prominent (Chauhan and Kumar 2016).

Color is an essential component of quality in the agricultural and food industries, since it plays a significant impact in the desirability of materials from the perspective of customer desire. Typically, thermal process causes the oxidation of color pigments. The high temperatures and extended drying durations accelerate pigment breakdown and enhance color variance in dried foods (Engin 2020).

In this study, the conditions for the solar drying process were optimized by RSM with CCD, as shown in Table 1. Each variable was varied with five coded level (lowest value coded as −1.68, middle value coded as 0, and highest value coded as +1.68). The CCD comprised 16 experimental runs with duplicate at center point. The effect of various parameters are related to the responses of moisture content and color value (Table 2). Analysis of variance (ANOVA) was performed to assess the effect of the variables and possible interactions using regression analysis for a second-order polynomial of multiple regression equation. The models were statistically valid, with a confidence interval 95%. For material properties, a starting *H. cordata* sample composed of 83% moisture content and the initial color parameters L^*, a^*, b^*, of fresh *H. cordata* were 62.11, 27.78, and 9.06, respectively. The initial values were used as a benchmark to compare with all dried samples.

3.2 Drying effect on moisture content

The correlation of drying parameters (temperature, material length, and relative humidity) and moisture content are illustrated in Fig. 2. The moisture content in *H. cordata* decreased sharply when the operating temperature increased from 30 to 70 °C. The reducing of material size showed a slight trend for removing of moisture content. Further reducing the relative humidity led to decrease in the moisture content of *H. cordata*. According to the results, the second-order polynomial was evaluated according to equation 5.

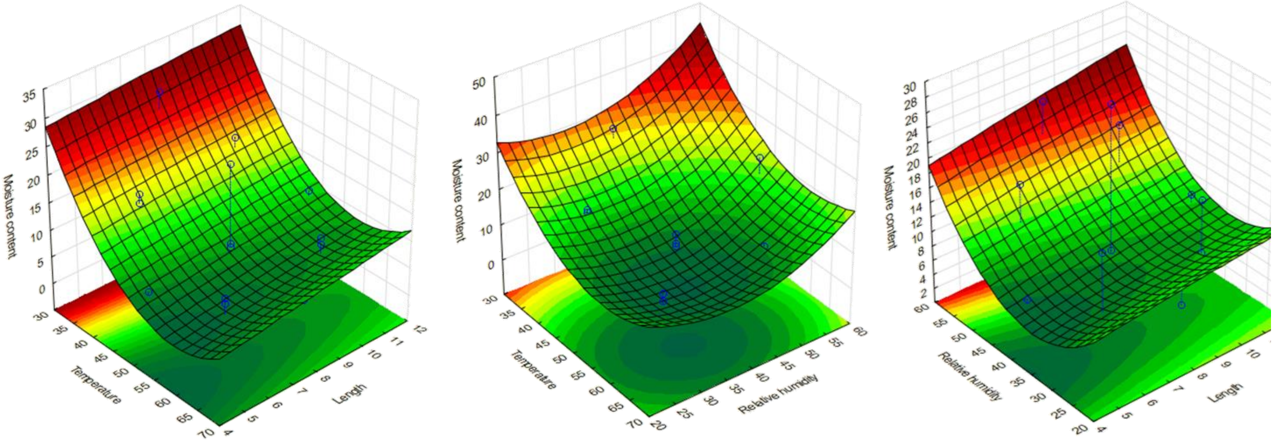

Fig. 2 Response surface between the correlation of various parameters on moisture content

Table 3
ANOVA for response surface quadratic model of moisture content

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	p-value	Comments
(1)Temperature(L)	358.3135	1	358.3135	30.60396	0.001470	Significance
Temperature(Q)	75.1596	1	75.1596	6.41946	0.044459	Significance
(2)Length (L)	13.2909	1	13.2909	1.13519	0.327656	
Length (Q)	0.0102	1	0.0102	0.00087	0.977443	
(3)Relative humidity(L)	77.3316	1	77.3316	6.60498	0.042334	Significance
Relative humidity(Q)	41.4982	1	41.4982	3.54441	0.108753	
1L by 2L	0.0924	1	0.0924	0.00790	0.932084	
1L by 3L	0.8064	1	0.8064	0.06888	0.801753	
2L by 3L	0.1922	1	0.1922	0.01642	0.902237	
Error	70.2484	6	11.7081			
Total SS	632.8322	15				

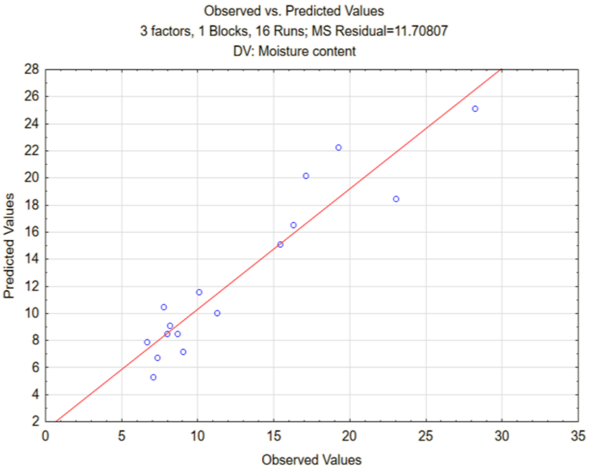

Fig. 3 The correlation of observed values and predicted values of moisture content

$$\text{Moisture content (\%)} = 8.4843 - (10.2444X_1) + (1.9730X_2) + (4.7592X_3) + (5.6967X_1^2) - (0.0663X_2^2) + (4.2329X_3^2) + (0.2150X_1X_2) - (0.6350X_1X_3) + (0.3100X_2X_3) \quad (5)$$

A comparison of predicted and experimental values of moisture content found that the model predicted moisture content gave accuracy 88.9% of the variation in the response (Fig. 3). The models were statistically valid with the r-square adjust of 72.24%. An ANOVA was performed using the quadratic model, as illustrated in Table 3. The p-value was used to evaluate the significance of each coefficient (p value < 0.05). A low p-value suggests that the associated model term significantly contributed to the response variable. As the results, the linear term of temperature, material length, and relative humidity showed p-values of 0.014, 0.3276, and 0.0423, respectively. These results indicate that temperature and relative humidity significantly affected moisture content. It was found that the temperature in quadratic had a significant effect, while the interaction term had no influence on moisture content in the solar drying process. According to F value of each individual, the level of the significant parameter was in the order of temperature (30.6039), relative humidity (6.6049), and material length (1.1351), respectively.

Based on the optimized temperature in this study, drying temperature showed the most influence parameter for drying of *H. cordata* which was correlated to previous work (Jha and Tripathy 2021). Increasing temperature led to higher removal rate of moisture. However, drying of *H. cordata* at high

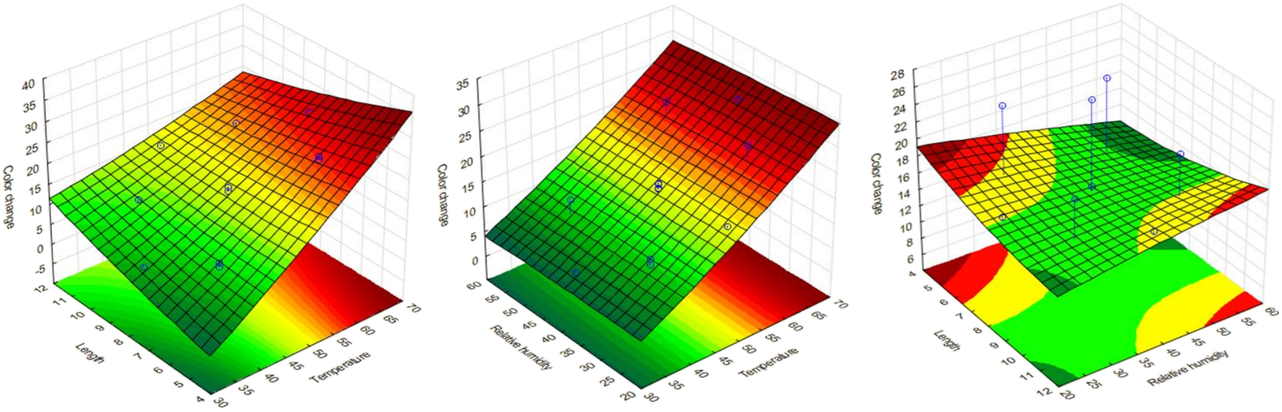

Fig. 4 Response surface between the correlation of various parameters on color value change

Table 4
ANOVA for response surface quadratic model of color value change

Source	Sum of Squares	Degree of Freedom	Mean Square	F Value	p-value	Comments
(1)Temperature(L)	508.7921	1	508.7921	545.9418	0.000000	Significance
Temperature(Q)	0.6154	1	0.6154	0.6604	0.447470	
(2)Length (L)	0.0649	1	0.0649	0.0696	0.800706	
Length (Q)	0.4086	1	0.4086	0.4384	0.532476	
(3)Relative humidity(L)	0.8849	1	0.8849	0.9495	0.367481	
Relative humidity(Q)	0.0230	1	0.0230	0.0247	0.880265	
1L by 2L	18.9113	1	18.9113	20.2921	0.004084	Significance
1L by 3L	0.0365	1	0.0365	0.0391	0.849758	
2L by 3L	2.2050	1	2.2050	2.3660	0.174923	
Error	5.5917	6	0.9320			
Total SS	537.6560	15				

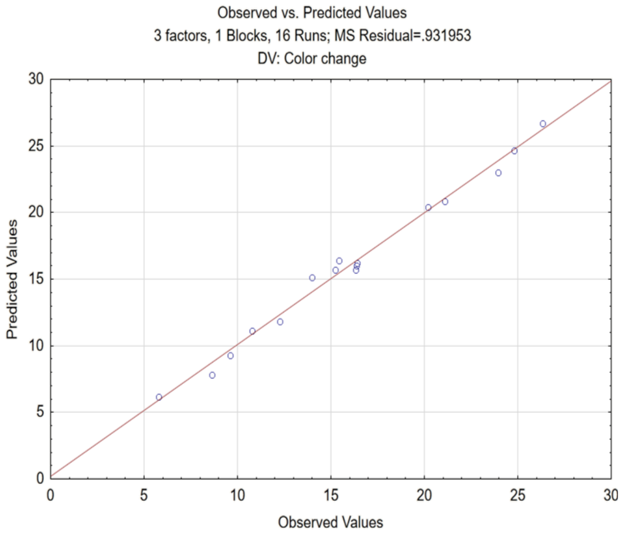

Fig. 5 The correlation of observed values and predicted values of color value change

temperature (above 60°C) also resulted in a low quality of product in term of color, hardness and phytochemical content (Nhut and Sang 2022). Since the acceptable of moisture content for *H. cordata* as valuable product in the market is less than 10% (Afolabi 2014). The recommended drying temperature was approximately 50 °C to be suitable for remaining moisture content of 8.33%. This condition was also preserved the color with light brown, which was correlated with the result in a part of the optimization of color value. The variation of relative humidity during *H. cordata* drying, it was noticed that the average relavtive humidity of ambient during experiment was 59.1%. The designed relative humidity of air in GTD was kept lower than ambient air which is sufficient for improvement of drying rate (Lingayat *et al.* 2020). The varied relavtive humidity showed a minor influence in drying process. Generally, at high drying temperature with low relative humidity resulted in the drying rate of solar dryers as previously observed (Azam *et al.* 2020). However, no substantial effect of material length on drying performance was observed under the experimental condition. It should be noted that the thickness of spread of materials should have reasonable depth to prevent the air from channeling through void age, which might affected to the drying performance (Özbek and Dadali 2007).

3.3 Drying effect on color value change

The correlation of drying parameters (temperature, material length, and relative humidity) and color value were evaluated as illustrated in Fig. 4. The level of drying temperature showed the obvious change of color value of *H. cordata* when the themperature increased from 30-70 °C. On the other hand, the varied condition of relative humidity and material length showed a minor modification of color value. According to the results, the second-order polynomial was evaluated according to equation 6.

$$\text{Color value change} = 15.7170 + (12.2074X_1) - (0.1378X_2) - (0.5090X_3) + (0.5154X_1^2) + (0.4200X_2^2) - (0.0997X_3^2) - (3.0750X_1X_2) - (0.1350X_1X_3) + (1.0500X_2X_3) \quad (6)$$

A comparison of predicted and experimental values of color value change found that the model predicted color value change gave an accuracy 98.96% of the variation in the response (Fig. 5). The models were statistically valid with the r-square adjust of 97.40%. An ANOVA was performed using the quadratic model, as illustrated in Table 4. According to the results, the linear term of temperature has a significant effect with p-value of 0.0000. In addition, the interaction term between temperature and material length showed an influence on color value change during solar drying. According to each individual's F value, the significant parameter level was in the order of temperature, relative humidity, and material length, respectively.

Since the color is one of the most important sensory characteristics of the dried material. The change may result from oxidation, enzymatic or non-enzymatic browning, oxidation, and heat breakdown of color pigments (Lakshmi *et al.* 2018). According to the results, the temperature increase exhibited an extremely significant difference on color value of *H. cordata*. Seeranguryar *et al.* (2019) also reported that using high temperatures for drying air results in a dark-brown color due to a non-enzymatic browning reaction. In this study, at the center point was obtained the average color value change with 15.78 which resulted in the light brown of dried *H. cordata*.

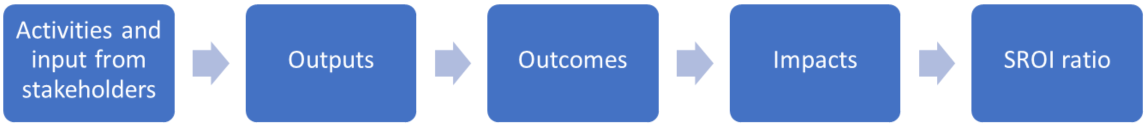

Fig. 6 Framework of calculating the social impact

Increasing temperature above 60°C led to increased the color value change higher than 20, which turned to dark brown. It could be described that the brown pigment of *H. cordata* at high temperature drying is caused by enzymatic activities, non-enzymatic reactions and the oxidation of phenolic compounds (Calín-Sánchez *et al.* 2020). The results of hot-air drying pumpkins (Chikpah *et al.* 2022), carrots (Demiray and Tulek 2015), and jackfruit (Saxena *et al.* 2012) were comparable.. Thus, the drying of *H. cordata* suggested to maintain the temperature lower than 50°C which correlated to the desired color of product. In term of material size, it was observed that reducing material size resulted in slight decrease of color value change. Similar to the previous observations in dried pumpkin (Chikpah *et al.* 2022). This is in agreement with the ANOVA result that the interation term of temperature and material length become an influence parameter. However, the parameter of relative humidity was no substantial change in color value. It is crucial to employ a suitable drying procedure for each product and to choose circumstances that will minimize any potential modifications.

3.4 *Economic feasibility*

Assessing the economic sustainability of solar dryer investments requires extensive financial and economic analyses since such investments are often undertaken based on perceived economic and technological viability. The productivity of open-air drying was compared against the solar dryer technology that determined optimal drying productivity. One of our goals is to reduce the cost of the prototype to be used in rural areas. Thus, priority is given to the operational cost rather than the investment cost.

To conduct an economic analysis for the dryer, the payback time by cost of dryers was determined. Table 5 presents the summarization of the various process of manufacturing and product cost. The result calculated the drying period based on the final moisture content of less than 10 wt.%. The moisture content of *H. cordata* was decreased to 10 wt.% after 7 days for open sun drying but only 3 days for solar drying. The applied GTD showed an effective process for drying of *H. cordata*. This is in good agreement to improve the drying performance compared to open sun traditional (Vengsungnle *et al.* 2020). Nimnuan and Nabnean (2020) also reported the solar greenhouse dryer could reduce the drying time as compared to the natural sun drying with saving drying time of 67%. An economic evaluation was calculated using the payback period criterion, which is found with a short return of 2.5 years compared to the life of the solar drying system.

3.5 *Social return on investment analysis*

SROI is a metric that quantifies and assesses the advantages and accomplishments achieved by organizations that engage in social activities (Courtney and Powell 2022). The framework for the 5 stages of calculating the SROI ratio is as follows Fig. 6. In this research, GTD in the Chiangrai province of Thailand was selected for SROI analysis. The logic model analysis identified the following five economic social impacts: conducting field observations, surveys, interviews, and literature reviews. After that, these results were validated by examining the parties' accounts depending on each indicator. To determine the monetary value, the researcher takes into account several factors that contribute to the reduction of the calculation, such as possible displacement, deadweight effects, attribution concerns, and drop-off effects. The evaluation of social impact using SROI is presented in Table 6. According to the SROI assessment results, the results were predicted for a 3 years plan from 2021 to 2023. The SROI ratio was 2.18, 2.52, and 2.91, respectively. These results indicated that there was a significant and beneficial effect made on the community as a result of the social investment.

Table 5
Cost and economic parameter of solar drying

	Solar drying	**Open-air drying**
Capital cost of solar dryer	12,500$	-
Annual electricity cost for fans	10$	-
Capacity of dryer	1,200 kg fresh *H. cordata*	1,200 kg fresh *H. cordata*
Price of fresh *H. cordata* (83% of initial moisture content)	1$/kg	1$/kg
Price of dried *H. cordata* (<10% of moisture content)	7$/kg	7$/kg
Life of dryer	20 years	-
Period of drying	3 days	7 days
Interest rate	8%	-
Inflation rate	5%	-

Table 6
Evaluation of social impact using SROI

No.	Information	2021 (Year 1)	2022 (Year 2)	2023 (Year 3)
Inputs	Total initial Investment	$12,500.0	0	0
	Discount	5%	5%	5%
	PV average rate	1.050	1.025	1.158
	Total PV investment	$12,500.0	$11,904.8	$11,337.9
Impacts	Proxy		$937.5[a], $15.6[b], $187.5[c]	
	Deadweight	30%[a], 70%[b], 50%[c]	30%[a], 70%[b], 50%[c]	30%[a], 70%[b], 50%[c]
	Attribution	80%[a], 20%[b], 50%[c]	80%[a], 20%[b], 50%[c]	80%[a], 20%[b], 50%[c]
	Displacement	0%	0%	0%
	Drop-off	10%[a], 0%[b], 10%[c]	10%[a], 0%[b], 10%[c]	10%[a], 0%[b], 10%[c]
	Total PV values of impact	$27,281.3	$30,000.0	$32,990.6
SROI ratio		2.18	2.52	2.91

Group of stakeholders: [a]Community enterprise; [b]Local agency; [c]Local community.

4. Conclusion

The influence parameters of the greenhouse tunnel dryer were evaluated to obtain maximum efficiency for drying of *H. cordata*. It was observed that the individual parameters of drying temperature showed an extreme effect on the response of moisture content and color value change, while the relative humidity had only an influence on moisture content. On the other hand, the parameter of material length was not significance on both responses. When compared to open sun drying, solar drying reduced the drying time of *H. cordata* by 57.14%. The payback period of the dryer was found to be 2.5 years. Furthermore, the results reveal that the SROI ratio in 2021 was 2.18, then increasing to 2.52 in 2022, and 2.91 in 2023, meaning that social investment created a significant positive impact on the community.

Nomenclature

GTD	Greenhouse Tunnel Dryer
CCD	Center Composite Design
ΔE	Color change or difference
M.C.	Moisture content
W_i	Initial weight of sample
W_f	Final weight of sample
CCD	Center Composite Design
RSM	Response Surface Methodology
ANOVA	Analysis of variance
SROI	Social Return on Investment

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Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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