Research Article

Development of Solar Oven for Controlling Fungus in Tea Oil Seeds

Pairoj Duangnakhon*, Supakit Thepbundit and Mingkwan Somphruek
Faculty of Industrial Technology, Chiang Rai Rajabhat University, Chiang Rai, Thailand

* Corresponding author. E-mail: rojchd@yahoo.com DOI: 10.14416/j.ijast.2018.02.001
Received: 26 November 2017; Accepted: 17 January 2018; Published online: 26 February 2018

Abstract
The purposes of this research are to develop and investigate the efficiency of solar oven for controlling fungus in tea oil seeds. This research also studies how to effectively roast tea oil seeds using 2 binary tree system with 4 scenarios method which consists of A_1B_1, A_1B_2, A_2B_1, and A_2B_2. The sample used in this study is 10 kg of tea oil seeds originally from Tea Oil and Plant Oils Development Center in Mae Sai District, Chiang Rai Province. The efficiency testing results show that the solar oven offers the maximum temperature of 69°C and the minimum moisture content of 33%. This solar oven is then used to roast tea oil seeds using 4 different methods for 7 day. The experimental results indicate that the A_1B_1 roasting method gives moisture content of 7.408%, and drying ratio of 0.440% with no fungus. While A_1B_2, A_2B_1, and A_2B_2 roasting methods provide moisture content of 5.967%, 0.102%, 0.003%, and drying ratio of 0.355%, 0.006%, 0.0001% respectively. The fungi are found at the end of experiments in all three methods.

Keywords: Solar oven, Tea oil seeds, Fungus control

1 Introduction

The production of tea oil from tea oil seeds requires dehydration of tea oil seeds by roasting before entering the oil extraction process for good quality and quantity of tea oil. This tea oil can be transformed to many consumer products; therefore, the production process of tea oil needs very high quality control of harvesting through manufacturing stage [1]. However, tea oil plantation is located in the remoted highland area and far away from tea oil production factory. Also, villagers do not have efficient storage process of tea oil seeds after harvesting so the tea oil seeds inevitably contain moisture and fungus before entering the oil extraction process. Clearly, this lends negative effects on the quality of tea oil production [2].

The researchers have found that tea oil farmers in Chiang Rai province do not have efficient tea oil seeds storage process while waiting for transportation to tea oil production factory. In this regard, the villagers need to have efficient equipment to help control the moisture in tea oil seeds at the appropriate level that prevents the emergence of fungus. This moisture controlling process refers to the time after harvesting and before tea oil seeds being delivered into the oil extraction process at Tea Oil and Plant Oils Development Center for producing variety of tea oil products. Therefore, the researchers aim to study and develop the prototype solar oven for controlling moisture in order to reduce the fungus problem in tea oil seeds so that the production of tea oil and the related products can meet the intended quality [3]. Thus, the objectives of this research are to build and examine the efficiency of tea oil seeds solar oven. Moreover, this research is conducted to study the roasting process in order to control fungus in tea oil seeds.

The paper is organized as follows. In the next section, the solar oven prototype, the design of the experiment and calculation of drying ratio and moisture

Please cite this article as: P. Duangnakhon, S. Thepbundit, and M. Somphruek, "Development of solar oven for controlling fungus in tea oil seeds," *KMUTNB Int J Appl Sci Technol*, vol. 11, no. 1, pp. 21–26, Jan.–Mar. 2018.

are described. The results of solar oven's efficiency examination and also the experiment results on tea oil seeds roasting by various methods are given in section 3. Finally, conclusion of the paper with suggestions for further studies will be presented in section 4.

2 Materials and Methods

To develop the solar oven, the relevant literature regarding oven specifications, temperature adjustment and ventilation system is firstly studied as follows.

2.1 *How to obtain the solar oven*

As the purposes of this research are to study, develop and examine the efficiency of solar oven, this can be achieved through five steps as follow.

Step 1: Literature review. The relevant research on various model of oven is firstly reviewed. The researchers also focus on necessary functions of the oven such as the increase of temperature and ventilation inside the oven. In addition, renewable energy resource using solar cell is studied and considered as electricity source of the oven.

Step 2: Designing. Based on the literature review, the solar oven is designed with an appropriate dimension. This oven contains removable tray for loading tea oil seeds. It offers moisture control function in order to reduce the emergence of fungus by using light bulbs and fans. The wheels are also attached to the oven to make it moveable.

Step 3: Building the prototype oven. The body of solar oven is built using food-grade stainless steel due to its superior characteristics such as cleanness, moisture protection and corrosion resistance. The solar cell is used as electricity supplement for temperature increasing system and ventilation.

Step 4: Oven testing and development. The performance of the solar oven in terms of temperature and ventilation properties was tested. In addition to an expert suggestion, size and position of tray, light bulbs and fans are adjusted to provide the effective performance of the solar oven.

Step 5: Efficiency examination. The temperature and humidity control system is also installed in order to record the temperature and moisture content inside the solar oven. The characteristics of solar oven such as maximum temperature and moisture content are finally examined.

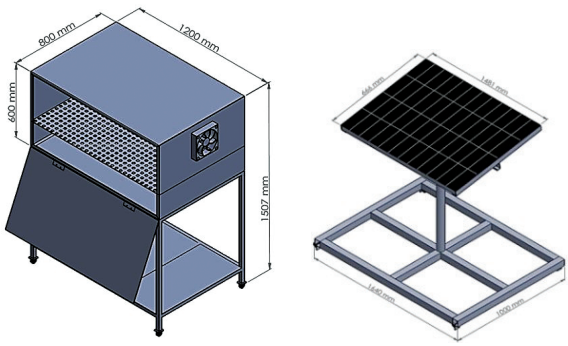


Figure 1: Solar Oven.

2.2 *Solar oven specifications*

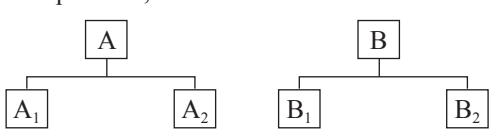
1. The inside dimension of the solar oven is 1,200 × 800 × 600 mm as shown in Figure 1. The size of tray is 1,200 × 800 mm in which maximum ten kilograms of tea oil seeds can be loaded. The light bulb is simply used as a heater due to it offers constant heat and temperature, easy to install and maintenance. An ordinary heater; on the other hand, gives very fluctuating heat with high power consumption and maintenance difficulty [4]. As in [5], the light bulb and fan are also applied to control temperature and ventilation inside the incubator which provide stable temperature and moisture content throughout the experiment. Therefore, the solar oven in this research uses three light bulbs and two fans for temperature adjustment and ventilation control, respectively.

2. The temperature and moisture content inside the solar oven are controlled and recorded using the temperature and humidity control system throughout the experiment.

3. The dimension of 120 W solar panels is 1,481 × 666 × 48 mm attached to steady stand as shown in Figure 1. The 12 V 130 Ah battery is also implemented to store energy from solar panels.

2.3 *Design of the experiment based on 2 binary tree system with 4 scenarios is A_1B_1, A_1B_2, A_2B_1, A_2B_2*

where
A = Temperature, B = Ventilation



A_1 = Increase temperature
A_2 = Temperature not increase
B_1 = Ventilation on
B_2 = Ventilation off
A_1B_1 = Increase temperature and ventilation on
A_1B_2 = Increase temperature but ventilation off
A_2B_1 = Temperature not increase but ventilation on
A_2B_2 = Temperature not increase and ventilation off

2.4 *Calculation of drying ratio and moisture (wet basis) [6], [7]*

The drying ration can be calculated as

$$Drying\ Ration = \frac{dX}{dt} = \frac{x_0 - x}{t - t_0} \quad (1)$$

in which
$x_0 - x$ = Dehydrated water
$t - t_0$ = Duration

The moisture reduction (wet basis) is given as

$$MC\ (\%wb) = \frac{(W_W - W_d) \times 100}{W_W} \quad (2)$$

where
$MC\ (\%wb)$ = Moisture (%wet basis)
W_w = Weight before Roasted
W_d = Weight after Roasted

3 Results

After the solar oven for tea oil seeds was built, the efficiency examination of the built oven was administered in various aspects as follow.

- Testing the increase of temperature inside the oven by using heat from three 100 W light bulbs.
- Testing the decrease of moisture by ventilating out the air from the oven using two 10 W fans.
- Testing the coherency between increasing temperature and ventilation of the oven.

Then, the experiment on roasting tea oil seeds for the control of fungus involved taking tea oil seeds sponsored by Tea Oil and Plant Oils Development Center Chiang Rai into the roasting process which involved placing tea oil seeds into the developed solar oven. The data was recorded for every 24 h on moisture of tea oil seeds, emergence of fungus, weight of tea oil seeds, temperature, and moisture inside the oven, moisture (wet basis), and drying ratio from day 1 to day 7 of the experiment. At the end of the experiment, tea oil seeds undergone roasting by different methods in the developed solar oven were tested for fungus. Four methods of roasting were A_1B_1 (Increase temperature and ventilation on), A_1B_2 (Increase temperature but ventilation off), A_2B_1 (Temperature not increase but ventilation on), and A_2B_2 (Temperature not increase and ventilation off) respectively [8], [9].

3.1 *Efficiency examination of the developed solar oven showed that:*

- The solar oven can offer up to 69°C maximum temperature, 33% of the lowest moisture control, and 80 h operation on battery performance without recharging.
- At the beginning of the experiment and turning on three 100 W light bulbs, the oven temperature was at 34°C and the moisture content was 60%. After 24 h of the experiment, the oven maximum temperature was at 69°C. After 4 h passing, the oven temperature was consistent at 69°C and moisture content was the lowest at 44%. After 8 h passing, the moisture content was consistent at 44% until the end of 24 h.
- In the case of turning on two 10 W fans, the oven temperature was at 34°C and moisture content was at 60%. After 24 h experiment, the oven maximum temperature was at 34°C from the beginning of the experiment and consistent at 34°C until the end of 24 h experiment. The lowest moisture content was 60% and maintained consistency at 60% until the end of 24 h experiment.
- In the case of turning on three 100 W light bulbs and two 10 W fans, the oven temperature was at 34°C and the moisture content was 60%. After 24 h experiment, the oven maximum temperature was at 69°C. After passing 4 h, the oven temperature was consistently stable at 69°C until the end of 24 h experiment. The lowest moisture content was 33%. After passing 9 h, the moisture content was consistently stable at 33% until the end of 24 h experiment.

3.2 *The experiment results on tea oil seeds roasting by A_1B_1, A_1B_2, A_2B_1, and A_2B_2 methods showed that*:

- A_1B_1 method turned on three 100 W light bulbs and turned on two 10 W fans. The results were shown

in the Table 1 where the drying ratio and moisture (wet basis) were calculated using Equations (1) and (2), respectively.

Table 1: Duration, weight, temperature, moisture, and drying ratio of A_1B_1 method

Duration (day)	Tea Oil Seeds Weight After Roasted (g)	Temp Inside Oven (°C)	Moisture Inside Oven (%)	Moisture (%wb)	Drying Ratio (g/h)
0	1000	34	60	-	-
1	990.08	69	33	0.992	0.413
2	971.66	69	33	1.860	0.590
3	927.90	69	33	4.503	1.001
4	926.02	69	33	0.202	0.770
5	925.96	69	33	0.006	0.587
6	925.94	69	33	0.002	0.514
7	925.92	69	33	0.002	0.440

From Table 1, roasting tea oil seeds by using A_1B_1 method in the solar oven for 7 days resulted in reduction of tea oil seeds weight per day as 990.08, 971.66, 927.90, 926.02, 925.96, 925.94, and 925.92 g respectively. The oven temperature per day was 69°C every day and the moisture content daily was 33% every day. The moisture reduction (wet basis) per day was 0.992, 1.860, 4.503, 0.202, 0.006, 0.002, and 0.002% respectively. The drying ratio per day was 0.413, 0.590, 1.001, 0.770, 0.587, 0.514, and 0.440% respectively.

- A_1B_2 method turned on three 100 W light bulbs and turned off two 10 W fans. The results were shown in the Table 2.

Table 2: Duration, weight, temperature, moisture, and drying ratio of A_1B_2 method

Duration (day)	Tea Oil Seeds Weight After Roasted (g)	Temp Inside Oven (°C)	Moisture Inside Oven (%)	Moisture (%wb)	Drying Ratio (g/h)
0	1000	34	60	-	-
1	992.86	69	44	0.714	0.297
2	977.32	69	44	1.565	0.472
3	941.66	69	44	3.648	0.810
4	940.38	69	44	0.135	0.621
5	940.36	69	44	0.002	0.473
6	940.34	69	44	0.002	0.414
7	940.33	69	44	0.001	0.355

From Table 2, roasting tea oil seeds by using A_1B_2 method in the solar oven for 7 days resulted in reduction of tea oil seeds weight per day as 992.86, 977.32, 941.66, 940.38, 940.36, 940.34, and 940.33 g respectively. The oven temperature per day was 69°C every day and the moisture content daily was 44% every day. The moisture reduction (wet basis) per day was 0.714, 1.565, 3.648, 0.135, 0.002, 0.002, and 0.001% respectively. The drying ratio per day was 0.297, 0.472, 0.810, 0.621, 0.473, 0.414, and 0.355% respectively.

- A_2B_1 method turned off three 100 W light bulbs and turned on two 10 W fans. The results were shown in the Table 3.

Table 3: Duration, weight, temperature, moisture, and drying ratio of A_2B_1 method

Duration (day)	Tea Oil Seeds Weight After Roasted (g)	Temp Inside Oven (°C)	Moisture Inside Oven (%)	Moisture (%wb)	Drying Ratio (g/h)
0	1000	34	60	-	-
1	999.82	34	60	0.018	0.007
2	999.62	34	59	0.020	0.007
3	999.33	34	59	0.029	0.009
4	999.15	34	59	0.018	0.008
5	999.04	34	59	0.011	0.007
6	998.98	34	59	0.006	0.007
7	998.98	34	59	0	0.006

From Table 3, roasting tea oil seeds by using A_2B_1 method in the solar oven for 7 days resulted in reduction of tea oil seeds weight per day as 999.82, 999.62, 999.33, 999.15, 999.04, 998.98, and 998.98 g respectively. The oven temperature per day was 34°C every day and the moisture content daily was 60, 59, 59, 59, 59, 59, and 59%. The moisture reduction (wet basis) per day was 0.018, 0.020, 0.029, 0.018, 0.011, 0.006, and 0% respectively. The drying ratio per day was 0.007, 0.007, 0.009, 0.008, 0.007, 0.007, and 0.006% respectively.

- A_2B_2 method turned off three 100 W light bulbs and turned off two 10 W fans. The results were shown in the Table 4.

Table 4: Duration, weight, temperature, moisture, and drying ratio of A_2B_2 method

Duration (day)	Tea Oil Seeds Weight After Roasted (g)	Temp Inside Oven (°C)	Moisture Inside Oven (%)	Moisture (%wb)	Drying Ratio (g/h)
0	1000	34	60	-	-
1	1000	34	60	0	0
2	999.99	34	60	0.001	0.0002
3	999.99	34	60	0	0.0001
4	999.98	34	60	0.001	0.0002
5	999.98	34	60	0	0.0001
6	999.98	34	60	0	0.0001
7	999.97	34	60	0.001	0.0001

From Table 4, roasting tea oil seeds by using A_2B_2 method in the solar oven for 7 day resulted in reduction of tea oil seeds weight per day as 1000, 999.99, 999.99, 999.98, 999.98, 999.98, and 999.97 g respectively. The oven temperature per day was 34°C every day and the moisture content daily was 60% every day. The moisture reduction (wet basis) per day was 0, 0.001, 0, 001, 0, 0, and 0.001% respectively. The drying ratio per day was 0, 0.0002, 0.0001, 0.0002, 0.0001, 0.0001, and 0.0001% respectively.

Table 1 to Table 4 showed that roasting tea oil seeds in the solar oven using A_1B_1, A_1B_2, A_2B_1, and A_2B_2 methods resulted in moisture reduction of tea oil seeds based on wet basis at different levels as shown in the Figure 2.

Figure 2 showed reduction of the moisture based on wet basis in roasting tea oil seeds by solar oven using 4 different methods for 7 days. The results indicated that the moisture based on wet basis decreased differently. The moisture reduction for A_1B_1 method was 0.992, 1.860, 4.503, 0.202, 0.006, 0.002, 0.002, A_1B_2 method was 0.714, 1.565, 3.648, 0.135, 0.002, 0.002, 0.001, A_2B_1 method was 0.018, 0.020, 0.029, 0.018, 0.011, 0.006, 0, and A_2B_2 method was 0, 0.001, 0, 0.001, 0, 0, 0.001 respectively.

After, the researchers took the roasted tea oil seeds for chemical examination in search for emergence of fungus. The examination results were shown in the Table 5.

Table 5: Fungus testing results of tea oil seeds after roasted by using different methods in the solar oven

Tea Oil Seeds Roasting Methods	Decrease of Moisture (wet basis) (%)	Drying Ratio (g/h)	Roasting Duration (days)	Fungus Found
A_1B_1	7.408	0.440	7	Not
A_1B_2	5.967	0.355	7	Found
A_2B_1	0.102	0.006	7	Found
A_2B_2	0.003	0.0001	7	Found

Table 5 showed that roasting tea oil seeds using A_1B_1 method resulted in moisture reduction at 7.408%. The drying ratio was at 0.440% and no fungus was found at the end of experiment. However, A_1B_2, A_2B_1, and A_2B_2 roasting methods resulted in moisture reduction at 5.967, 0.102, and 0.003% respectively. The drying ratio was at 0.355, 0.006, 0.0001%, and fungi were found in all 3 methods at the end of experiment.

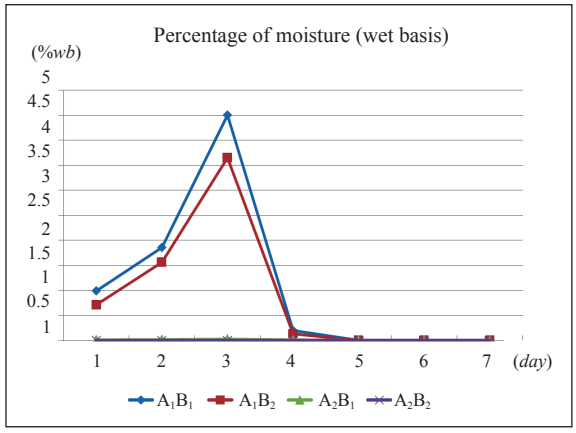


Figure 2: The decrease of moisture (wet basis) during roasting of tea oil seeds.

4 Conclusions

The proposed solar oven to control fungus in tea oil seeds can offer maximum temperature of 69°C and the moisture inside the oven can be reduced to the lowest level of 33% with the use of ventilation system. Since the battery is implemented with solar panels, this oven can operate for 80 h without charging. The oven is therefore perfect for use in unfavorable weather conditions such as raining or cloudy sky with no sunshine. Due to the fact that tea oil seeds harvesting usually takes place in rainy season during August to November, this oven is designed to be able to control temperature and ventilation and it can overcome the emergence of fungus in tea oil seeds [10].

The experiment results on roasting tea oil seeds using 4 different methods including A_1B_1, A_1B_2, A_2B_1, and A_2B_2 showed that three methods, that are, A_1B_2 (turn on light but turn off fans), A_2B_1 (turn off light but turn on fans), and A_2B_2 (turn off light and turn off fans) were unable to control or reduce fungus in tea oil seeds after undergone roasting for 7 day. However, A_1B_1 (turn on light and turn on fans) was efficiently able to control fungus in tea oil seeds. It can be concluded that A_1B_1 method is superior to other method due to no existence of fungus. The results supported the situational context of tea oil farmers in Chiang Rai province as their plantation area is located in remoted highland area and they need to keep and store tea oil seeds after harvesting while waiting for transportation of tea oil seeds into factory to produce tea oil and

other related products [11]. Therefore, it could be summarized that tea oil seeds storage process should increase temperature and ventilate air out to reduce moisture inside the tea oil seeds oven or at the area where farmers keep and store tea oil seeds while waiting for transportation. Like this, it could reduce the fungus problems in tea oils seeds before entering the production processes of tea oil and other related products.

Recommendations for Application:

- Roasting tea oil seeds by solar oven should always expose the solar cells against the sun during daytime for recharging and maintaining efficient functionality of the oven.
- In the case of closed weather with no sunshine for more than 3 day, the farmers should use home electricity system to power tea oil seeds oven in order to prevent damages on tea oil seeds while storing and waiting for transportation to factory.
- In using tea oil seeds oven, light bulbs must be turned on for increasing temperature and also fans to ventilate out air for reducing moisture. Two systems must always be used to efficiently control fungus.

Recommendation for further studies:

- Larger oven should be built and developed to accommodate the produce at community scale. The temperature and moisture control system should be studied for a larger scale oven.
- The solar oven should be developed to handle storage purpose of other agricultural produce such as rice, banana, longan, strawberries, tomato, lemongrass, fish, and herbal plants.
- The oven using other types of alternative energy such as natural gas should be developed and investigated for costing, breakeven point, and efficiency.
- Moisture control should be studied and implemented with large-scale silo that stores large amount of agricultural produce for a long time while maintain its good quality.

References

[1] The Chaipattana Foundation. (2016, Mar.). Oil Tea. The Chaipattana Foundation. Bangkok, Thailand [Online]. Available: http://www.chaipat.or.th (in Thai).

[2] Tea Oil and Plants Oil Development Center Chiangrai. (2016, Mar.). We love Thai King. Thailand [Online]. Available: http://welovethaiking.com (in Thai).

[3] W. Sanprasert. (2016, Mar.). Oil Tea. Naewna. Bangkok, Thailand [Online]. Available: http://www.naewna.com (in Thai).

[4] A. Butdeewong. (2016, May.). Heater. Technology Instruments. Bangkok, Thailand [Online]. Available: http://www.tic.co.th (in Thai).

[5] A. Luemasueni, L. Smarnpituk, and S. Kasor, "Research and design incubator to control temperature the egg back automatically," *YRU Journal of Science and Technology*, vol. 2, no. 1, pp. 39–49, 2017.

[6] P. Pornchaloempong and N. Rattanapanon. (2016, Apr.). Drying Ratio. Food Network Solution Co., Ltd. Bangkok. Thailand [Online]. Available: http://www.foodnetworksolution.com (in Thai).

[7] S. Niseng and P. Suaybangdam, "Drying oven for cayenne papper using electric energy coupled with solar energy," in *The 9th National Conference on Technical Education*, 2016, pp. 50–54.

[8] K. Poniyom, P. Singrat, and I. Chaorakam. (2016, Apr.). Development of Solar Powered Herb Dryer. Kasetsart University. Bangkok, Thailand [Online]. Available: http://kukr.lib.ku.ac.th (in Thai).

[9] S. Phamonlsmit. (2016, Apr.). Dried Tilapia by Solar Drying with Infrared. Office of the Higher Education Commission. Bangkok, Thailand [Online]. Available: http://tdc.thailis.or.th (in Thai).

[10] Ramathibodi Poison Center, Mahidol University. (2016, Mar.). Mycotoxins. Mahidol University. Bangkok, Thailand [Online]. Available: http://med.mahidol.ac.th

[11] Tea Oil and Plants Oil Development Center, The Chaipattana Foundation. (2016, Mar.). Tea Oil (Camellia Oleifera Abel). The Chaipattana Foundation. Chiang Rai, Thailand [Online]. Available: http://www.teaoilcenter.org