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COSTS AND BENEFITS OF USING PARABOLIC GREENHOUSE SOLAR DRYERS FOR DRIED HERB PRODUCTS IN THAILAND

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ABSTRACT: Parabolic greenhouse solar dryers have been developed to overcome product quality and postharvest loss problems. It uses solar energy, a renewable source of energy. Due to their high investment costs, economic feasibility and the potential of carbon dioxide (CO_2) mitigation were investigated. Owners and managers of 17 enterprises, producing several varieties of herb products, investing in different sizes of solar dryers and using various traditional drying methods before investing in solar dryers, were interviewed in depth to create a data set. The net present value (NPV), internal rate of return (IRR), payback period and CO_2 mitigation were evaluated. The enterprises with annual production capacities higher than 1,200 kg or the annual revenues higher than solar dryer investment costs tended to have positive NPV indicating that the investments were attractive. Most enterprises showing CO_2 mitigation higher than 130 tCO_2e over 15 years had positive NPV. The annual production capacity, annual revenue and the amount of CO_2 mitigation could be used to assess investing in greenhouse solar dryers.

Keywords: Carbon dioxide mitigation, Food loss, Drying selection, Medicinal plants, Renewable energy

1. INTRODUCTION

Drying is an important method used for herb preservation in tropical countries [1]. Traditionally, open sun drying is mostly used due to its simplicity and low cost [2]. Because the process is slow, raw material or product losses can occur. Moreover, it has several limitations that affect the product quality due to dust, wind, pests and insects [3].

In rainy season, open sun drying cannot be conducted. Some enterprises continue the production process using auxiliary heat for which fossil fuel may be used as the heat source. Enterprises endeavoring to avoid raw material losses and product quality problems use other drying methods employing fossil fuel as the major heat source. However, fuel combustion causes greenhouse gas emissions which increase climate change impacts [4].

A solar dryer is a system that uses solar power, a renewable source of energy. It can be used to reduce the cost of energy and decrease carbon dioxide emissions [5]. The parabolic greenhouse solar dryer (Fig.1) has been developed which could support high production capacity and overcome production problems [6]. The systems are W6 × L8.2 m^2, W8 × L12.4 m^2 and W8 × L20.8 m^2 for small, medium, and large size of solar dryers, respectively. Due to the high price of solar dryers and the different costs of each size, entrepreneurs need to consider the benefits gained from both economic and environmental aspects to determine their investment [7]. The purpose of this study was to investigate the economic viability and potential CO_2 mitigation in using greenhouse solar drying systems for dried herb production in Thailand.

Fig. 1 Large sized parabolic greenhouse solar dryer.
Source: Janjai [6]

2. METHODOLOGY

2.1 Data Collection

A primary data set was obtained from enterprises that invested in various sizes of parabolic greenhouse solar dryers whose main products were dried herbs. The selected enterprises produced the dried herb products using various traditional drying methods before investing in solar dryers to determine the benefits gained from their investment. The owners or managers of the seventeen enterprises were interviewed in-depth after completing tested questionnaires, covering product data, quantity and type of fuel used for drying before investment, annual production capacity, annual revenues, solar dryer size and annual savings gained.

2.2 Economic Analysis

The value of annual total savings per annual revenue ($V_{s/r}$) was determined as:

$$V_{s/r} = \frac{S_T}{R_a} \tag{1}$$

where R_a represents the annual revenues and S_T denotes the total savings gained from investing calculated using the following formula:

$$S_T = S_f + S_w + S_l \tag{2}$$

where S_f is the savings gained from fuel reduction; S_w denotes the savings gained from food waste or raw material loss reduction, and S_l is the savings gained from labor cost reduction.

The most commonly used economic indicators, namely, net present value (NPV), internal rate of return (IRR) and payback period (PBP) were investigated in this study. NPV was calculated using the following formula [8]:

$$NPV = C_I + \sum_{t=0}^{t=k} \frac{S_{T,t}}{(1+d)^t} \tag{3}$$

where C_I denotes the investment cost of the solar dryers which is negative because it represents the expense at the beginning of investing; d denotes the discount rate; t denotes the specific year of investing and k is the total number of years of investing which was 15 years in this study according to the lifespan of the solar dryer [6].

The IRR is one of the economic parameters used to indicate economic feasibility. It is the discount rate that makes NPV equal to zero and was determined using the formula below:

$$NPV = C_I + \sum_{t=0}^{t=k} \frac{S_{T,t}}{(1+IRR)^t} = 0 \tag{4}$$

The PBP is the amount of time required to recover the cost of investing and was calculated using the formula below [9]:

$$PBP = \frac{C_I}{S_T} \tag{5}$$

2.3 Carbon Dioxide Mitigation

Total carbon dioxide mitigation was calculated using the following formula:

$$CM_T = CM_f + CM_w \tag{6}$$

where CM_T denotes the total carbon dioxide mitigation; CM_f is the carbon dioxide mitigation from reducing fuel consumption, and CM_w is the carbon dioxide mitigation from waste reduction.

Carbon dioxide mitigation from fuel use reduction was determined by the following formula:

$$CM_f = CE_{f,b} - CE_{f,a} \tag{7}$$

where $CE_{f,b}$ and $CE_{f,a}$ represent the carbon dioxide emissions from fuel consumption before and after investing in the solar dryer, respectively.

Carbon dioxide mitigation from waste reduction was calculated using the following formula:

$$CM_w = CE_{w,b} - CE_{w,a} \tag{8}$$

where $CE_{w,b}$ and $CE_{w,a}$ represent carbon dioxide emissions from food waste before and after investing in the solar dryer, respectively.

Carbon dioxide emissions from fuel consumption and food waste can be estimated using the following expressions:

$$CE_{f,b} = Q_{i,b} \times EF_i \tag{9}$$

$$CE_{f,a} = Q_{i,a} \times EF_i \tag{10}$$

$$CE_{w,b} = Q_{j,b} \times EF_j \tag{11}$$

$$CE_{w,a} = Q_{j,a} \times EF_j \tag{12}$$

where $Q_{i,b}$ and $Q_{i,a}$ are the quantity of fuel i used before and after investing in the solar dryer; EF_i is the carbon dioxide emission factor of fuel i; $Q_{j,b}$ and $Q_{j,a}$ are the quantity of food waste before and after investing, and EF_j is the carbon dioxide emission factor of food waste. The study assumed that all the food waste would be disposed of by landfill and the related emission factor was 2.53 kgCO_2e/kg waste [10].

Carbon dioxide mitigation cost was calculated using the following formula:

$$MC = \frac{C_I}{CM_T} \tag{13}$$

where MC denotes the mitigation cost.

3. RESULTS AND DISCUSSION

3.1 Economic Analysis

Nine enterprises had positive NPV indicating that the investment was worthwhile (Table 1). Sixty-seven percent of the enterprises having positive NPV were those that replaced fuel with solar energy. All enterprises in the group using fuel as traditional drying method that invested in small and medium size solar dryers, except enterprise FM3, had positive NPV. Enterprise FM3 gained low savings from fuel reduction. Moreover, enterprise FM3 had incurred expenses using more labor forces to move products from the solar dryer to the drying oven. It showed that lowered savings from one factor and increased expenses from another factor could create a negative NPV.

Only 37.50% of the enterprises using sun drying as a traditional method had a positive NPV. Enterprise investing in small and medium solar dryers exhibited an annual production capacity more than 1,300 kg and those investing in large solar dryers had 9,600 kg. This indicated that high annual production capacity could generate a positive NPV. The result was similar to the enterprise group using fuel before the solar dryer investment for which 85.71% of these enterprises having a positive NPV exhibited an annual production capacity higher than 1,200 kg. However, some enterprises, having an annual production capacity higher than 1,200 kg, had a negative NPV while some enterprises, having an annual production capacity lower than 1,000 kg, had a positive NPV.

Enterprises FS1 and FS3 invested in small solar dryers and could gain a high amount of savings resulting in the highest IRR and the lowest PBP of 0.69 years for FS1 and 1.11 years for FS3 (Fig.2). Fifty-five percent of the enterprises that had a positive NPV invested in small solar dryers showing that small dryers tended to provide higher economic viability. According to Janjai and Tung [1], another type of solar dryer for drying herbs was investigated and they reported that its payback period of 3.9 years was a feasible investment in Thailand.

All enterprises that had an annual production capacity less than 1,000 kg, except enterprise FS4, had the PBP longer than the lifespan of the dryer. They could hardly breakeven. However, enterprise FS4 could reduce the use of fuel and invested in a small dryer, so it could achieve a positive NPV.

Table 1 Summary data of enterprises and calculated NPV.

No.	Code*	Dried product	Conventional fuel used	Annual production capacity (kg)	Annual revenues (USD***)	NPV (USD***)
1	SS1	Moringa leaf, Bamboo grass	-**	1,380	157,500	13,637
2	SS2	Jewel vine, Indian gooseberry, Kariyat, Butterfly pea	-**	1,445	4,141	- 4,239
3	SS3	Bael, Long pepper	-**	555	1,276	- 5,771
4	SS4	Kaffir lime peel, Barbed grass	-**	229	1,653	- 6,792
5	SM1	Kariyat, Turmeric	-**	1,800	61,250	32,100
6	SM2	Cat whiskers plant, Turmeric	-**	758	2,619	- 13,014
7	SM3	Pandan leaf	-**	744	1,976	- 17,270
8	SL1	Stevia	-**	9,600	180,000	75,954
9	FS1	Mixed herbs	LPG and Wood	9,733	1,520,781	113,228
10	FS2	Stevia	Wood	2,850	26,719	2,571
11	FS3	Kariyat, *Stephania venosa*, *Curcuma zanthorrhiza*	Electricity	2,000	187,500	67,263
12	FS4	Butterfly pea, Sabah snake grass	Electricity	650	14,219	5,125
13	FM1	Turmeric, Cassumunar ginger	Electricity	1,200	25,125	15,077
14	FM2	Turmeric, Pandan leaf	Electricity	1,243	14,129	2,308
15	FM3	Ginger, Galangal	Electricity	1,609	13,134	- 14,631
16	FL1	Mixed Tom Yum herbs	Electricity	375	28,125	- 30,277
17	FL2	Chilli	LPG	4,320	16,200	- 10,018

Note: *The first code letter represents the traditional drying method (S = sun drying and F = fuel), the second code letter represents solar dryer size (S = small, M = medium and L = large); **The enterprises used open sun drying as a traditional method before investing in solar dryers; ***1 USD = 32 THB

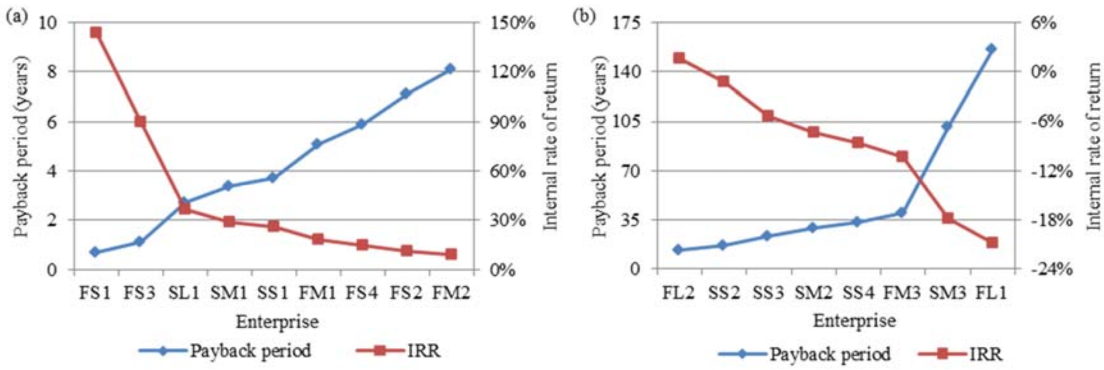

Fig. 2 PBP and IRR of enterprises having positive NPV (a) and negative NPV (b).

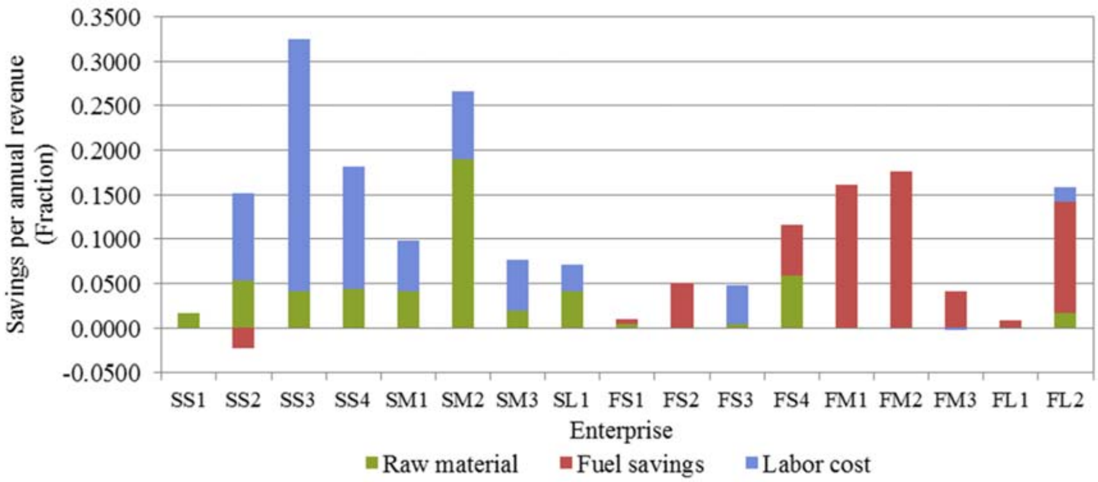

Fig. 3 Total savings per annual product revenue of each enterprise.#

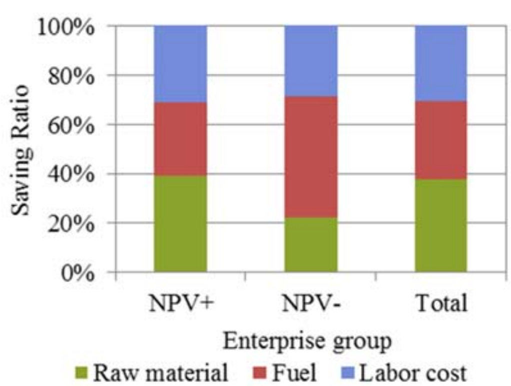

Fig. 4 Savings ratio of the enterprise group that had positive NPV, negative NPV and all enterprises.

Figure 3 illustrates small solar dryer enterprises, having low savings per annual revenue including SS1, FS1, FS2 and FS3, had a positive NPV, whereas enterprises having high savings per annual revenue, namely, SS2, SS3 and SS4, had a negative NPV. It reveals that the savings per annual revenue did not indicate economic viability. However, the price of the products affected economic feasibility.

According to the enterprises that had negative NPV, except FL1, the price of their products was low, less than 9 USD/kg. In contrast, the enterprises with positive NPV had product prices higher than 9 USD/kg. Nevertheless, enterprise FL1, with an average product price at 75 USD/kg, had a negative NPV because its annual production capacity was as low as 375 kg. The results showed that the total savings gained per annual revenue did not affect economic viability and enterprises having low priced products or low annual production capacity might not be suitable for the investment.#

The group of the enterprises that had a positive NPV gained savings of 30% from reduced fuel, 39% from reduced raw material loss, and 31% from reduced labor cost (Fig.4). Thus, reduced raw material loss played an important role providing benefits to the enterprises.

The investment costs of the solar dryer invested by each enterprise are presented in Fig. 5. Enterprises with annual revenue higher than the investment costs would have a positive NPV. Entrepreneurs could use annual revenues to decide to invest in a greenhouse solar dryer. However, enterprise FM2, reporting annual revenues less than investment costs, also had a positive NPV.#FM2 could gain a positive NPV as a direct result of high savings.

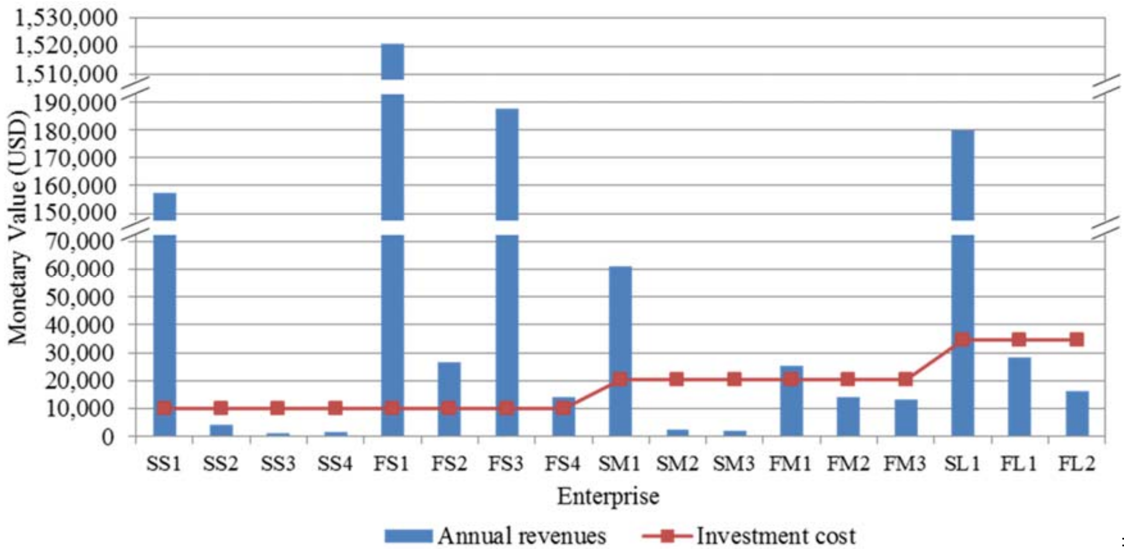

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Fig. 5 Annual revenue and the investment cost of each enterprise.

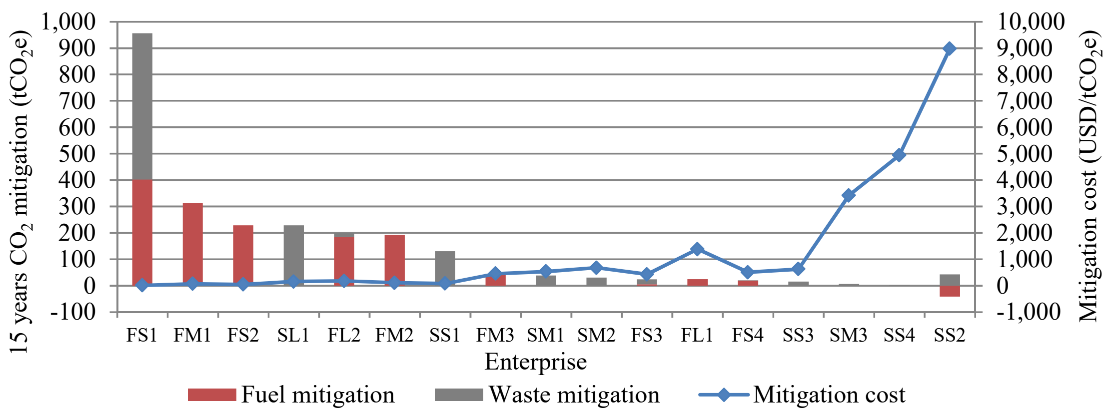

Fig. 6 CO_2 mitigation during 15 years of solar dryer life time.

3.2 Carbon Dioxide Mitigation

Seven enterprises could reduce more than 130 tCO_2e during 15 years of using greenhouse solar dryers (Fig.6). Eighty-six percent had a positive NPV, except FL2. The highest CO_2 mitigation was from enterprise FS1. This enterprise alone could reduce 956 tCO_2e, with 402 tCO_2e from reduced fuel and 554 tCO_2e from reduced waste due to the high amount of fuel replaced and waste reduced. All these seven enterprises could reduce CO_2 up to 1,318 tCO_2e from reduced fuel and 929 tCO_2e from reduced waste.

Among nine enterprises using fuel (LPG, wood, and electricity), FS1, FS2 and FL2 could reduce high CO_2 from the use of LPG or wood fuel#at the first, the third and the fourth rank, respectively. It showed that enterprises which could reduce the use of LPG or wood fuel tended to have high CO_2 mitigation.

Although enterprise FL2 was in the#top seven mitigation rankings, it had a negative NPV. The enterprise invested in the large solar dryer at a high cost. Its savings gained were low compared with the investment cost; thus, NPV was negative and IRR was low at 2%. Thus, selecting the appropriate size solar dryer is also an important factor to be considered for investing.#

When comparing among three different sizes of solar dryers, a lower CO_2 mitigation was related to a higher mitigation cost. For example, enterprise FL1 had almost the same CO_2 mitigation as enterprise FS3, FS4, SS3, and SM2, but its mitigation cost was much higher than the others because of the high investment cost of a large solar dryer. The enterprise FL1 could reduce CO_2 emission to a low amount compared with high investment cost (Fig.5); thus, the mitigation cost was as high as 1,383 USD/tCO_2e. From the case of enterprises FL1 and FL2, the size of solar dryer was the factor that entrepreneurs needed to consider because its investment cost could affect either NPV or mitigation cost. When the enterprises invested in smaller solar dryers, which still matched their annual production capacity, at over 1,200 kg, they might achieve a positive NPV or the mitigation cost would be decreased [5].

4. CONCLUSIONS

The enterprises with annual revenues higher than their investment costs of solar dryers would have a positive NPV indicating that the investment was attractive. The enterprises that used fuel in the traditional drying method should invest in small or medium sized solar dryers because they tended to obtain a positive NPV. The enterprises with a product price less than 9 USD/kg or annual production capacity less than 1,000 kg should not invest due to the high possibility of obtaining a negative NPV. Enterprises that could substitute the use of fuel by investing in solar dryers would gain more benefits than enterprises using sun drying in the traditional drying method. Most enterprises showing CO_2 mitigation higher than 130 tCO_2e during 15 years had a positive NPV. To gain the most benefit regarding both economic and environmental aspects in terms of a positive NPV, high IRR and short PBP together with high CO_2 mitigation, entrepreneurs should select the most appropriate size solar dryer for their investments. However, other uncertain parameters, including inflation rate and enterprises' marketing strategies, should be considered in a future study.

5. ACKNOWLEDGEMENTS

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